The performance of traditional African vegetables in urban outdoor modular living wall systems for food security in Gauteng, South Africa

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ABSTRACT

Urban agriculture can potentially lower global carbon emissions and create climate-resilient livelihoods and food security. As part of this quest for sustainable development, living wall systems (LWSs) with traditional African vegetables (TAV) can provide biophilic value and ecosystem services.

This research analyses the performance of outdoor modular LWSs with TAV to improve household food security in South African (SA) urban environments. The pragmatic study entails three integrated focus areas: the contribution of urban small-scale food production to household food security and interrelated SDGs, the performance of outdoor modular LWSs as edible green infrastructure, and the performance of TAV crops in modular LWSs for household food security.

Data capturing involved a three-pronged mixed-method methodology. Local experts provided insight into local LWS typologies and TAV crops through questionnaires. The six-month experimental study of two selected LWSs and nine TAV crops included variables of minimum and maximum daily temperatures, relative humidity, precipitation, soil

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temperature, water content and electrical conductivity, leaf biomass yield and plant stress. The researcher monitored fresh and dry biomass yields with a calibrated laboratory balance as the first performance indicator. Plant stress, the second performance indicator, was measured by chlorophyll fluorescence analysis. Data were statistically analysed.

The research guides the technical characteristics of outdoor modular LWSs as edible green infrastructure in SA urban environments for performance improvement. It contributes to the revival of neglected crops by identifying TAV species suitable for utilisation in LWSs to improve household food security.

The results favour locally produced outdoor modular LWSs with limited, robust, lightweight, recycled components entailing uncomplicated assembly. The study identifies seven TAV species suitable for household food production in LWSs. These include *Asystasia gangetica* (creeping foxglove), *Coleus amboinicus* (Indian borage), *Corchorus confusus* (jute plant), *Dicliptera clinopodia* (pink ribbons), *Mentha aquatica* (water mint), *Portulacaria afra* prostrata (dwarf elephant's food) and *Vigna unguiculata* (black-eyed pea). *Coleus amboinicus* (Indian borage) and *Portulacaria afra* prostrata (dwarf elephant's food) produced statistically significantly higher yields than the other crops. Selected compact TAV crops tolerating sunny, dry conditions can contribute to household food production in SA cities with a monsoon-influenced humid subtropical (Cwa) Köppen-Geiger climate classification.

Keywords

Household-scale, food production, vertical, edible, green infrastructure, living wall systems, African vegetables, Sustainable Development Goals, South Africa, Sub-Saharan Africa

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RESEARCH CONTRIBUTIONS RELATED TO THIS STUDY

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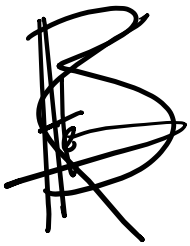
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ETHICS STATEMENT

The author, whose name appears on this dissertation's title page, has obtained the applicable research ethics approval for the research described in this work (EBIT/84/2019 date obtained 13 June 2019). The author declares that she has observed the ethical standards required in terms of the University of Pretoria's Code of Ethics for Researchers and the Policy Guidelines for Responsible Research.

DECLARATION

I declare that the thesis, which I hereby submit for the degree at the University of Pretoria, is my own work and has not previously been submitted by me for a degree at this or any other tertiary institution.



Karen Botes

21 August 2023

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For Leon, Kayla, and my late father and mother, Ed and Rina Hartwig

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LIST OF ACRONYMS

AIRCA	Association of International Research and Development Centres for Agriculture
ALV	African Leafy Vegetables
ANOVA	Analysis of variance
AVRDC	World Vegetable Centre
AOC	African Orphan Crops
BIA	Building Integrated Architecture
CFF	Crops for the Future
DF	Daylength
EGI	Edible Green Infrastructure
EC	Electrical conductivity
FAO	Food and Agriculture Organisation
FC	Field capacity
Fv/Fm	Quantum efficiency of the pigment-protein complex Photosystem II (PSII)
GAPAD	Global Action Plan for Agricultural Diversification
GDP	Gross Domestic Product
GHG	Greenhouse Gas
h	Hour
IFAD	International Fund for Agricultural Development
ILV	Indigenous leafy vegetables
IPCC	Intergovernmental Panel on Climate Change
l	Litre
LWS	Living wall system
mm	Millimetre
N	Nitrogen

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NDP	National Development Plan
NUS	Neglected and underutilised species
P	Precipitation
PAR	Photosynthetic active radiation
PEA	Plant Efficiency Analyser
PI	Performance Index
ProNIVA	Promotion of Neglected Indigenous Leafy and Legume Vegetable Crops for Nutritional Health in Eastern and Southern Africa
PSII	Photosystem II
PWP	Permanent wilting point
RH	Relative humidity
s	Second
SDGs	Sustainable Development Goals
sp.	Species (singular)
spp.	Species (plural)
SA	South Africa
SSA	Sub-Saharan Africa
ST	Soil temperature
Stats SA	Statistics South Africa
TAV	Traditional African Vegetables
UNICEF	United Nations Children's Emergency Fund
VF	Vertical farming
VGS	Vertical Greening system
VWC	Soil Volumetric Water Content
WFP	World Food Programme
WHO	World Health Organisation

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Chapter 1

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1. BACKGROUND AND RATIONALE

The period between 2020 and 2030 is "the decade of action to deliver the sustainable development goals by 2030. It is a critical period to advance a shared vision and accelerate responses to the world's gravest challenges – from eliminating poverty and hunger to reversing climate change." (United Nations Statistics Division, 2020)

1.1 Introducing the research context and focus

1.1.1 Global issues

Food security and climate change are two of the most significant global challenges of the 21st century (FAO et al., 2018). The world is not making satisfactory progress in meeting the UN's targets to address hunger, food insecurity, and malnutrition in sustainable development goal (SDG) 2, as set out in the 2030 Agenda for Sustainable Development (FAO et al., 2018). Besides the correlation between climate change (SDG 13) and no hunger (SDG 2), food security is also interconnected with the goals of no poverty (SDG 1), reduced inequalities (SDG 10), sustainable cities and communities (SDG 11) and responsible consumption and production (SDG 12) (FAO et al., 2018).

Risks and challenges in food security and agriculture are exacerbated by the impact of climate change on the frequency and severity of natural disasters (United Nations Statistics Division, 2020). Global temperatures are predicted to increase to 3.2°C by 2100, with 2010 to 2019 recorded as the warmest decade leading to worldwide hurricanes, wildfires, droughts, and floods (United Nations Statistics Division, 2020). Over and above increased global temperatures, heat waves in cities are intensified through the effect of the urban heat island (UHI) (IPCC, 2018), which impacts urban agriculture and greening. Greening initiatives to address climate change, the UHI effect, and rising urban microclimates are vital to improving food production and security. These initiatives include edible green infrastructure (EGI) to enhance the sustainability of cities and agriculture as significant greenhouse gas (GHG) emission sources and improve food security.

The impact of climate extremes on Africa is significant, considering urbanisation projections and the effect on the agricultural sector (Botes and Breed, 2021; Davis-Reddy and Vincent, 2017; Dosio, 2017). In South Africa, climate prediction entails an increase in temperature and a decrease in precipitation, with droughts and increases in hot extremes

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and more frequent and prolonged heat waves (Engelbrecht et al., 2015; Dosio, 2017). This has consequences for urban food production, which can be addressed by selecting crops that can tolerate these climate conditions.

As a direct or indirect source of food and one of the planet's primary sources of oxygen, plants play a vital role in mitigating these challenges (Khan and Ahmed, 2017). Policymakers and built-environment designers, therefore, need innovative thinking for urban greening and cooling to minimise the impact of climate change (Benke and Tomkins, 2017). Mitigating heatwaves in cities due to the heat island effect (IPCC, 2018) through greening, insulation, and cooling strategies such as edible living walls is important (Botes and Breed, 2021; Kohler, 2008).

1.1.2 Opportunities and challenges of living walls

The concept of green facades holds great potential for city greening and cooling. In inner cities with limited ground space, the potential area for façade greenery is almost double the footprint of buildings, with the potential to offer more environmental benefits than green roofs (Kohler, 2008). Green facades, entailing climbing or hanging plants to cover the surface, has been expanded through technological development into living walls.

Living walls comprise vegetation in the wall structure or on the vertical surface (Vosloo, 2016) rooted on the walls or in a substrate attached to the walls itself (Francis and Lorimer, 2011) using technology or material to support the plant material (Manso and Castro-Gomes, 2015). Living walls thus make use of planter boxes or plant growth facilitated through systems on interior or exterior walls that do not require rooting space at ground level (Kohler, 2008) and increase the range of species that can be utilised (Vosloo, 2016). Living wall benefits (to former systems) include a more consistent growth over the entire vertical surface and applications in a broader variety of building vertical surfaces and heights (Manso and Castro-Gomes, 2015).

In addition to the aesthetical value, living walls provide numerous functional direct and indirect benefits to deliver ecosystem services and increase the sustainability of cities and human health and well-being (Pérez-Urrestarazu et al., 2015; Ling and Chiang, 2018). These include noise absorption and sound insulation (Davis et al., 2017), improved thermal insulation (Kohler, 2008; Yang et al., 2018; Coma et al., 2017), and reduction of air pollutants (Francis and Lorimer, 2011). Although increased biodiversity (Collins et al., 2017) is viewed by some researchers as an advantage, the variety and quality of habitats are questioned (Mayrand and Clergeau, 2018). Research on integrating living wall systems (LWSs) and

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green roofs into natural systems to enhance ecosystem services is necessary (Bartesaghi Koc et al., 2017).

Edible green infrastructure (EGI) provides ecosystem services integral to sustainable cities (Russo et al., 2017; Ling and Chiang, 2018; Russo and Cirella, 2019). Outdoor living walls provide much-needed urban ecosystem services (Collins et al., 2017) in addition to the above benefits. A prime contemporary research focus is the potential of living walls to improve the urban microclimate through thermal insulation (Köhler, 2008). Other research areas include cooling buildings and their direct environments through evapotranspiration (Pérez-Urrestarazu et al., 2015; Price et al., 2015; Davis and Hirmer, 2015) and wind or sun screening (Cameron et al., 2014). Another recent area of interest is urban small-scale, vertical outdoor food production (Nagle et al., 2017). Localised food production holds significant benefits in terms of contributing to ecosystem services and decreasing GHG emissions due to the reduced transportation of food from remote areas (Lee et al., 2015; Russo et al., 2017).

Despite the psychological and aesthetic benefits, the economic feasibility of LWSs needs improvement (Mårtensson et al., 2016; Russo et al., 2017; Ling and Chiang, 2018). A way to increase the economic feasibility of LWSs is to introduce edible crops (Mårtensson et al., 2016; Russo et al., 2017; Ling and Chiang, 2018).

Despommier (2013) paved the way for vertical farms with his book “The Vertical Farm: Feeding the World in the 21st Century”. This book sparked many debates about vertical farms as a response strategy to food security, with several working vertical farming (VF) projects since 2009 in Canada, Japan, The Netherlands, North America, Singapore, Sweden, and South Korea (Khan and Ahmed, 2017; Despommier, 2013; Kalantari et al., 2018; Pinstrup-Andersen, 2018; Benke and Tomkins, 2017). Vertical farming has been proven to have advantages over ground-based traditional farming due to its efficiency, adaptability, protection from climate extremes and pests, and social and environmental benefits (Kalantari et al., 2018; Pinstrup-Andersen, 2018; Benke and Tomkins, 2017). However, many disadvantages make VF associated with controlled environment agriculture an unfeasible option for developing countries. Vertical farming challenges include a limited scope of suitable food crops (tomatoes, grapes, lettuce species, strawberries, and grain crops), high start-up costs, high technology, highly skilled labour, possible robotics usage (Benke and Tomkins, 2017), and the economic scale outcompeting small-scale producers (Pinstrup-Andersen, 2018).

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1.1.3 Sustainability of food systems

The global food system relies on five principal kinds of cereal as critical components of the human diet and only 30 crops to provide for the nutritional requirements of the human population (Mabhaudhi et al., 2018). This makes food systems vulnerable to climate variability, especially in developing economies like SSA. The human population will be more vulnerable if one of these crop species falters due to climate change. Rice, maize, millet, and wheat form a critical component of the diet of the African population, with maize comprising the highest national daily calorie intake in eastern and southern Africa.

With the increase in the intensity and frequency of extreme climate events such as heat, drought, storms, and floods associated with climate change reducing arable areas, the need for crops that can tolerate these conditions is increasing (FAO et al., 2018; Mabhaudhi et al., 2019). One of the strategies entails the reinvigoration of African orphan crops (AOC) and traditional African vegetables (TAV) to improve diets and their sustainable agricultural use (Mabhaudhi et al., 2017; Mabhaudhi et al., 2019).

1.1.4 The undeveloped potential of African orphan crops and traditional African vegetables

African orphan crops include edible, under-researched crops adapted to Africa's extreme climate and soil stresses (AOCC., 2020). These crops are locally indigenous to Africa or had been introduced to Africa centuries ago and are still used in traditional local diets (AOCC., 2020). For a good reason, these species are also called understudied, neglected, and underutilised crops for the future (Tadele, 2019; National Research Council (NRC), 2006). Neglected and underutilised species refer to crops of a geographical region whose potential is hindered by negative social perceptions, arduous preparation, and minimal economic value (Mabhaudhi et al., 2017). It is also referred to as under-researched and unimproved wild species, which are cultivated by rural communities based on traditional knowledge and practices with low-cost resources (Mabhaudhi et al., 2016; FAO et al., 2018)

Vegetables, cereals, legumes, fruit, and root crops form the categories of AOC (National Research Council (NRC), 2006; Tadele and Assefa, 2012a). Towns and Shackleton (2019) proposed the term traditional African vegetables to describe nutrient-dense species compared to dark, leafy green vegetables. Traditional African Vegetables are considered to have the potential for sustainable and resilient small-scale agriculture and food systems in Sub-Saharan Africa (SSA) as they are adapted to local conditions (Mabhaudhi et al., 2017; Mabhaudhi et al., 2019).

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Traditional African Vegetables are served as a condiment to accompany staple starchy food and exclude fruits, dry pulses, nuts, sap crops, herbs, spices, or large root crops (Schippers R.R., 2002). African Orphan crops and TAV have numerous advantages over exotic food crops due to their tolerance to local climate conditions, high nutritional value, short growing season, and low maintenance requirements for irrigation and agrochemicals (Araya, 2014). Moreover, African vegetables are more resistant to pathogens than exotic vegetables (Aworh, 2018).

Refer to Chapter 2 (Literature review).

1.1.5 Research focus

Limited empirical studies have been conducted on the benefits of modular living walls with food crops. Three studies with a similar research focus were identified, located in Pennsylvania (Nagle et al., 2017), Veitshöchheim, Germany (Demling, 2018), and Yogyakarta, Indonesia (Utami et al., 2012). These studies demonstrate that growing vegetables in LWSs in urban environments offers improved air circulation for crops with reduced pests and diseases. Furthermore, LWSs with vegetables have aesthetic value for enhanced human well-being and deliver productive yields, which exceed conventional agriculture gains such as crop productivity in terms of biomass in the case of some species, with improved accessibility for harvesting. Research results on using edible crops and other perennials in Sweden concurred that living wall systems benefit these species in the Scandinavian climate (Mårtensson et al., 2016).

Radić et al. (2019) argue that further research is required to explore living wall systems with edible plants. Empirical research that can holistically assess the potential of growing food crops in LWS to improve its efficiency, especially given global issues related to food security, is required. Riley (2017) claims that LWSs should be planned as systems including plant palettes that can tolerate climate and seasonal changes, considering affordability, sustainability, and longevity. Therefore, this study considers local crops, which can endure harsh climate conditions impacts and are also anticipated to require less water usage than mainstream vegetable crops.

This study aims to empirically assess the potential of urban edible outdoor modular LWSs with TAV to address food security and related SDGs. This is achieved by analysing the suitability of LWSs for growing edible crops such as TAV, and assessing the efficiency of selected TAV crops for vertical food production.

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1.2 Defining the research problem

1.2.1 Research questions

i. Main research question

The research poses the following question:

To what extent can outdoor modular LWSs with TAV contribute to local household food security as EGI in urban environments (Gauteng, South Africa)?

As illustrated in Figure 1.1, three integrated focus areas are studied, namely;

i. The potential of LWS as a form of urban agriculture that can contribute to household food security and interrelated United Nations Sustainable Development Goals (SDGs) in Sub-Saharan Africa.
ii. How the performance of outdoor modular LWSs as EGI can be improved, and
iii. The production of TAV crops in modular LWSs in local urban environments (Gauteng, South Africa) for household food security.

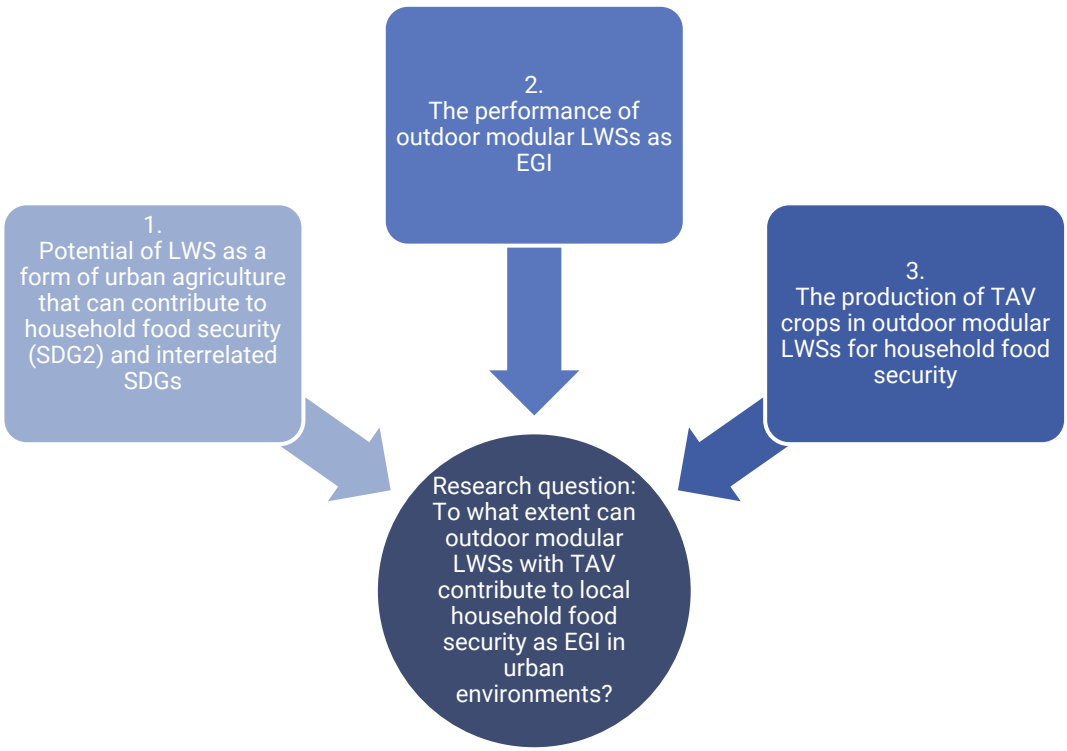


Figure 1.1: Diagram illustrating the three integrated focus areas of the research

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ii. Sub-questions

The main research question can be deconstructed into five sub-questions. The research sub-questions are listed in Table 1.1 to illustrate how they fit into the three focus areas.

Table 1.1: Research sub-questions relating to the three focus areas of the study

Research focus areas	Research sub-questions
i. **The potential of LWSs as a form of urban agriculture that can contribute to household food security and interrelated SDGs in Sub-Saharan Africa.**	1) What is the status of LWSs as a form of urban agriculture in contributing to household food security and related SDGs globally and in Sub-Saharan Africa?
ii. The performance of outdoor modular LWSs as EGI.	2) Which factors negatively affected the performance of modular LWS in contributing to food security (SDG 2) in the recent past?
	3) How can the technical characteristics of modular LWS improve their performance as EGI for growing TAV in local urban conditions (Gauteng, South Africa)?
iii. The production of TAV crops in modular LWSs for household food security.	4) To what extent do TAV contribute to household food security in SSA, and which factors hampered household-scale food production and consumption utilising TAV in addressing food security recently?
	5) Which TAV species have the potential for household vertical food production in outdoor urban environments in Gauteng, South Africa?

1.2.2 Significance of the study

The Covid-19 pandemic has underpinned the importance of meeting the UN's targets to address the SDGs. Given the link between food security, climate change, poverty, and urbanisation, novel approaches to promote sustainable urban development through food production are vital (Botes and Breed, 2022). Food production accounts for almost 25% of total global GHG emissions, mainly due to energy-intensive agricultural production processes and the transport of food products (Lopez et al., 2019). Localised food production is necessary to reduce GHG emissions and address local access to food. Moreover, with urbanisation being an unavoidable global reality and cities accounting for 75% of global CO_2 emissions (UNEP, 2020), sustainable solutions for food production are becoming increasingly important (Specht et al., 2014). Therefore, Urban agriculture has moved to the centre of the global public discourse, mainly due to its potential contribution to addressing climate change and health concerns (Specht et al., 2014; Bohn and Viljoen, 2011).

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Urban agriculture and living walls are established concepts and have been researched extensively independently. However, joint research on living walls and urban agriculture is needed to ensure sustainable Z-farming practices. Z-farming is an urban farming category known as zero-acreage farming and entails urban agriculture without using farmland or open space (Specht et al., 2014; Lopez et al., 2019). It can include rooftop food gardens, edible walls, indoor farms, or vertical greenhouses (Specht et al., 2014; Lopez et al., 2019).

Z-farming's environmental and socio-economic advantages should be enhanced, and its challenges addressed (Specht et al., 2014). Despite the psychological and aesthetic benefits, a way to increase the economic feasibility of LWSs is to introduce edible crops (Mårtensson et al., 2016; Russo et al., 2017; Ling and Chiang, 2018).

Edible LWSs with TAV potentially offer a resilient approach to climatic conditions in SSA, mainly semi-arid to arid, with intense weather extremes due to climate change (Botes and Breed, 2022). The focus of research on TAV entails mainly the evaluation of species and nutritional value (Towns and Shackleton, 2019) and the need for TAV to address food security on a micro-level (Garekae and Shackleton, 2020).

South Africa is a biodiverse country and boasts a range of plants, which include 2260 wild crop relative species (Raimondo D, 2015). TAV and AOC are relevant not only in Africa but have the potential for utilisation globally (National Research Council (NRC), 2006). TAV and AOC can be regarded as neglected resources of Africa to help African people and are the point of departure for collaboration in research, development, growth, and trade (National Research Council, 2008). TAV are imperative for marginal nations due to their benefits in terms of health, income generation (Shackleton et al., 2009), food security, and malnutrition as an alternative to diets comprising mainly staple cereals with an inadequate intake of vegetables and fruits (Garekae and Shackleton, 2020).

The research will also further the knowledge of the utilisation of TAV in living walls by developing design information on the physiognomy of living wall systems and edible species suitable for use in living walls.

1.2.3 The rationale of the study

The UN SDGs, which represent the global sustainability goals of our planet, point out the link between climate change, food security, poverty, and urbanisation (United Nations Statistics Division, 2020). Novel approaches to promote sustainable urban development through food production are vital, and so is the diversification of food sources (Cheng et al.,

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2017). A paradigm shift to reconfigure the food systems in Sub-Saharan Africa (SSA) in response to growing planetary concerns is necessary. Food production of TAV shows potential (Mabhaudhi et al., 2017; Mabhaudhi et al., 2019) but needs to be drastically increased to provide for the growing population in Africa (Tadele and Assefa, 2012a). In South Africa, obtaining household food security is crucial.

Edible green infrastructure (EGI) provides ecosystem services integral to sustainable cities (Russo et al., 2017; Ling and Chiang, 2018; Russo and Cirella, 2019). Localised food production holds significant benefits in contributing to ecosystem services and decreasing GHG emissions due to the reduced transportation of food from remote areas (Lee et al., 2015; Russo et al., 2017). A prime contemporary research focus is the potential of living walls to improve urban small-scale, vertical outdoor food production (Nagle et al., 2017).

This study maintains that growing food crops in living walls in urban environments in South African cities as EGI can be investigated to increase the economic feasibility of LWSs (Mårtensson et al., 2016; Russo et al., 2017; Ling and Chiang, 2018) and improve household food security. Utilising local crops such as TAV can further enhance the benefits of living walls. Through investigating the success of TAV in improving diets and their sustainable use (Mabhaudhi et al., 2017; Mabhaudhi et al., 2019) and living wall systems, the potential of LWSs for vertical food production with local crops can be determined.

1.2.4 Research Aims and Objectives

This study aims to define the technical characteristics of modular LWSs as EGI in local urban conditions (Gauteng, South Africa) for improved performance and to determine which TAV could grow productively in modular LWS to improve local household food security. Based on the research questions, the following objectives have been identified (See Figure 1.2):

1) To determine the status of living walls as a form of urban agriculture in terms of its contribution to household food security and related SDGs globally and SSA.
   i. To explore SDGs related to household food security.
   ii. To define the status of the contribution of urban food production to household food security and related SDGs.
   iii. To identify the potential contribution of outdoor modular LWSs as EGI to address food security (SDG 2) and related SDGs.

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2) To define factors affecting the performance of modular LWS negatively in contributing to food security (SDG 2) in the recent past.
   i. To list and identify the different LWS typologies.
   ii. To record and elaborate on factors affecting the performance of modular LWSs.
   iii. To determine criteria for modular LWSs that are efficient for food production.
3) To define the technical characteristics of outdoor modular LWSs as EGI for improved performance for growing TAV in local urban conditions (Gauteng, South Africa) based on their performance in an empirical study.
   i. To select LWS typologies for the empirical study based on the criteria for efficient modular LWSs.
   ii. Construct selected LWS typologies and a natural soil area for empirical research with similar environmental conditions.
   iii. To monitor and analyse the efficiency of the selected LWS typologies in providing optimal growing conditions for TAV in Gauteng, South Africa.
4) To determine the status of TAV's efficiency in contributing to household food security globally and related SDGs in sub-Saharan Africa, and to identify factors that hampered household-scale food production and utilisation of TAV in addressing food security in the recent past.
   i. To determine the status of TAV's efficiency in contributing to household food security.
   ii. To establish how TAV relate to AOC.
   iii. To determine TAV's production and utilisation and determine barriers to growing and consuming TAV.
   iv. To determine the advantages of TAV.
   v. To document the most prominent TAV utilised in SA.
   vi. To establish and analyse factors affecting the potential of TAV to be grown and consumed.

5). To identify TAV species that have the potential for household vertical food production in outdoor urban environments in Gauteng, South Africa.

   i. To identify a shortlist of the most prominent TAV species based on the literature review and expert consultation for growth in the two LWS typologies for empirical research.
   ii. To monitor and analyse the performance of the selected TAV crops by comparing the performance of selected species to that of a commercial crop.

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iii. To identify TAV species that have the potential for cultivation in outdoor living walls in Gauteng, South Africa.

1.2.5 Research outcomes

This study has the following outcomes in response to the aim, objectives and research questions (See Figure 1.2);

1) A synthesis of the status of urban agriculture in terms of its contribution to household food security and related SDGs globally.
2) A synthesis of the status of TAV in terms of their contribution to household food security and related SDGs globally.
3) Performance guidelines to improve the technical characteristics of outdoor modular LWS as EGI in local urban environments (Gauteng, South Africa).
4) A summary of factors hampering the efficiency of food security and household-scale food production and utilisation of TAV in addressing food security.
5) A list of TAV species with the potential for small-scale vertical food production in outdoor urban environments in Gauteng, South Africa.

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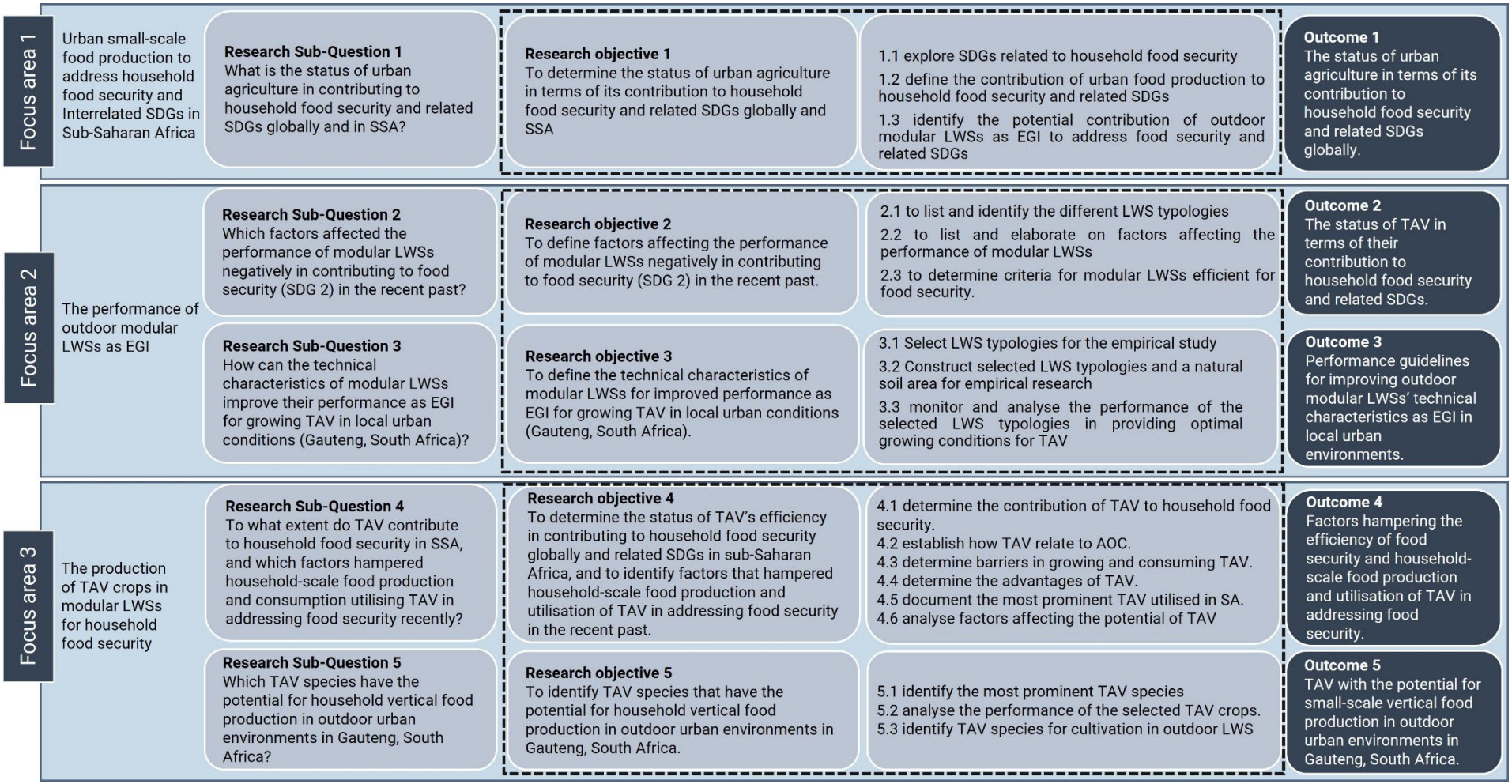


Figure 1.2 The questions, objectives, sub-objectives and outcomes guiding the research study

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1.3 Definitions of terms and concepts

The following key terms, which may not necessarily have the same meanings as per other literature sources, are used in this thesis:

Traditional African vegetables: also referred to as African leafy vegetables/ indigenous leafy vegetables (ILV), *merogo* (Sesotho, an indigenous language in Southern Africa), *imfino* (isiZulu, isiXhosa), and *miroho* (tshiVhenda), which is translated to green leafy vegetables. It can be defined as green leafy vegetables that are naturalised, adapted to Africa, or selected for local conditions (Oelofse and Van Averbeke, 2012; Towns and Shackleton, 2019) and described by Towns & Shackleton (2019: 471) as their; "cultivation, collection, preparation, and consumption deeply embedded in local cuisine, culture, folklore, and language."

African orphan crops: also referred to as neglected crops, Indigenous and traditional foods crops (ITFCs), or the "lost Crops of Africa", African Orphan Crops (AOC) are part of Africa's cultural heritage and are essential to local diets in Africa and comprise underutilised, neglected or lost crops, consisting of cereals, legumes, vegetables, and root crops (Tadele and Assefa, 2012a), adapted to the harsh conditions of the African continent with unrealised potential as edibles to address hunger, malnutrition, health and well-being and poverty, and not receiving the necessary scientific or institutional support (National Research Council (NRC), 2006).

Edible green infrastructure (EGI) refers to an urban or peri-urban network of edible food structures that mainly provide ecosystem services through sustainable food production techniques that protect the biophysical and social environments (Russo et al., 2017). EGI excludes urban agriculture practices involving commercial farming, aquaculture, and livestock (Russo et al., 2017; Eigenbrod and Gruda, 2015).

Leafy vegetables comprise crops whose leaves are used for human consumption. Preparation can be raw, cooked, boiled, or roasted, and leaves can be combined with flowers, stems, or shoots (Kidane et al., 2015).

Modular living wall systems: refer to living wall systems (LWS) that comprise planter boxes or pots attached to walls or building facades that contain the growth medium for rooting plants (Kȍhler, 2008).

Vertical farming: refers to the cultivation of horticultural crops in vertical layers involving protected soil-free growth systems under controlled conditions to increase crop production per unit area of land as an alternative to conventional agricultural farming (Beacham et al., 2019; Khalil et al., 2020; Jȕrkenbeck et al., 2019).

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1.4 Delineation, limitations, and assumptions of the study

1.4.1 Delineation

The study is delineated to;

1) Commercially and financially[1] viable TAV based on consultation with local experts.
2) TAV, which comprises food plants comprising groundcovers, herbs, and climbers with leafy upper-ground edible parts (leaves) that are used for consumption, are selected due to ease of hand harvesting. Plants with underground parts (roots, bulbs, tubers, stems, and rhizomes) as the primary food source have been delimited from this study, as plants need to be replaced after harvesting. This study does not consider cereals/ grains and millets as harvesting involves a more complicated process than vegetables, and drying before consumption.
3) Household-scale modular living wall systems, which are manufactured locally in South Africa, are considered. Hydroponic, aquaponic, and aeroponic systems are not considered in this study.
4) One test site that is representative of typical urban environmental conditions with potential for food growth.

1.4.2 Limitations

The following limitations can be listed;

1) The study was conducted during a growing season in Pretoria (Gauteng Province, South Africa). Findings might, therefore, not be generalisable to other climatic regions in South Africa or the rest of the world but are only applicable to areas with similar conditions (temperature, precipitation, water, humidity, wind, aspect, height, as well as soil volume, composition, & nutrient replenishment of soil cells).
2) The results apply to the monsoon-influenced humid subtropical (Cwa) Köppen-Geiger climate classification.
3) The results are limited to the selected and similar LWS systems. Technical and efficiency recommendations can apply to systems with matching technologies.
4) The results are limited to the species tested.

[1] Crops which are grown in South Africa and are available at market-related prices

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5) The following external factors impacted the planned data collection period beyond the control of the researcher;
   - Species loss due to consumption by local dassies (rock hyrax).
   - A faulty main irrigation system interrupted the water supply in November 2021 and January 2022. The water shortage during this period impacted the soil volumetric water content and electrical conductivity.
   - Technical difficulties hampered the initial intentions of using a PAR meter, resulting in the impact of photosynthetic active radiation on biomass and plant stress not being captured and analysed.
6) Some of the initially planted species were incompatible with the system.
7) Two species, Portulaca oleracea and Amaranthus thunbergii, had shorter lifespans than the other TAV crops.
8) The goodness of fit of the linear regression results was based on the r^2 value and not attested by Chi-squared tests and Akaike Information Criteria compared across models combining different variables. Therefore, only nine or 10 percent of variation can be explained by the model, and so these results are not generalisable or significant.

1.4.3 Assumptions

The study builds on the following assumptions;

1) Predictions about the expected increase of more than 3,5% of the estimated 25.9% of the global population in 2019 of people affected by moderate to severe food insecurity due to the COVID-19 pandemic and the cumulative impact of natural disasters due to climate change (United Nations Statistics Division, 2020) are correct based on current trends.
2) Current trends show global temperatures will increase by 3.2°C by 2100 (United Nations Statistics Division, 2020).
3) That predicted urbanisation would reach 90% in Africa (Gregory et al., 2019), and almost 70% of the world's population would occupy cities by 2050, according to Kundu and Pandey (2020)

1.5 Dissertation Outline

The study is divided into three parts. The first part describes the study's background, research question, and premise, followed by the literature review. Furthermore, it outlines the research design and provides the study site's context. Part two explains the study's

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findings, and part three discusses the results, makes recommendations, and draws conclusions. Figure 1.3 shows the graphic layout of the thesis, with the chapter layout elaborated below.

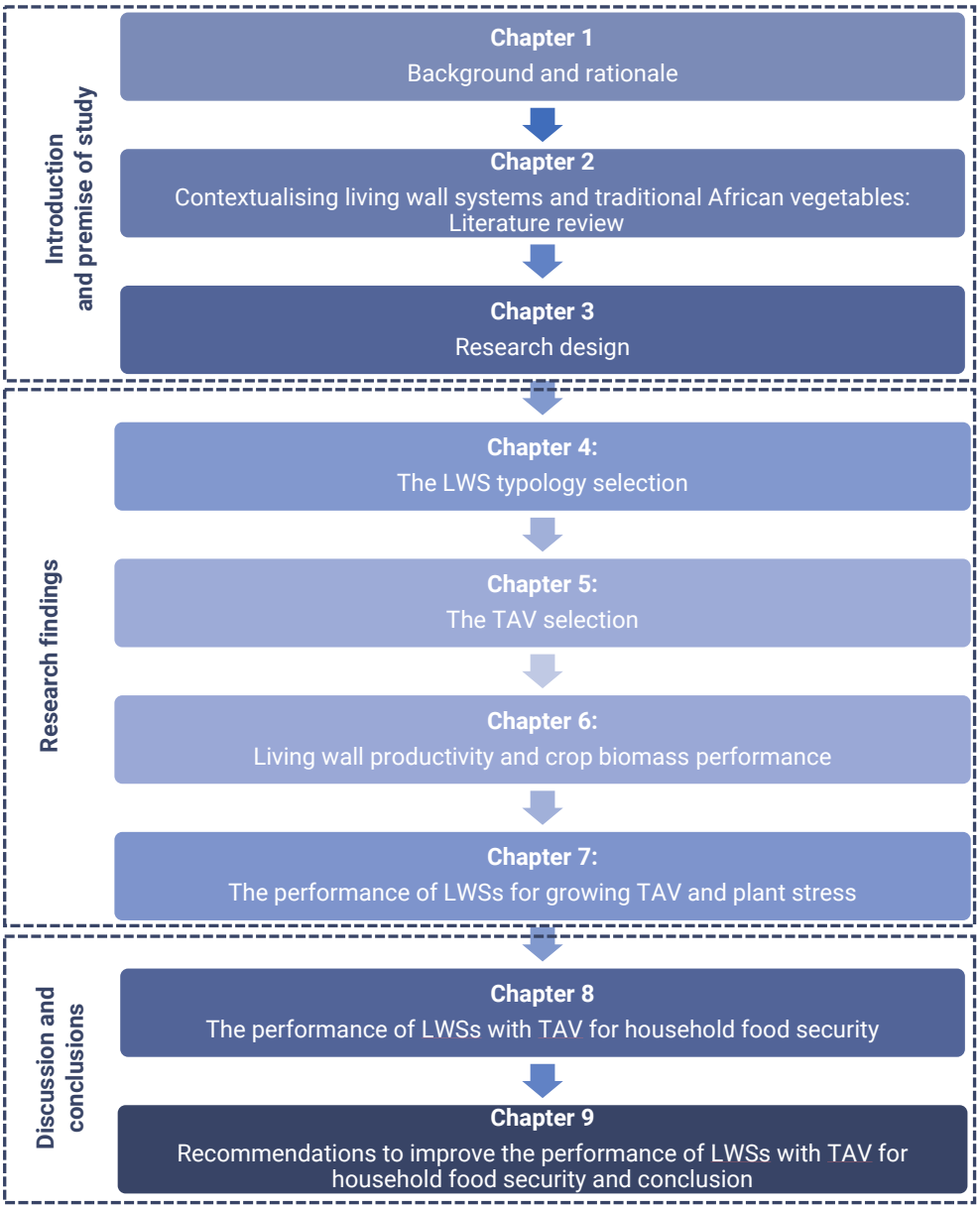


Figure 1.3: Graphic illustration of the thesis structure

Part 1 entails the introduction and premise of the study and comprises chapters 1 to 3. Chapter 1 outlines the background, problem, and importance of addressing the issue. Definitions, research questions, outcomes, and delimitations are provided, together with the structure and layout of the study.

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Chapter 2 considers literature to determine the status of urban agriculture in contributing to food security and related SDG targets, synthesises factors affecting the efficiency of LWSs and the potential contribution of TAV to address household food security, including factors hampering their production and utilisation. The results of the literature review guide the LWS and TAV selection for the empirical study. Similar empirical studies with related objectives are analysed to identify current knowledge gaps.

Chapter 3, the last chapter of part 1 of the research, explains the study's design. The chapter first provides an overview of possible research designs considered for the quantitative empirical stage of this study, after which the rationale for the proposed research design method is discussed. Chapter 3 further describes the study area, population and sample sizes, the research methods, variables, research instruments, sampling and data collection methods, and the data analysis. To conclude Chapter 3, the researcher reflects on the rigour and validity, strengths and limitations of the selected research design, and ethical considerations.

Part 2 of the study deals with the results from the expert consultation in Chapters 4 and 5 and the experimental research findings in Chapters 6 and 7. Chapter 4 describes the results from the semi-structured interviews as part of the expert consultation to select LWS typologies for the empirical research and provides the results of selecting two locally manufactured LWS typologies for the experimental research stage.

Chapter 5 delivers the findings of expert interviews for selecting the TAV species shortlist. The specialist panel selection and criteria are described first, followed by an explanation of the selection process for the initial list of TAV species and the shortlist of selected TAV species.

Chapter 6 provides the findings of the living wall productivity and biomass analysis conducted during the empirical stage of the study. The chapter first describes the abiotic conditions that applied to the experimental research, followed by the results of the biomass yields in the LWSs compared to the control area. The analysis of the crop performance in terms of biomass yield, based on the positioning of the crops, is then provided. The chapter explains the analysis of the TAV species by providing the results of the total biomass yield per crop, after which the three typologies are compared in terms of their performance based on the TAV biomass yield. Graphs present the key results from the statistical analysis to reflect the performance of the TAV crops and LWSs compared to the controls considering the biomass yield.

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Chapter 7 discusses the performance of the LWSs and control, considering their suitability for growing TAV based on the plant stress findings. The chapter provides the analysis results comparing the three typologies based on the maximum quantum yield and total performance index of crops in each typology. Lastly, the analysis results of the crops are provided to determine the crop suitability for food production in LWSs in urban environments in Gauteng, South Africa.

Part 3, comprising Chapters 8 and 9, includes a discussion of a combination of Chapters 6 and 7 findings, recommendations to improve the performance of LWSs with TAV for household food production, and conclusions. The efficiency of LWS for food production with TAV and the selected TAV species are compared to the results of similar studies.

Chapter 9, the final chapter, provides the study's outcomes, draws conclusions, and reflects on the research process and findings. The chapter first discusses the research findings by responding to each of the study's research sub-questions. In addition, recommendations for improving outdoor modular LWSs with TAV for household food security are discussed as primary research contributions. These entail recommendations for outdoor modular LWSs technical characteristics for enhanced performance to grow TAV crops for household food production and TAV crops suitable for household food production in modular LWSs in Gauteng, South Africa. Finally, this chapter proposes recommendations for theory, practice, and future research areas.

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Chapter 2

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2. CONTEXTUALISING URBAN AGRICULTURE, LIVING WALL SYSTEMS AND TRADITIONAL AFRICAN VEGETABLES: LITERATURE REVIEW

> *"… it is estimated that between 720 and 811 million people in the world faced hunger in 2020. Considering the middle of the projected range (768 million), 118 million more people were facing hunger in 2020 than in 2019 – or as many as 161 million, considering the upper bound of the range. Compared with 2019, 46 million more people in Africa, almost 57 million more in Asia, and about 14 million more in Latin America and the Caribbean were affected by hunger in 2020"* (FAO, 2021: xv)

2.1 Introduction

The literature review, conducted as the first stage of this dissertation to contextualise the problem and document information and knowledge gaps, has three focus areas. The first focus area responds to research sub-question 1, entailing the status of urban agriculture in terms of its contribution to household food security and related SDGs globally and SSA. Therefore, 1) SDGs related to household food security are investigated, 2) the status of the contribution of urban food production to household food security and related SDGs is determined, and 3) the potential contribution of outdoor modular LWSs as EGI to address food security (SDG 2) and related SDGs is investigated.

In response to research sub-question 2, the second focus area entails investigating existing studies on factors affecting the efficiency of modular LWS negatively in contributing to food security (SDG 2) in the recent past. This entails 1) listing and identifying the different LWS typologies, 2) recording and elaborating on factors affecting the efficiency of modular LWSs, and 3) determining criteria for modular LWSs that are efficient for food production.

The third focus area, which responds to research sub-question 4, investigates the status of TAV's efficiency in contributing to household food security globally and related SDGs in Sub-Saharan Africa (SSA) and identifies factors that hampered household-scale food production and utilisation of TAV in addressing food security in the recent past. This focus area 1) determines the status of TAV's efficiency in contributing to household food security, 2) establishes how TAV relate to AOC, 3) compares the production and utilisation of TAV to that of exotic western vegetables and determines barriers in growing and consuming TAV, 4) determines the advantages of TAV, 5) documents the most prominent TAV utilised in South Africa (SA) and 6) establishes and analyses factors affecting the potential of TAV to

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be grown and consumed based on peer-reviewed literature. Figure 2.1 provides a diagram and graphical layout of the chapter and illustrates the relationship between the research sub-questions and focus areas.

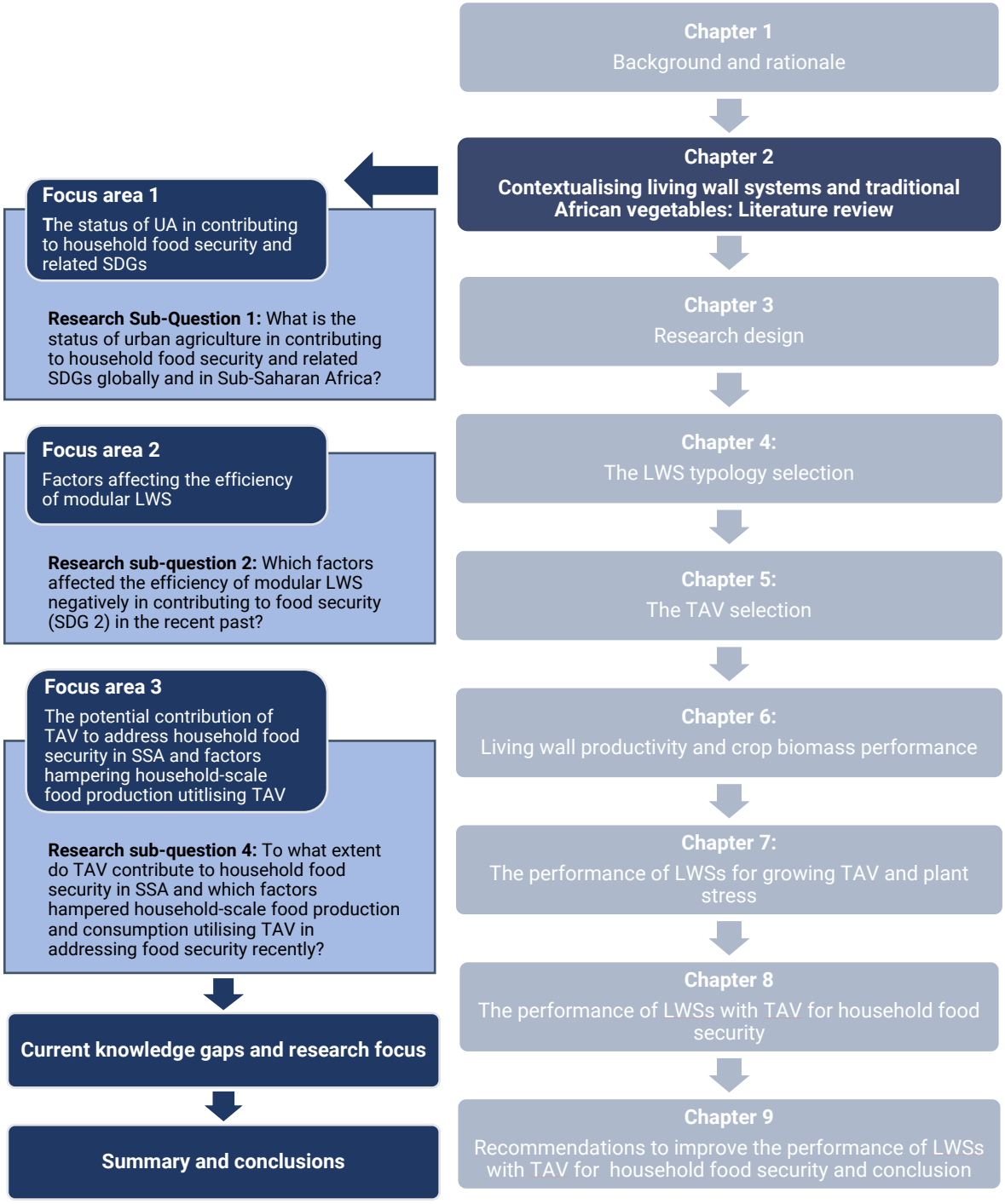


Figure 2.1: Graphic illustration of the literature review chapter structure and the relation of focus areas to research questions

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The chapter describes the process followed in selecting literature studies for this research. Subsequently, the chapter explores the status quo of the three focus areas to address the research questions and then discusses current knowledge gaps and research foci. Areas, where further research is required, are pointed out. Finally, a conclusion on the chapter's main findings sets out the rationale for utilising LWSs as EGI by discussing their contributions to the SDG targets and the potential of TAV as food crops instead of commercial crops.

2.1.1 Literature selection

An integrative literature review process was followed. The review allows for the inclusion of experimental and non-experimental research to inform research, practice and policy (Whittemore and Knafl 2005). Data was collected to combine different perspectives and fields of research rather than cover all published information on the topic (Snyder, 2019). The review process entailed the following steps: problem identification, literature search, data evaluation, selection of studies for inclusion, data analysis, and presentation in line with a framework (Whittemore and Knafl, 2005).

An initial search was conducted of publications between 2017 and 2021 using the Scopus and ScienceDirect databases and Google Scholar with keywords on living walls with food plants. Keywords included "vertical garden" OR "Living wall" OR "green wall" PLUS "edible plants" OR "food crops" OR "edible crops" "edible vertical gardens" AND "edible living walls"; "edible green walls"; "vertical food gardens"; "vertical urban agriculture"; "green walls with food plants"; "living walls with food plants". Peer-reviewed journals were identified from Scopus (n = 0), ScienceDirect (n = 15) and Google Scholar (n = 179) as being relevant to this study and were included in the review. A second search to assess research on the appropriate plant species involved the keywords "African vegetables", "African orphan crops", "neglected crops", "African leafy vegetables", "indigenous leafy vegetables", "living walls", "food production", and "traditional African vegetables". The results entailed peer-reviewed publications selected from Scopus (n = 0), ScienceDirect (n = 69) and Google Scholar (n = 696). The combination of keywords limited the results, with limited papers found due to the combination of keywords. The review list was extended with additional publications based on the keywords "traditional African vegetables" OR "African vegetables" OR "African orphan crops" OR "neglected crops" OR "African leafy vegetables" OR "indigenous leafy vegetables" OR "living walls" AND "food production", resulting in additional

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peer-reviewed publications from Scopus (n = 14), ScienceDirect (n = 249) and Google Scholar (n = 1510). A list of eight books and 115 articles were selected for this study after titles and abstracts of the peer-reviewed publications were scanned in terms of relevance. Relevance criteria included urban agriculture projects, outdoor living walls with edible plants, small-scale non-commercial food production, and modular walls involving a growth medium. These primary sources were divided into subgroups to facilitate analysis. Subgroups entailed the efficiency of LWSs, outdoor edible LWS benefits and ecosystem service provisioning, and TAV as food plants. A final number of 51 journal articles was included in the core review. These journal articles are categorised in urban agriculture, living walls, African vegetables, sustainable development goals and food security.

The research focuses on how the performance of outdoor modular LWS as EGI can be improved and how the production of TAV crops in modular LWS in local urban environments (Gauteng, South Africa) can contribute to household food security and connected SDGs in South Africa.

2.2 The status of living wall systems as a form of urban agriculture that can contribute to food security and related SDGs

The City Feeding People Programme (CFP) defines urban agriculture as;

> *"An industry located within (intra-urban) or on the fringe (peri-urban) of a town, a city, or a metropolis, which grows or raises, processes, and distributes a diversity of food and non-food products. It (re)uses daily human and natural resources, products, and services largely found in and around that urban area and, in turn, supplies daily human and material resources, products, and services largely to that urban area" (Mougeot and International Development Research, 2006).*

This section considers the contribution of urban food production on food security (SDG2) in response to research objective one below, as shown in Figure 2.2.:

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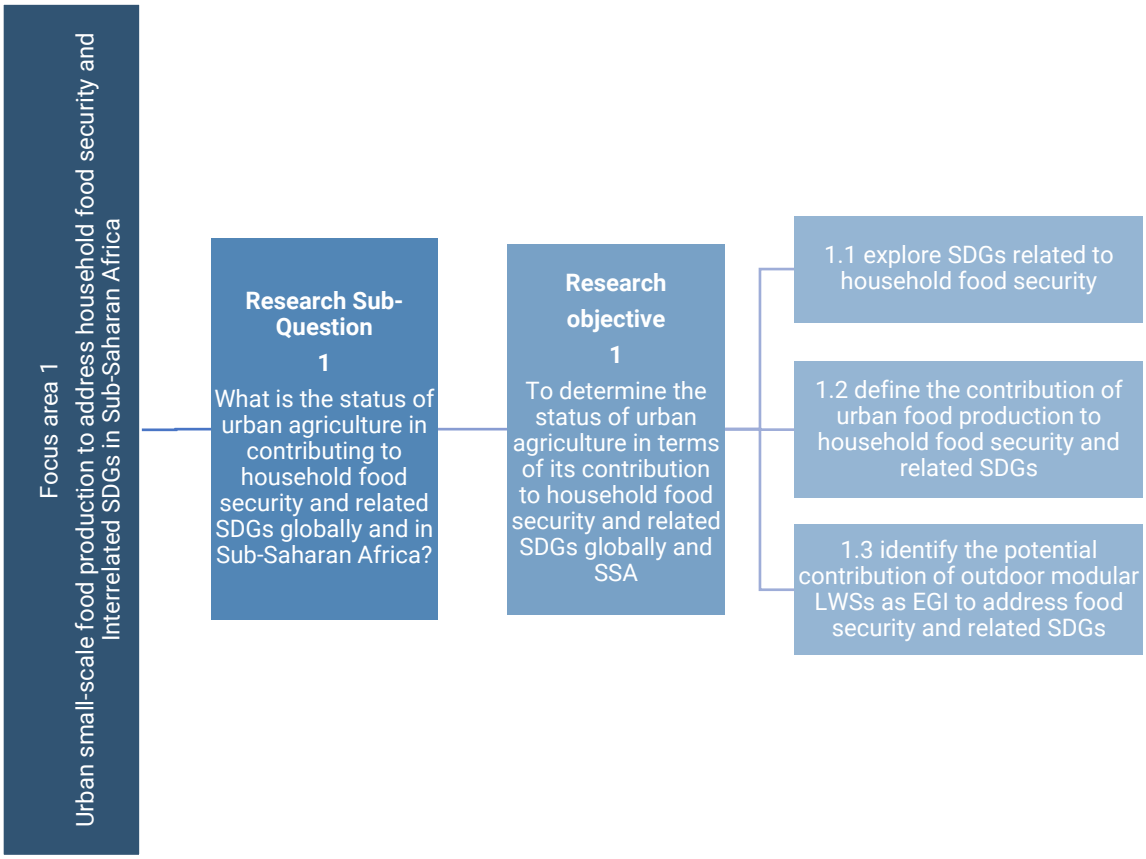


Figure 2.2. Graphic illustration of the first focus area of the literature review relating to research question 1 and research objective 1

Food security cannot be considered in isolation, as it interacts with and depends on other SDGs and vice versa (Manandhar et al., 2018). Siddiqui et al. (2020) argue that the SDG targets can only sustainably be addressed by looking at the interrelated targets together, not in isolation. This section, therefore, commences by explaining the relationship between food security and the identified interrelated SDGs. Subsequently, the status of the progress made in contributing to food security (SDG 2) is explored in the second part of this section. The related eight SDGs will be elaborated on in the third part.

2.2.1 The link between food security and identified SDGs

Food security is defined by the Food and Agriculture Organization of the United Nations (FAO) as access for all people to adequate, safe, and nutritious food (FAO et al., 2018). Herrero et al. (2021) stress the importance of looking holistically at the different dimensions of global food systems to ensure sustainability and social justice. Although food security is related to at least 12 of the 17 SDG targets (Siddiqui et al., 2020), the author selected 8

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SDGs, considered to have a solid two-way link with ending hunger, reducing food insecurity and improving nutrition and agriculture (SDG 2) for this study.

These include ending poverty (SDG 1), good health and well-being (SDG 3), gender equality (SDG 5), decent work and economic growth (SDG 8), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), climate action (SDG 13) and life on land (SDG 15).

Figure 2.3 provides a diagram of the nine related SDGs.

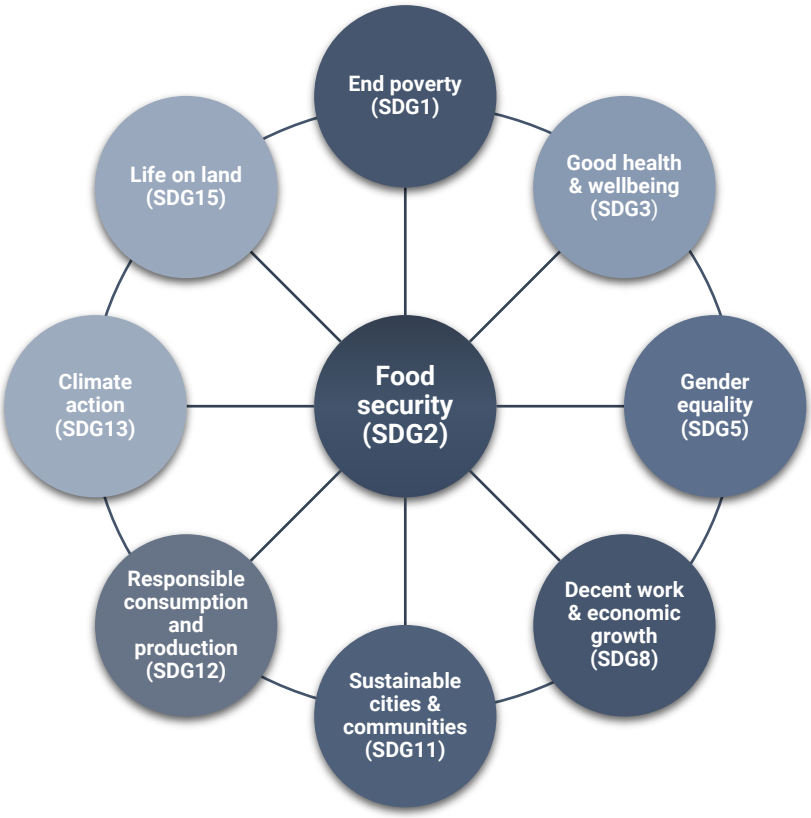


Figure 2.3: Eight SDGs closely affecting and affected by food security (SDG2), identified for this research

The motivation for selecting these SDGs and how they relate to each SDG with food security are deliberated below. Developing countries experience a higher likelihood of severe food insecurity compared to middle-income countries (FAO et al., 2018; Siddiqui et al., 2020). Malnutrition, hunger and poverty are causes and consequences of each other, with hunger and malnutrition reducing work capacity and income and vice versa (Siddiqui et al., 2020). Related to economic welfare, good health and well-being (SDG 3) was a significant outcome

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of food security. Food insecurity significantly impacts well-being in low-income, food-deficient, drought-affected countries (Kornher and Sakketa, 2021). Health and well-being are also linked with economic productivity (Kornher and Sakketa, 2021).

Regarding gender equality, women are disadvantaged in food distribution and, therefore, affected worse than men by food insecurity (Manandhar et al., 2018), experiencing it more extensively than men (FAO et al., 2018). Also, the SA agricultural sector, which comprised 5,28% of all employees in South Africa in 2019, was dominated by females (52,8%) (Stats SA 2019). Therefore, urban agriculture can empower women by addressing decent work, economic growth (SDG 8), and gender equality (SDG 5). Gender equality and empowering women and girls could improve health and development (Manandhar et al., 2018).

Regarding sustainable cities and communities (SDG 11), the role of ecosystem services in addressing integrated goals is essential (Yang et al., 2020). This includes ecosystem services such as climate action (SDG13), food security (SDG 2), and biodiversity/ life on land (SDG 15) (Yang et al., 2020).

Concerning responsible consumption and production (SDG 12), around a third of food is wasted globally, while almost 690 million people experience food insecurity annually (FAO, 2022). Food systems impact the world's ecosystems, and agriculture practices are the most significant contributors to GHG emissions (FAO, 2022).

Each of the eight UN SDGs is discussed in Par 2.2.3 The potential contribution of urban food production to address SDGs related to food security concerning urban agriculture.

2.2.2 The status quo and potential contribution of urban agriculture to end hunger, achieve food security and improved nutrition and promote sustainable agriculture (SDG2)

Sustainable urban agriculture mitigates environmental (reduce transport emissions, energy and water resource use, reduction of organic waste and climate change), social (food security, poverty, health) and economic challenges (pressure on arable land) simultaneously (Specht et al., 2014). This sub-section considers the status of urban agriculture in contributing to food security (SDG 2).

Four SDG 2 targets relating to this study are discussed below. These include ending hunger, improving nutrition, assisting small-scale food producers in improving their income, and ensuring sustainable agriculture (United Nations, 2022).

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i. End hunger

Six comma eight million South Africans and 1,7 million households were affected by hunger in 2017, with almost 0,9 million (5,5 %) of the total 16,2 million SA households experiencing severely inadequate food access (Statistics South Africa, 2019b). The South African government's National Development Plan (NDP) list agricultural productivity and food security as essential priorities (Statistics South Africa, 2019b). One of the critical actions of the National Food and Nutrition Security Plan (2018-2023) entails supporting smallholder producers to enhance productivity and access to nutritious food (Department of Planning Monitoring and Evaluation, 2017). However, no feedback is reported on the progress made by the government.

Food must fulfil people's dietary needs and preferences to enable them to lead an active, healthy life (FAO et al., 2018). People affected by mild food insecurity cannot frequently eat a balanced, healthy diet, and people affected by severe food insecurity do not have access to food for a day or several days (United Nations Statistics Division, 2020). An estimated 25,9% of the global population was affected by moderate to severe food insecurity in 2019 (United Nations Statistics Division, 2020). This figure increased by 3,5% from 2014 and is expected to increase further due to the COVID-19 pandemic and the cumulative impact of natural disasters due to climate change (United Nations Statistics Division, 2020).

ii. Improved nutrition

Urban environments in predominantly low-income areas offer many convenience and fast food stores, with less access to healthy, nutritious foods such as fresh produce, leading to nutrition-related health problems (Besthorn, 2013). Malnutrition is integral to food security (Oelofse and Van Averbeke, 2012). It is the root of low birth weight, stunting and wasting (low weight for length) in children under five years of age, micro-nutrient (vitamin and mineral) deficiency, anaemia (iron deficiency), underweight and obesity in adults (Development Initiatives, 2018; FAO et al., 2018). Obesity leads to Type II diabetes, high blood pressure, heart attacks and cancer. Africa has the highest undernourishment prevalence, with almost 21 per cent of the population affected (FAO et al., 2018). In South Africa, 65% of underlying causes of premature illness and death are directly related to malnutrition (Department of Planning Monitoring and Evaluation, 2017).

Although fruit and vegetable consumption has increased globally over the last three decades, the World Health Organization's (WHO) recommended daily targets are still unmet

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(Stadlmayr et al., 2023), especially in developing countries (Okop et al., 2019; WHO, 2020; Mensah et al., 2019). The WHO recommends a minimum of 400g of fruit and vegetables, excluding starchy tubers and potatoes (WHO, 2020). Vitamin A-rich fruit and vegetables are the lowest-consumed group in South Africa (Labadarios et al., 2011), with vitamin A, iodine and zinc being the primary deficiencies amongst South Africans and vitamin A and iodine being the most substantial micronutrient deficiencies globally (Wenhold Friedeburg and Faber Mieke, 2008; Oelofse and Van Averbeke, 2012; Harika et al., 2017).

Based on data from the Global Nutrition Report, insufficient progress has been made regarding targets to end malnutrition by 2030 (Development Initiatives, 2018). One-hundred-and-forty-one countries were analysed in 2018 to measure nutrition targets adopted by the World Health Organisation (WHO) and the World Health Assembly in 2012 (Development Initiatives, 2018). None met all nine targets, two African countries are on track to meet four targets, and only 6 African countries are on course to meet at least one (Development Initiatives, 2018). South Africa does not meet global nutrition targets for under-five stunting, low birth weight, adult male and female obesity, women of reproductive age (WRA) anaemia and diabetes in adult males and females (Development Initiatives, 2018). The FAO urges that "[a] shift is needed towards nutrition-sensitive agriculture and food systems that provide safe and high-quality food, promoting healthy diets for all" (FAO, 2018: 35).

Food systems must adapt to provide improved nutrition, more effective use of natural resources and increased resilience of production systems (Gordon et al., 2017). Cilliers (2019) argues that urban agriculture can potentially increase access to healthy food options in urban areas. Another study found that urban community gardeners consumed more vegetables and fruit (He, 2015).

iii. Small-scale food producers

Of the 14,8% South African households involved in agricultural production activities in 2018, more than 90% were engaged in small-scale agricultural activities, and 53,3% cultivated fruit and vegetables (Statistics South Africa, 2019a). However, drought and climate variability significantly reduced production by over 6% between 2011 and 2016 (Statistics South Africa, 2019b). Local crops that can tolerate these climatic conditions, such as TAV, could offer a solution (Botes and Breed, 2021) to assist small-scale food producers in increasing their productivity and income.

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iv. Sustainable Agriculture

The impact of traditional agricultural practices, which entails horizontal ground-based agriculture (Khalil et al., 2020), on the natural environment is well-known. Consequences include the destruction of natural habitats and wildlife species, deforestation, high water usage, increased GHG emissions due to the transportation of food, increased waste and climate change (Cilliers, 2019).

Building-integrated agriculture, which involves integrating food production in urban buildings and includes vertical farming (Khan and Ahmed 2017), is growing in developed communities. However, it is still an unfeasible option for SSA. Vertical farming as an urban agriculture solution is a challenge due to the high cost of land in or close to cities (Despommier, 2013; Khan and Ahmed, 2017; Benke and Tomkins, 2017). Other researchers challenge this viewpoint to utilise derelict, unused areas and factory buildings to establish VF within and surrounding cities (Kalantari et al., 2018). Contrasting consumer responses exist regarding controlled environment agriculture crops, the one viewing these crops as clean, green and gourmet food, and the other viewing it as unnatural and non-organic food due to their production without a growing medium and shorter production cycles regarded as impacting negatively on nutrient value (Pinstrup-Andersen, 2018; Benke and Tomkins, 2017).

Urban agriculture offers a sustainable strategy to address household food security (Cilliers, 2019). With predicted urbanisation of 90% in Africa (Gregory et al., 2019) and almost 70% of the world population to occupy cities by 2050, according to Kundu and Pandey (2020), with 56% of the world's poor in urban areas, cities need to be optimised for urban agriculture purposes to supplement conventional rural agriculture (Eigenbrod and Gruda, 2015). Additional potential benefits include community well-being, addressing poverty and creating employment opportunities (Cilliers et al., 2020). The high cost of urban land and pollution impacts urban agriculture (Eigenbrod and Gruda, 2015), although integrating urban agriculture into urban planning is critical to sustainable urban agriculture. This will ensure the management of social impacts and locations considering polluted areas to prevent risks of trace metals, especially leafy vegetables (Eigenbrod and Gruda, 2015; Säumel et al., 2012). Urban agriculture can improve access to, availability of, and quality of food. Combined with rural agriculture and indoor farms, it could contribute significantly to addressing food security, which will become more critical in response to urban pollution and weather extremes due to climate change (Eigenbrod and Gruda, 2015). The potential

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of urban agriculture to contribute to addressing food security is promoted by various food policy councils (FPC), including Cities Farming for the Future (CFF) and the RUAF Foundation (Resource Centres on Urban Agriculture and Food Security) (Gregory et al., 2019).

Eigenbrod et al. (2014) report that urban agriculture increased globally and that vegetable production is the most significant contributor to food security. Informal economic activities, including urban agriculture, are central to developing countries and SSA (Crush et al., 2020). Based on an extrapolation of a study by Zezza and Tasciotti (2010), Hamilton et al. (2014) estimated a total of 265 million households practising urban agriculture in developing countries, with 29 million in Africa (Crush et al., 2020). Statistics on urban agriculture remain challenging due to the unavailability of other records in the informal sector (Crush et al., 2020). Given the significance of urban agriculture in the informal sector, this lack of statistics is a significant data gap (Crush et al., 2020).

Technological advances in urban agriculture, such as edible living walls and rooftop gardens, could optimise food production in South African cities (Cilliers et al., 2020). Moreover, novel technologies are required to increase efficiency and sustainability (Eigenbrod and Gruda, 2015). A study conducted in the City of San Jose in California found that community garden practices delivered a 0,15 pounds (68 grams) higher yield per square foot than conventional agricultural practices, with an expected increase should vertical crops be used (Kulkarni, 2019). This underpins the need for research on edible LWS in urban areas. A shift towards nutrition-rich food, produced through more efficient utilisation of natural resources through resilient systems, is required (Gordon et al., 2017).

2.2.3 The potential contribution of urban food production to address SDGs related to food security

This section considers eight UN SDGs identified by the author based on the links with food security (SDG 2) that are relevant to this study. It is, therefore, essential to determine the status of urban agriculture in contributing to these SDGs (Sub-question 1).

With the world passing the one-third mark of its journey to meet the 2030 Agenda for Sustainable Development Goals, the impact of the COVID-19 pandemic exacerbated current trajectories not in line to meet global goals by 2030 (United Nations Statistics Division, 2020). Progress in contributions to address goals related to poverty, food security, decent

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work and economic growth, sustainable cities, climate change and biodiversity are therefore fundamental as a point of departure for this research and are deliberated below.

i. End poverty in all its forms everywhere (SDG 1)

Poverty is interconnected with food security and malnutrition and the well-being and health of people, and even more so in marginalised countries. Global poverty figures were reported to increase to 8,8% in 2020, along with extreme climate events such as drought, hurricanes, floods and earthquakes (United Nations Statistics Division, 2020). Extreme poverty in Sub-Saharan Africa and Asia is expected to increase significantly, with 26 million people affected by poverty (United Nations Statistics Division, 2020). Seventy-three per cent of direct economic losses in 2020 were documented in the agricultural sector in 2020, with the most significant impact on small-scale farmers in sub-Saharan Africa (United Nations Statistics Division, 2020). Recent data from Statistics South Africa suggests that the segment of the population living in poverty stands at 55,5%, which accounts for an alarming 30,4 million people (Cilliers et al., 2020).

The literature presents two conflicting viewpoints regarding the potential of urban agriculture to alleviate poverty. A study conducted between 2008 and 2009 on 6,453 households in Southern Africa concludes that urban agriculture holds limited benefits in alleviating food security and poverty (Frayne et al., 2014). Frayne et al. (2014) highlight the importance of urban context, modes of practice and regulation in impacting urban agriculture activities and stress the importance of further research. Moreover, the study concludes that services, financial access, infrastructure, and skills development are necessary to implement urban agriculture successfully (Frayne et al., 2014).

More recent studies argue that the urban agriculture sector can potentially address income, employment (Crush et al., 2020), and food security. Still, support from the government is necessary for marginalised countries especially (Eigenbrod and Gruda, 2015). As a response strategy to the increase in food demands owing to the growing world population, urban food production is expected to contribute to employment opportunities linked to poverty (Eigenbrod and Gruda, 2015; De Bon et al., 2010). The viewpoint that UA can potentially address income is supported by Battersby and Watson (2018), who argue that low-income households depend highly on informal food vendors.

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ii. Ensure healthy lives and promote well-being for all at all ages (SDG 3)

Social work professionals' understanding of well-being is grounded on person-in-environment, which implies a holistic approach involving environmental awareness (Besthorn, 2013). Including the socio-cultural and political environments is equally important to the ecosystems in which food systems are embedded (Shauna et al., 2020). Availability, affordability, convenience, promotion, quality and sustainable properties of the food impact the quality of food environments (Shauna et al., 2020).

Urban agriculture contributes to improved stewardship of the environment by connecting people to food production systems, with increased well-being and mental benefits, promoting more significant levels of physical activity and better neighbourhood relations (Alcock et al., 2014; Gordon et al., 2017). A study on a residential-scale LWS prototype with vegetables and herbs in Sri Lanka to analyse the social impact demonstrated that edible LWSs in cities and communities had psychological, aesthetic, health and social advantages, i.e. the impact on human behaviour (Weerasinghe et al., 2020). Positive effects exceed negative consequences, although research is required to address life cycle impacts, thermal performance, air quality, and carbon footprint (Weerasinghe et al., 2020). The researchers express the need for further research to develop a sustainable LWS for Sri Lanka (Weerasinghe et al., 2020). The value of urban agriculture is also evident in Mexico, where Nadal et al. (2018) concluded that urban agriculture strengthens the identity of the people and improves their current food and health conditions (Nadal et al., 2018). In Medellin, Schwab et al. (2018) also found that urban agriculture is embedded in the culture of residents, going beyond the mere subsistence value. Not only satisfying basic nutritional needs but also creating aesthetic and cultural values are critical for identity-building (Schwab et al. 2018).

This is evident from the growing interest in environmentally friendly, healthy, organic and locally produced products, slow food movements and ‘farm-to-fork’ restaurants (Gordon et al., 2017; Jürkenbeck et al., 2019), which are not affordable for the majority of the South African population (Mabhaudhi et al., 2018).

iii. Achieve gender equality and empower all women and girls (SDG 5)

Although gender equality in the workplace has improved, a mere 39% of women in the global working-age population were employed in 2019, with 28% in managerial positions and women facing more obstacles than men in getting hired (United Nations Statistics Division,

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2020). Current agricultural practices target commercial farmers with resources, resulting in more considerable challenges for women and smallholders despite their significant roles in farming in Africa (United Nations Statistics Division, 2020).

The World Vegetable Centre (previously known as the Asian Vegetable Research and Development Centre) (AVRDC) and the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) conducted two research projects. These projects promote agricultural practices by women and disadvantaged groups on a home garden scale to produce a variety of vegetables and legumes throughout the year. Moreso, these projects entailed the "Promotion of Neglected Indigenous Leafy and Legume Vegetable Crops for Nutritional Health in Eastern and Southern Africa" (ProNIVA), which ended in 2009 and was followed up by "Vegetable Breeding and Seed Systems for Poverty Reduction in Africa (vBSS)" which ended in 2010 (Ojiewo et al., 2015).

The International Fund for Agricultural Development (IFAD) launched the first UN effort to enhance the sustainable conservation and use of AOC between 2001 and 2010 through two global projects in Bolivia, Peru and India (Padulosi et al., 2013). The objective was to use AOC to enhance the livelihood of poor communities and validate the efficiency thereof to stimulate economic growth and food security. Two findings from these projects applicable to this study entail addressing the perception of AOC as [1]poverty crops to address the demand for AOC and the importance of farming to include women (Padulosi et al., 2013).

Vorster, Stevens et al. (2008) confirm that research on TAV needs to consider female dominance in agricultural activities aimed at TAV production in rural communities, which entail technologies comprising reduced labour, low resources, increased indigenous knowledge (IK) and access to land (Vorster et al., 2008). Food systems need to empower women due to their role in the production of TAV in South Africa (Mabhaudhi et al., 2019). Stadlmayr et al. (2023) emphasise the importance of women's empowerment.

[1] Poverty crops are perceived by communities as crops that are consumed by poverished people, and therefore have a stigma associated to growing and eating these crops

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iv. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all (SDG 8)

Low-income countries are not meeting the SDG target of at least 7 % real GDP growth per annum, and the pandemic is expected to have increased this shortfall significantly (United Nations Statistics Division, 2020). The global unemployment rate was 5% in 2019 (United Nations Statistics Division, 2020), with an unemployment rate of 29,1% in 2019 in South Africa, an increase of 1.6% from the previous year (StatsSA, 2019). Although rural, the primary source of income in Sub-Saharan Africa is small-scale rainfed farming (Hadebe et al., 2017). The agriculture sector increased by 4.5% in 2019, while the informal industry decreased by 0,7% in 2019 (StatsSA, 2019). The impact of the pandemic on global employment was significant (United Nations Statistics Division, 2020), with people in food production the most vulnerable regarding economic growth and climate extremes associated with climate change.

As a response strategy to the rise in food demands due to the growing world population, urban agriculture can potentially contribute to self-sufficiency, micro-businesses and employment opportunities (Ling et al., 2018; Eigenbrod and Gruda, 2015; De Bon et al., 2010). Implementing small-scale, low-technology urban agriculture projects with vegetables would enhance these opportunities.

v. Make cities and human settlements inclusive, safe, resilient and sustainable (SDG 11)

The world population is currently standing at almost 8 billion (US Census Bureau, 2021), with 86% of the world's population in developed regions and 64% in less developed areas who will stay in cities in 2050, as predicted by the United Nations (Hu et al., 2020). Urbanization in South Africa exceeded 66 % in 2019, with a population density of 46 people per square kilometre (Plecher H, 2020).

The distance to food environments and natural landscapes plays vital roles in the consumption patterns of fruit and vegetables (Stadlmayr et al., 2023). Only 29,7% of people in Sub-Saharan Africa are within walking distance of 400 metres of a public open space, compared to the global average of 46,7% (United Nations Statistics Division, 2020). Besides the inadequate provisioning of open space, the importance of the greening of cities and the well-being of people, especially given the impact of the pandemic, emphasizes the need for responsible and sustainable urban planning (United Nations Statistics Division, 2020). In

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addition, nine out of ten people in urban areas globally are exposed to conditions not complying with air quality guidelines, with more than 50% of the world's population exposed to air pollution levels of at least 2,5 times above the acceptable value (United Nations Statistics Division, 2020). These statistics further stress the need for increased vegetation in urban areas, which provides air purification and cooling benefits besides other benefits such as aesthetic and biophilic value. Based on the reliance of conventional agriculture on arable land, almost 70% of freshwater resources of our planet and over 80% of available land for agriculture currently used, our resources will not be able to sustain the world population's increasing dietary requirements (Lim and Liu, 2010; Besthorn, 2013) if alternatives are not explored.

Localised food production, as opposed to conventional agriculture, holds significant benefits in terms of the contribution to ecosystem services and decreased GHG emissions due to the reduced transportation of food from remote areas (Russo et al., 2017; Lee et al., 2015). Innovative urban agriculture, which entails optimised food production by employing recent technological innovations such as LWSs can potentially address food security, depending on implementing sustainable practices (Armanda et al., 2019). However, the scale and technology should consider the socio-economic environment of developing economies. Edible green infrastructure (EGI) benefits communities by providing ecosystem services integral to sustainable cities (Russo and Cirella, 2019; Russo et al., 2017; Ling and Chiang, 2018). Urban agriculture provides ecosystem services, which are benefits from the natural environment provided to humans through providing provisioning, supporting, cultural and regulating services. Ecosystem services delivered by vegetation can mitigate urbanisation disadvantages, including food provision, climate change events, water management and air pollution (Perez and Perini, 2018), all contributing to sustainable cities and communities (See Fig. 2.6).

vi. Ensure sustainable consumption and production patterns (SDG 12)

The global footprint, which stood at 85,9 billion metric tons in 2017, increased by more than 17% since 2010, more than population growth and economic output, with fossil fuels and the food supply chain of significant concern (United Nations Statistics Division, 2020). This is due to almost 14% of food being wasted after harvesting through transport, storage and processing globally, which affects environmental sustainability and food security (United Nations Statistics Division, 2020).

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Localised urban food production is necessary to reduce GHG emissions from energy-intensive production processes and the transport of food products (Lopez et al., 2019) and address local access to food.

vii. Take urgent action to combat climate change and its impacts (SDG 13)

Climate change impacts food production and vice versa. More frequent climate extremes such as drought, heat and floods affect agriculture and yields (IPCC, 2018). On the contrary, fossil fuels and agrochemicals used in unsustainable conventional ground-based agricultural practices negatively impact climate change (Besthorn, 2013; Specht et al., 2014; Eigenbrod and Gruda, 2015). Between 20 and 30% of global greenhouse gas emissions are attributed to agricultural practices (Eigenbrod and Gruda, 2015; Kulak et al., 2013), mainly due to food wastage as a result of poor infrastructure and storage and food spoilage due to inferior quality or overproduction (IPCC, 2018). Increased agricultural efficiency resulting in reduced wastage is suggested as a response strategy to mitigate climate change and the impact on biodiversity by unsustainable agriculture practices (IPCC, 2018). The cooling benefits of vegetation in LWS on buildings to minimise the heat island effect and address CO_2 emissions are demonstrated in many studies (Cameron et al., 2014; Davis and Hirmer, 2015; Yang et al., 2018; Wong et al., 2010; Natarajan et al., 2015).

The first contributing factor to high carbon emissions during food production is energy usage, which entails 20 calories to produce every 11-calorie food processed on average. Food miles or transport of food products between agricultural areas, processing plants and supermarkets, and food packaging are the second contributing factors (Lopez et al., 2019).

The benefits of urban agriculture, and mainly as part of living walls, include not only a reduction in energy usage due to locations closer to consumers but also mitigation of the urban heat island effect, with vegetation cover providing carbon sequestration and oxygen (Lopez et al., 2019; Salazar-Moreno et al., 2018; Price et al., 2015; Zaid et al., 2018).

Urban agriculture is regarded as an urban greening solution for climate change and addressing the heat island effect (Specht et al., 2014). Because of climate change, the demand for resilient landscapes is becoming more essential (Ling et al., 2018), as climate change directly impacts agriculture through increased atmospheric CO_2 concentrations and changes in temperature and rainfall patterns. These temperature changes can also lead to added impacts such as increased pests and diseases (Lopez et al., 2019).

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viii. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss (SDG 15)

Agricultural activities are accountable for a 31,2% decline in forests in 2020 (United Nations Statistics Division, 2020) and impacts on natural ecosystems and biodiversity (IPCC, 2018). The last three decades showed a 10% increase in biodiversity loss, with a 0,02 increase in the Red List Index between 2015 and 2020, implying more than 31,000 species are threatened with extinction mainly due to unsustainable agriculture, deforestation and invasive alien species (United Nations Statistics Division, 2020).

Provided that a network of urban agriculture green infrastructure, which applies conservation and restoration principles, is created to ensure the delivery of ecosystem services, the impact on land degradation and biodiversity loss can be mitigated (Cilliers et al., 2020). Under some scenarios, urban agriculture can potentially conserve land, reduce GHG emissions and waste, and enable food production with a low carbon and water footprint compared to conventional agriculture activities (Cilliers, 2019). These scenarios would include repurposed urban spaces with socio-economic benefits and limiting biophysical impact, with a need for novel urban agriculture approaches.

2.2.4 Concluding remarks on the status of living wall systems as a form of urban agriculture in contributing to food security and related SDGs

This part of the literature review considered the status of urban agriculture in terms of its contribution to household food security and related SDGs. The literature review confirmed that food security could only be addressed with related SDG targets, which are interdependent and linked to ending hunger, reducing food insecurity and improving nutrition and agriculture (SDG 2). The researcher explored the following SDG targets related to food security: addressing poverty, good health and well-being, gender equality, decent work and economic growth, sustainable cities and communities, responsible consumption and production, climate action and life on land. The literature agrees that the world and South Africa are not making sufficient progress in meeting the UN SDG targets, with food insecurity increasing exacerbated by climate change and the recent pandemic. Most African countries, including South Africa, still do not meet global malnutrition targets.

The synthesis of literature sources emphasises the potential of living wall systems as edible green infrastructure to address food security and malnutrition, but also promote good

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health and well-being through aesthetic, functional and resilient natural city features that combat climate change by providing cooling and purifying the air and therefore our city environments. Edible green infrastructure will make our cities more inclusive by creating employment and economic growth for all genders. Current agricultural practices need to achieve gender equality through the upliftment of women. Poverty will be addressed through more accessible food and localised food provisioning, also reducing food miles, food waste and use of valuable resources such as energy. Moreover, the link between the above SDG targets highlights the need for novel approaches such as living walls with edible plants to promote sustainable urban development through local food production. The current slow progress in reaching SDG targets, and high food insecurity, malnutrition and poverty statistics in SSA, stress the need for more sustainable, resilient food systems that consider natural resources. The literature reviewed further emphasises the need for increased and improved urban agriculture efforts globally and in SSA. These efforts need to be sustainable, resilient, and inclusive. Most importantly, urban agriculture efforts need to not only contribute to food security, but also to interrelated SDGs, such as poverty, healthy lives and well-being, gender equality, and responsible consumption and production.

2.3 Factors affecting the performance of modular living wall systems

Concerning the performance of LWSs, limited empirical studies have been conducted on the benefits, with social and educational benefits being the least researched (Radić et al., 2019). This section aims to synthesize literature on modular LWS, provide a brief overview of research conducted regarding LWS as EGI and lastly, factors that impact the efficiency of LWS in response to research objective 2, as shown in Figure 2.4.

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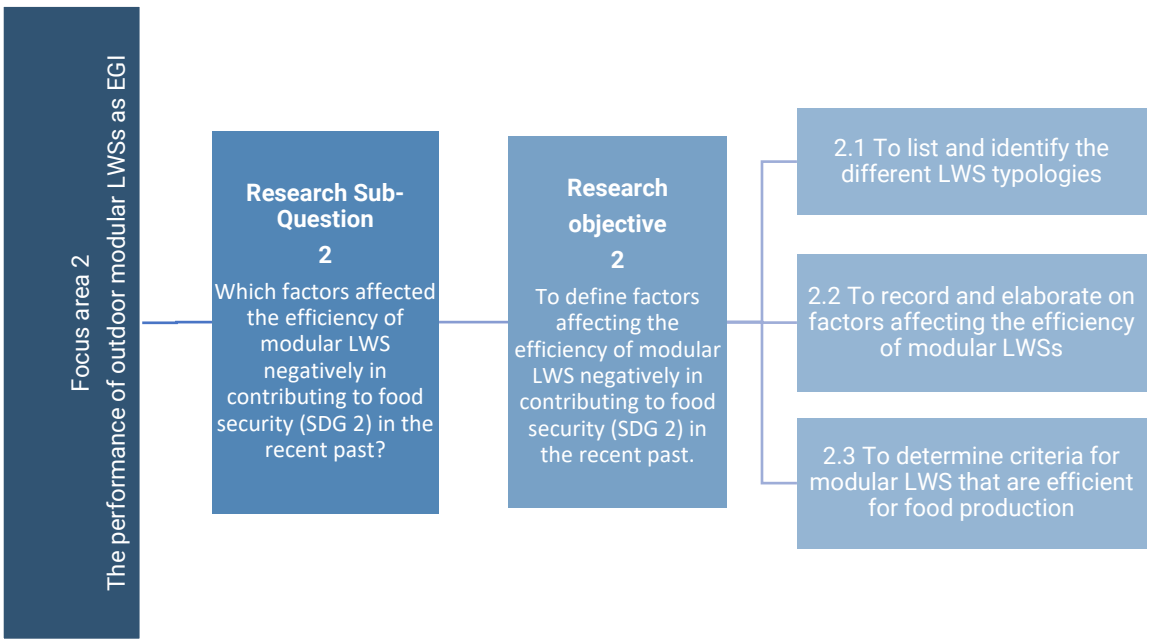


Figure 2.4. Graphic illustration of the second focus area of the literature review relating to research question 2 and research objective 2

The criteria for modular LWS that are efficient for food production form the basis for selecting two LWS typologies for the empirical study.

Modular LWSs have been selected as the focus of this study due to the advantages set out in Modular systems (section 2.3.1). It is important to note that modular LWSs, for the study, include outdoor LWSs, either free-standing/ attached to the outdoor façade of a building. Building-integrated agriculture (BIA), which involves integrating food production in urban buildings and includes vertical food farming (Khan and Ahmed, 2017), is excluded from this study, as it is unfeasible for SSA.

Lastly, the section elaborates on the four factors affecting the efficiency of modular living wall systems. These include cost efficiency, low resilience and high maintenance, health risks and the carbon footprint of LWSs.

The conclusion synthesises the factors affecting the efficiency of LWSs and identifies a criteria list to guide the selection of LWS typologies for the empirical study.

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2.3.1 [1]LWSs definition and typologies

Green or living walls, also referred to as vertical greenery systems (VGS) or living wall systems (LWS), are vertical growing platforms, typically part of the façade of a building (Kȯhler, 2008), containing structural support, in which plants are rooted, that is attached to an interior or exterior of a building and receive their nutrients and water (Radić et al., 2019).

According to Manso & Castro-Gomes (2014), continuous and modular LWSs are different types of LWSs. While modular systems incorporate substrates and consist of containers with predefined dimensions and a variety of compositions, weights, and assembly techniques, continuous systems involve lightweight screens without a substrate for plant development (Botes and Breed, 2021; Manso and Castro-Gomes, 2015).

Living wall projects in South Africa have used local and imported items, making local products more affordable for the customer and the environment. Table 2.1 lists the four most popular vertical food-growing systems and describes their potential for use as built environment infrastructure applications.

[1] Botes, K. L. & Breed, C. A. 2021. Outdoor living wall systems in a developing economy: A prospect for supplementary urban food production? *Acta Structilia* [Online], 28

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Table 2.1: Comparison of living wall system typologies in terms of resilience, feasibility, and sustainability in the South African environment

Criterion	Modular	Continuous systems		
		Hydroponic	**Aquaponic**	**Aeroponic**
Reliance on high technology	There are low-technology systems available, although most are high-technology systems.	Yes, crop yields are impacted by algae, water availability, quality, and pH	Yes, proper illumination levels and balancing between fish and plant nutrient requirements are required for food safety when consuming fish (Mchunu et al., 2018)	Yes, the system requires complex technology, high control, and expertise. Specialised high-pressure pumps, misters, and timers, including specific nutrient concentration parameters, are needed (Botes and Breed, 2021).
Reliance on electricity and water	Partially, it can function for roughly 24 hours without water and electricity.	Yes, these systems rely on electricity and water provision to manage the water quality (Manso and Castro-Gomes, 2015).	Yes, these systems rely on electricity and water provision to manage the water quality (Mchunu et al., 2018).	Yes, the system requires a steady supply of electricity and water (Nir, 1980).
Easy replacement of individual plants	Yes	Yes	Yes	Yes
Resilience in terms of a 24-hour dry period	Yes, due to the soil medium	No. plant species can perish during a temporary system failure.	No, plant species can perish during a temporary system failure.	No, Short-term water and energy outages or a minor system fault can adversely impact the condition of the plant.
Effective disease control	Yes, it is not a continuous system and, therefore, limits the spread of disease.	No, continuous system	No, continuous system	No, continuous system
LWS is locally produced	Yes	Yes	Yes	Yes

Source: adapted from Botes and Breed (2021:147)

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i. Modular systems

Modular LWSs consist of structures of specific dimensions that support elements such as trays, vessels, or bags (Manso & Castro-Gomes, 2014) that contain a growing medium, such as soil, for growing plants. These elements can also be fixed directly to the building's vertical surface (Botes and Breed, 2021; Manso and Castro-Gomes, 2015).

There are four types of modular LWSs:

1. Trays have interlocked compartments or modules to hold each plant and the growing medium. They are typically constructed from thin polymeric materials, mounted on frames, fastened to vertical surfaces, and connected to irrigation systems. (Botes and Breed, 2021; Manso and Castro-Gomes, 2015).
2. Plant-filled containers that can be stacked vertically are referred to as vessels. (Botes and Breed, 2021; Manso and Castro-Gomes, 2015).
3. Planter tiles with plant pockets and flat back edges are glued or mechanically fixed to the vertical surface to serve as modular cladding (Botes and Breed, 2021; Manso and Castro-Gomes, 2015).
4. Flexible bags filled with growth media are composed of flexible polymeric material. They work well on surfaces with various curves, such as curved or slanted walls. (Botes and Breed, 2021; Manso and Castro-Gomes, 2015).

The most popular local systems currently are modular LWSs, primarily due to their immediate impact after installation. Because separate modules are provided for each plant, plants can be pre-grown off-site in advance and replaced with little impact on the aesthetics or other plants. Systems made locally include the Vicinity Wall and Modiwall systems. Most products have a soil capacity of 1 to 3 litres. In the Modiwall system, the soil is directly added to the modules. However, the soil in the Vicinity system is contained in hexagonal pots using geotextile bags (Botes and Breed, 2021).

The Eco Green Wall, a locally produced patent, was developed by Abrus Enterprises in response to the economic and sustainability challenges experienced with modular LWSs. The Eco Green Wall was designed with outdoor applications in mind and is based on vegetation-bearing architecture. It comprises lightweight blocks made from cement and locally produced recycled polystyrene aggregate. The seed trays for the growing medium and plants have a volume of 1.59 litres, and there are two options for watering: trunking

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with a wick or a drip irrigation system (Van der Walt, 2019). Assembly is straightforward. The end product is a lightweight, fire-resistant system with thermal, acoustic, and limited solar exposure to enhance plant longevity and moisture retention (Botes and Breed, 2021).

In modular LWSs, the growing medium is an essential element. The growing medium's composition must be adapted to the species' requirements to enhance optimal plant growth. Weight and plant preferences determine the organic and inorganic chemicals and nutrients (Botes and Breed, 2021; Manso and Castro-Gomes, 2015). As it affects the functionality and survival of plant species, effective moisture retention is essential (Van der Walt, 2019).

Local advantages of the Eco Green Wall include increased system resilience to environmental changes, particularly the harsh, dry climate of Gauteng, and events like power outages. Further improvement of modular LWSs is required to optimise plant survival rates and overall sustainability throughout the life cycle of these walls. The following factors must be considered: reducing the ecological footprint by selecting recycled/ recyclable materials for the supporting structure and other components, selecting tolerant plant species, and reducing water usage, maintenance requirements, and overall cost (Botes and Breed, 2021).

ii. Hydroponics

Patrick Blanc invented living walls in the modern era and is the inventor of hydroponic living walls. They were among the most widely used systems at first. They include structures made of thin screens where plants are grown without a substrate and depend on a steady water supply and nutrient supply (Manso and Castro-Gomes, 2015). Hydroponic systems have been actively used in South Africa for architectural green wall projects and their recent application for commercial agriculture (Botes and Breed, 2021).

The low ambient humidity in many areas of South Africa, particularly in Gauteng, where yearly humidity averages 59% and is below 50% in the winter months (Weather and Climate, 2020), renders these systems susceptible and less effective despite successful outdoor instances. Plant species can perish during a temporary power outage or other system failure. Plants under drought stress are more vulnerable to pests that swiftly spread through the continuous system. With crop yields easily impacted by algae, the water's availability, quality, and pH are crucial for the effectiveness of these systems. Moreover, the required foliar cleaning in enclosed spaces may contribute to the spread of plant diseases in the system. Hydroponic systems' resilience and sustainability, especially in low-humidity

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environments, are questionable despite the easy plant replacement (Botes and Breed, 2021).

iii. Aquaponics

Aquaponics involves the production of vegetables in combination with fish, using fish waste as the primary nutrient source, and is still emerging in South Africa (Mchunu et al., 2018). These systems have the potential for food production, particularly for leafy crops. However, they would be vulnerable to vandalism and pollution, making them less practical for projects involving the built environment. Aquaponic systems are not yet viable for Gauteng's urban surroundings because of issues with water quality, the region's harsh local climate, complexity, and a lack of understanding of the systems. These systems are fragile when managing water quality due to the proper illumination levels, fish tank ratios, and balancing between fish feed and plant nutrient requirements, which can be complex and problematic (Mchunu et al., 2018). If the system is not maintained correctly, fish may not be suitable for human consumption and could impact food safety (Mchunu et al., 2018). Furthermore, climatic adjustments, such as changes in water temperature, are required for systems to be profitable, which are essential for metabolic processes. There is a shortage of knowledge and information about these systems (Mchunu et al., 2018; Botes and Breed, 2021)

iv. Aeroponics

Aeroponics entails a sealed soil-free cultivation system, with nutrient-rich fluid sprayed directly onto the exposed plant roots by atomizers (Lakhiar et al., 2018). Impilo Projects introduced this technology in South Africa in 2017 after five years of intensive research in The Netherlands (Van Niekerk, 2021). The design of aeroponic systems makes it simple to measure, track, and change the amount of moisture and nutrients delivered to plants (Botes and Breed, 2021).

These systems are ideal for retrofitting commercial buildings because of their lightweight construction. Aeroponics is a costly option; however, they are space-efficient, produce a high yield in a short period, and require low maintenance, nutrients and water and easy access for root health inspections (Reyes et al., 2012; Nir, 1980). The system requires a steady supply of electricity and water (Nir, 1980). Despite its advantages, the practicality of aeroponics for low-key, low-cost metropolitan settings is debatable due to its high cost, complex technology, high control, and the expertise required (Botes and Breed, 2021). Specialised high-pressure pumps, misters, and timers, including specific nutrient

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concentration parameters, are needed. Even though root chamber cleaning and disinfection constitute the extent of maintenance, Reyes et al. (2012) found that this system is susceptible to bacterial growth because of the high moisture content in the root chamber. Like hydroponics, these systems are incredibly delicate and have little resistance to the dry local climate. Short-term water and energy outages or a minor system fault can adversely impact the condition of the plant (Botes and Breed, 2021).

2.3.2 Cost efficiency

Public perception of LWSs is vital for their feasibility, and studies have proven the value of increased biodiversity and noise reduction (Collins et al., 2017; Veisten et al., 2012). Moreover, the health benefits also impact their feasibility. LWS with edible crops are reported to enhance the environment, and the consumption of vegetables and fruit by urban community gardeners was also found to be higher than that of non-community gardeners (He, 2015; Botes and Breed, 2022).

The challenges of living walls in terms of economic feasibility and sustainability are confirmed by a life cycle analysis of LWS conducted in Delft, the Netherlands, which concluded that LWS are not feasible as their environmental burden exceeds their cooling benefits (Ottelé et al., 2011). A cost-benefit analysis was conducted to determine the economic sustainability of LWS, comparing the installation, maintenance and disposal costs to the social benefits (including real estate value, energy demand reduction, durability and air quality improvement) over the life cycle of the analysed systems (Perini and Rosasco, 2013). They concluded that the economic feasibility could be improved through cost-effective installation and maintenance and by ensuring a wider use by increasing social benefits and improving environmental conditions for cities, which could lead to government incentives (Medl et al., 2017; Perini and Rosasco, 2013; Botes and Breed, 2022).

In line with the study by Perini and Rosasco, installation and maintenance cost perceptions of LWS impacted the progress of Singapore by 2016, which was still below 50% of their 2030 target of 2km^2 skyrise greenery, despite initiatives to encourage vertical greenery through certification to acknowledge greening excellence and their Green Building rating system, (Huang et al., 2019b). A life cycle cost (LCC) study to compare three different systems in Singapore confirmed that the maintenance in the operational phase contributed to the highest expenditure, with support systems comprising climbers at the base growing on a frame the most cost-efficient (Huang et al., 2019b). The study showed modular systems with individual pots were more efficient than framed modular systems, where

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plants were grouped in units within a frame mounted onto a wall (Huang et al., 2019b; Botes and Breed, 2022).

The affordability and durability of living walls are argued to be significantly improved through an integrated in-situ cast pervious concrete layer in front of the structural backup layer (Riley et al., 2019). However, the researchers admitted that further research is required to address optimal plant growth on exterior walls, the weight of the wall and standing water in pores, which could potentially host pests such as mosquitoes (Riley et al., 2019). It was also found that the irrigation and rainwater's calcium oxide and pH levels could impact food crops (Riley et al., 2019). However, the researchers did not consider this problematic (Riley et al., 2019). It is unclear from the literature how the drip irrigation system was installed to determine the efficiency of watering, drainage and maintenance (Botes and Breed, 2022).

Crop selection is confirmed to be essential for increasing feasibility, with small crop sizes and short production cycles making these crops more appropriate choices (Beacham et al., 2019; Botes and Breed, 2022).

LWS with soil-grown crops are preferred over hydroponically grown crops due to perceptions of “unnatural” conditions, and a need for energy-efficient LWS offering environmental benefits with optimum yields was identified (Al-Chalabi, 2015; Botes and Breed, 2022).

2.3.3 Low resilience and high maintenance

Living walls for food production face challenges such as accessibility for harvesting of crops if the LWS is too high above ground level, equal water provision on all levels and light availability in urban areas (Beacham et al., 2019). Hemicryptophytes, which are perennials with renewal buds located near the soil surface, were found to be the most dominant life form in planted retaining walls, based on research conducted on 70 wall-vegetated areas with 196 species in Trabzon, a hilly city in Turkey (Yalcinalp and Meral, 2017). A case study conducted in a high-rise environment in Singapore found that food crops with higher light saturation levels were more tolerant of harsh conditions within the built environment, with extreme photosynthetically active radiation (PAR) variability due to the sun’s north-south oscillation and high-temperature levels during mid-day hours, as well as annual PAR variability due the sun’s north-south oscillation (Song et al., 2018). Increased photoperiods (more than 12 hours) led to increased biomass in both photoperiod-sensitive crops, such as tomato (*Lycopersicon esculentum*) and non-photoperiod-sensitive crops, such as sweet

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pepper (*Capsicum annuum*) crops, although associated with leaf chlorosis (Song et al., 2018; Dorais et al., 1996). Depending on PAR and crop selection, the study found that building-integrated architecture could potentially address food production in city environments (Song et al., 2018). The utilisation of TAV and suitable production technologies such as LWS are believed to be a resilient approach for local conditions of the global south, which primarily consists of semi-arid to arid conditions with intense weather extremes due to global warming, and supports the climate-smart agriculture (CSA) approach (FAO et al., 2018; Mabhaudhi et al., 2016; Botes and Breed, 2022).

Limited empirical studies addressing the affordability and durability of LWSs exist. Riley *et al.* (2019) developed a LWS with an integrated *in-situ* pervious cast concrete layer in front of the structural backup layer. However, the study requires further research to address optimal plant growth on outdoor walls and other factors that negatively impact people or food crops (Riley et al., 2019). These include the weight of the wall and standing water in pores, which could potentially host pests such as mosquitoes (Riley et al., 2019).

2.3.4 Health risks

Health risks for consumers are a reality in the case of edible living walls in city environments due to pollution from contaminated soil, water and air. Inadequately treated water in the case of grey water, or polluted water, and air pollution when in the proximity of roads can lead to contamination of crops (Specht et al., 2014; Säumel et al., 2012; Beacham et al., 2019; Amato-Lourenco et al., 2016). High concentrations of heavy metals such as Arsenic (As), Cadmium (Cd), Copper (Cu) and Lead (Pb) in soils in inner city areas are of concern (Rossiter, 2007; Szolnoki et al., 2013; He, 2015). The trace metal content in crop biomass in inner city areas and especially high-traffic regions is, however, argued to be mitigated through the erection of barriers between food crops and roads (Säumel et al., 2012).

2.3.5 Carbon footprint

It is argued that the carbon footprint of vertical farming (VF) to produce crops is considerably higher than that of conventional agriculture (Al-Chalabi, 2015). The greenhouse gas (GHG) emissions generated by the VF construction and production of systems can be reduced through localised crop production in urban areas due to minimised energy resources and transport requirements (Beacham et al., 2019). It is suggested that water usage during the operational phase of LWS should be targeted to reduce life-cycle energy usage and GHG emissions through measures such as water harvesting, drip

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irrigation, a pumpless-gravity fed watering system and drought tolerant plant species to achieve these reductions (Natarajan et al., 2015; Botes and Breed, 2022).

2.3.6 Summary of the characteristics of LWSs for improved performance

The literature review concluded that modular LWSs offer a more viable solution than continuous LWSs as EGI in developing countries such as South Africa (Huang et al., 2019b; Botes and Breed, 2022). This is mainly due to their resilience in interrupted electricity and water provision, low technology requirements, and effective disease control (Botes and Breed, 2022; Botes and Breed, 2021).

Several aspects to be addressed for improved LWS performance emerged from the literature review. The first aspect includes reducing the carbon footprint and costs through local production of the system (Botes and Breed, 2022; Perini and Rosasco, 2013; Akinwolemiwa et al., 2018). The installation and maintenance costs must be reduced (Akinwolemiwa et al., 2018; Botes and Breed, 2021; Huang et al., 2019b). Akinwolemiwa et al. (2018) and Botes and Breed (2021) reiterated the importance of developing LWSs that require low-skilled, non-specialised technology and workmanship.

Reduced potable water usage during the operational phase through water harvesting, drip irrigation and plant selection is important (Natarajan et al., 2015). The importance of plant selection through integrating agriculture, nature, and ecology, and also for increasing resilience and performance, is vital (Russo and Cirella, 2019; Russo et al., 2017; Beacham et al., 2019). The importance of reducing the carbon footprint using recycled material is also highlighted (Ottelé et al., 2011).

Living wall systems should be viewed as integrated units or systems, including increasing crop performance by addressing the suitability of the plant palette (Russo and Cirella, 2019; Russo et al., 2017), increasing the social benefits (Perini and Rosasco, 2013) and reducing irrigation and energy usage (Beacham et al., 2019; Natarajan et al., 2015) as equally important factors in the system's performance.

2.3.7 Concluding remarks on the factors affecting the efficiency of modular living wall systems

This section of the literature review considered factors affecting the efficiency of modular LWS negatively in contributing to food security in the recent past. The literature unanimously agrees that the cost efficiency of LWSs and low resilience, high maintenance,

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and carbon footprint negatively impact their efficiency. The literature further highlights that further research is required to improve their sustainability, cost, and effectiveness.

Four recurring viewpoints on factors impacting the performance of LWSs transpire in the synthesised journal articles. The first factor entails that the LWS components, such as the wall, rainwater storage tanks, irrigation, and workable plant palettes, are viewed separately as isolated instead of living walls being considered holistically as units or systems. The second factor entails the high installation and maintenance costs, with limited benefits such as social benefits and crop performance impacting the economic feasibility and performance of LWSs. The third factor entails the carbon footprint and environmental burden of LWSs due to imported environmentally unfriendly materials, with reduced resilience by reliance on high technology, water and electricity. The fourth factor impacting the performance of edible LWSs entails possible health risks resulting from the contamination of crops due to polluted soil, irrigation water and air in city environments.

In developing countries such as South Africa, modular LWSs offer a more viable solution as EGI than continuous LWSs due to their resilience in interrupted electricity and water provision, low technology requirements, and effective disease control. The health risks of edible LWS should also be managed through spatial planning to limit contamination risks. At the same time, water for irrigation should be treated appropriately before utilisation for the irrigation of crops.

The factors impacting the performance of LWSs identified through the literature review on improving the efficiency of LWSs guided the selection criteria for the LWS typologies for the empirical study. The following criteria for the system were therefore identified to assist in the LWS selection: 1) It must be modular and locally produced, 2) Its components must be manufactured from recycled material/ must be recycled to limit the carbon footprint, 3) It must include a drip irrigation system to minimise potable water consumption, 4) It must be cost-effective, and 5) involve uncomplicated assembly.

2.4 The potential contribution of TAV to address food security in South Africa

This section focuses on the potential contribution of TAV to address food security in South Africa and documents the most prominent TAV utilised in SA. Twenty-one percent of the South African population experienced food insecurity and severe food insecurity in 2021 (Statistics South Africa, 2023). To improve South Africa's food security, TAV can potentially provide for the nutritional needs of the 4,7 million households experiencing hunger while

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tolerating the country's semi-arid conditions (Mabhaudhi et al., 2017; Statistics South Africa, 2023). Therefore, South African food networks need to prioritise the research and development of TAV and other underutilised crops for innovation instead of using conventional practices involving a limited number of major crops. Literature on TAV in the context of their potential contribution to addressing food security in South Africa is therefore synthesised to address research objective 4:

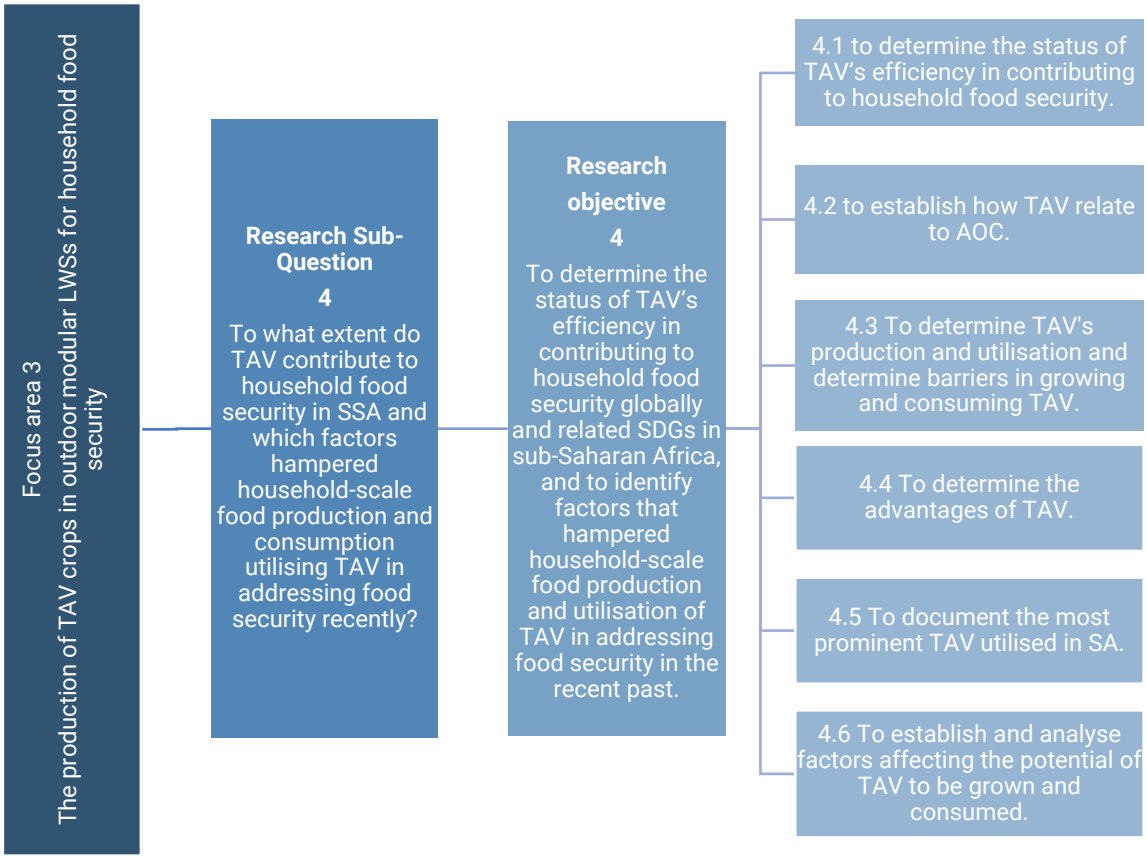


Figure 2.5. Graphic illustration of the second focus area of the literature review relating to research question 4 and research objective 4

First, the term AOC is defined to introduce and provide the background to TAV, which is one of the categories of AOC. Subsequently, the importance of TAV compared to exotic western vegetables is investigated, after which their value in food security and the eight SDGs related to food security, as identified in par. 2.2.1 is reviewed. The following section describes current research on TAV and their global recognition, after which the most

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prominent TAV in SA, as found in the literature, are highlighted. Factors affecting the potential of TAV are identified and described. Finally, the review of TAV is concluded.

2.4.1 African Orphan Crops

Fox and Young (1982) describe a plant as edible when eaten regularly due to taste and texture, adding flavour and variety to traditional dishes such as porridge and meat without causing any ill-side effects.

African Orphan Crops (AOC) include edible under-researched crops adapted to Africa's extreme climate and soil stresses (AOCC., 2020). These crops are still used in traditional local diets and are locally indigenous to Africa or introduced in Africa centuries ago. Many terms for African Orphan Crops exist in the literature. These include lost crops (National Research Council, 1996; National Research Council (NRC), 2006; National Research Council, 2008), disadvantaged crops, minor crops, orphan crops (Hendre et al., 2019), understudied crops, underutilized crops, neglected crops, neglected and underutilised species (NUS) and crops for the future (CFF, 2021).

Vegetables, cereals, legumes, fruit and root crops form the AOC categories (Tadele and Assefa, 2012a; National Research Council, 1996; National Research Council (NRC), 2006; National Research Council, 2008). Welcome and Van Wyk (2019) compiled an inventory of edible plants of the Flora of Southern Africa, which comprises South Africa, Namibia, Botswana, Lesotho and Swaziland, for 1740 plant taxa with 711 genera and 156 families (Welcome and Van Wyk, 2020). This is as an update to the initial inventory of just more than 800 species by Fox and Norwood Young in their book “Food from the Veld” (1982), Wehmeyer (1986) with 62 additional species, Peters et al. (1992) with 46 other records and Schippers (2002) with 183 African vegetable species recorded.

2.4.2 Traditional African Vegetables

Towns and Shackleton (2018) investigated different terms used for indigenous African leafy vegetables and proposed the term “Traditional African Vegetables” (TAV).

Traditional African Vegetables are nutrient-dense, compared to dark leafy green vegetables (DLGV), adapted to local conditions, and vital to sustainable and resilient small-scale agriculture and food systems in SSA (Mabhaudhi et al., 2017; Mabhaudhi et al., 2019).

Traditional African Vegetables are divided into different categories based on the mode of reproduction or propagation – the first is self-propagating with no/ limited human input. It

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is second propagated by humans, with the third the plant part used for nutrition, being leafy (Towns and Shackleton, 2019). Although there are also vegetable crops with fruits, flowers, seeds and tubers used for nutrition, TAV for this study refers to vegetables where leaves are used for food. Oelofse and Van Averbeke (2012) based the categorisation on the use and adaptation of these species. Categories include indigenous, which refers to the local origin, defined by Oelofse and Van Averbeke (2012) and Jansen van Rensburg et al. (2009) as species that have evolved through natural processes and accepted in the local food culture after its introduction to an area and exotic species.

2.4.3 The importance of TAV

Although the "Green Revolution" dramatically increased agricultural productivity in the 1960s to combat hunger through high-yielding plant crops by introducing plant breeding techniques, fertilisers, pesticides and irrigation (Andreosso-O'Callaghan, 2003), it had many shortcomings. These shortcomings related to its ecological footprint initiated a renewed interest in sustainable options such as AOC and TAV, given the effects of climate change, the importance of nutrient-rich diets and rural development (Shackleton et al., 2009; Jaenicke, 2013). Moreover, the 'Green Revolution" technologies alleviated global hunger but were too advanced and costly for Africa, and the species list did not include locally adapted African crops (Shackleton et al., 2009; Tadele and Assefa, 2012a).

Vegetables in the Western world, like TAV, originated as wild plants with information about their origins rarely available, and they were developed through mutation, selection and crossbreeding (Fox et al., 1982). Compared to locally produced crops in Africa, sophisticated food plants stand a greater risk of failure due to a lack of resilience when grown under natural conditions, especially in drought. This initiated a renewed interest in the propagation of local African crops, with over 2000 plants comprising one of the first studies, "Edible Plants of the World", published by Sturtevant in 1919 (Fox et al., 1982). More than 1,500 peer-reviewed publications on studies of local African crops and the rich indigenous knowledge of field botany amongst traditional cultures of Africa have followed since 1997.

Traditional African Vegetables are an important source of vitamins, minerals, trace elements and essential amino acids. *Amaranthus* spp. (Amaranthus) *Corchorus olitorius* (Jew's mallow) and *Bidens pilosa* (blackjack) are regarded as more valuable sources of vitamin C, vitamins A and E, and iron and zinc when compared with exotic vegetables such as *Lactuca sativa* (lettuce), *Brassica oleracea* var. botrytis (cauliflower), *Brassica olearia*

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(cabbage) and *Beta vulgaris* L. var. cicla (Swiss chard) (Modi et al., 2006; Kidane et al., 2015). Vitamin A and, to a lesser extent, the iron content of TAV can contribute to the critical nutrients of the diets of developing countries (van Jaarsveld et al., 2014).

2.4.4 The potential contribution of AOC and TAV to address hunger and SDGs related to food security

The global food system relies on 30 crops to provide for the nutritional requirements of the human population, which makes food systems vulnerable to climate variability (Gordon et al., 2017; MacFall et al., 2015; Mabhaudhi et al., 2018; Chang et al., 2018), especially in marginalised countries such as South Africa. With an increase in the intensity and frequency of extreme climate events such as heat, drought, storms and floods associated with climate change reducing arable land areas, the need for crops such as AOC, which can tolerate these conditions, is increasing (Mabhaudhi et al., 2019; FAO et al., 2018). Stadlmayr et al. (2023) propose enhancing agricultural biodiversity by incorporating indigenous crops such as AOC and TAV to address food security in SSA. Food systems in marginalised countries in SSA must be reconfigured in response to growing concerns regarding climate change, environmental degradation and loss of biodiversity, with one of the strategies to reinvigorate AOC and TAV to improve diets and their sustainability (Mabhaudhi et al., 2019; Mabhaudhi et al., 2017; Drimie and Pereira, 2016).

With almost 11% of the 83 million ha of arable land in southern Africa under irrigation and 89% reliant on rainfall for major crop production, regional food production is still inadequate for the demand, necessitating food imports of about US$35 billion (Mabhaudhi et al., 2019; FAO, 2003).

As part of EGI, using TAV supports the climate-smart agriculture approach (FAO et al., 2018; Mabhaudhi et al., 2016). Moreover, including AOC and TAV in agricultural production can potentially contribute to supporting several SDGs. These include SDG 1 (End poverty in all forms everywhere), SDG 2 (End hunger, achieve food security and improved nutrition and promote sustainable agriculture), SDG 3 (Ensure healthy lives and promote well–being for all ages), SDG 8 (Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all), SDG 13 (Climate action)(Mabhaudhi et al., 2019) and SDG 15 (Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss) (Mabhaudhi et al., 2016; United Nations). A review confirms this to assess AOC's potential contribution towards sustainable food systems and agricultural

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sustainability considering climate change (Mabhaudhi et al., 2019). Mabhaudhi et al. (2016) concluded that AOC could potentially contribute towards the socio-economic development of low input and output agriculture systems, should seed systems and production, genetic traits, agronomy and utilisation be improved.

Target 9 for the period 2015 to 2025 of the National Biodiversity Strategy and Action Plan of South Africa's National Conservation Strategy entails the conservation of the genetic diversity of, among other things, indigenous edible plants and maintaining the indigenous knowledge of these crops and their wild relatives as a response strategy to food safety, food security and climate change (Raimondo D, 2015; Government of South Africa, 2015). This could also be addressed by including AOC and TAV in agricultural production.

2.4.5 Global Recognition and Research of AOC and TAV

The initial interest in AOC in 1998 with the founding of the International Centre for Underutilised Crops (ICUC) expanded into the establishment of organisations such as the Plant Resources of Tropical Africa (PROTA) network in 2000, the Global Facilitation Unit for Underutilized Species (GFU) in 2002, IndigenoVeg in 2006 (Shackleton et al., 2009), and the African Orphan Crop Consortium (AOCC) in 2011 (Hendre et al., 2019; Tadele, 2019; Tadele and Bartels, 2019). The AOCC aims to mainstream 101 AOC species into food production through genomics and genomics-assisted breeding (Hendre et al., 2019). The Consultative Group on International Agricultural Research's (CGIAR's) Science Council in 2005 also initiated AOC research in the 2010 strategic programme of the World Vegetable Centre (Shackleton et al., 2009; Tadele, 2019; AVRDC). The Forum for Agricultural Research in Africa (FARA) was founded in 1990 and advocated agricultural research for development (AR4D) in Africa (FARA, 2018). The Research Centre of Crops for the Future (CFF), based at the University of Nottingham in Malaysia, was launched in 2011 as a member of the Association of International Research and Development Centres for Agriculture (AIRCA). The CFF researches underutilised crops, focusing on the diversification of future agriculture to address food security in line with the Global Action Plan for Agricultural Diversification (GAPAD) (Gregory et al., 2019; CFF, 2021). A germplasm collection of AOC is also held at Svalbard Seed Vault in Norway (Tadele, 2019).

In South Africa, the National Policy on Food and Nutrition Security supports promoting AOC research, development and utilisation (Department of Agriculture Forestry and Fisheries, 2013; Mabhaudhi et al., 2017).

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Rural South African areas are affected the worst countrywide in terms of poverty and food security and, therefore, require novel approaches towards sustainable, low-input agricultural systems (Mabhaudhi et al., 2017). AOC and TAV offer unique opportunities for especially marginalised nations as a resource for diversification of food production due to their nutritional value and ability to adapt to low input and harsh environmental conditions to mitigate the impact of climate change on agricultural production (Hughes and Ebert, 2013; Jaenicke, 2013; Dawson et al., 2019). However, increased awareness of the importance of TAV in diets and their nutritional value among South African urban communities is required. Further research on the accessibility, utilisation and stability of AOC and TAV is essential to elucidate their contribution to urban diets to address food security (Garekae and Shackleton, 2020).

2.4.6 Most prominent traditional African vegetables in South Africa

Literature was assessed to determine the most prominent AOC and TAV in publications regarding production and use to select species for this research. Although other crops are referred to, the focus remains on TAV and production with low resources on a household scale for household consumption.

Apocynaceae, Fabaceae, Asteraceae, Poaceae and Iridiceae comprise the most species-rich edible plant families in Southern Africa, similar to sub-Saharan Africa, which contains the same except for Asteraceae and Iridaceae (Welcome and Van Wyk, 2019). Asteraceae, Asphodelaceae, Amaranthaceae, Apiaceae and Brassicaceae (with a total of 659 species recorded for all families) are the most prominent families used for vegetables in the flora of Southern Africa region (Welcome and Van Wyk, 2019). The Apocynaceae and Fabaceae families provide the highest diversity of edible plant parts, namely roots, stems, leaves, fruit, and seed, with the added provision of gum in the case of Fabaceae (Welcome and Van Wyk, 2020). Preference for food plant families in Southern Africa is linked to the subsistence strategies of the different cultural groups, with agrarians preferring ruderal vegetables of the Malvaceae and Amaranthaceae with above-ground edible parts (Welcome and Van Wyk, 2020).

Food plants classified as vegetables included in the list of most cited food plants in the flora of Southern Africa region (Welcome and Van Wyk, 2019) are *Amaranthus hybridus* (green amaranth), *Amaranthus thunbergii* (Thunberg's pigweed), *Bidens pilosa* (blackjack), *Chenopodium album* (pigweed), *Chorcorus tridens* (Jew's mallow), *Cleome gynandra* (spider flower), *Colocasia (esculenata* (taro), *Cucumus africanus* (wild cucumber), *Cucumis*

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metuliferus (horned melon), *Cucurbita pepo* (pumpkin), *Momordica balsamica* (balsam apple), *Portulaca oleraceae* (purslane), *Solanum nigrum* (nightshade), *Solanum retroflexum* (nightshade), *Sonchus olearaceus* (sow thistle), and *Vigna unguiculata* (black-eyed pea).

For household-scale production, 8 TAV were selected in 2012 as part of a research project by the Water Research Council (WRC) to determine their tolerance of drought and heat, water usage, agronomic requirements and potential nutritional value for human consumption (Oelofse and Van Averbeke, 2012). The species were selected based on the distribution of consumption, seasonality and evidence of cultivation and included *Amaranthus cruentus* (pigweed), *Brassica rapa* subsp. chinensis (Chinese cabbage), *Citrillus lanatus* (Tsamma melon), *Cleome gynandra* (spider flower), *Cucurbita maxima* (pumpkin), *Corchorus olitorius* (Jew's mallow), *Solanum retroflexum* (nightshade), and *Vigna unguiculata* (black-eyed pea). The study concluded that these species proved successful for cultivation in vulnerable communities on a residential scale using local resources (Oelofse and Van Averbeke, 2012).

Jansen van Rensburg and Van Averbeke (2009) found that *Amaranthus* spp, *Cleome gynandra* (spider flower), *Brassica rapa* subsp *chinensis (Chinese cabbage)*, *Solanum retroflexum* (nightshade), *Corchorus olitorius* and *C. tridens (Jew's mallow), Cucurbita pepeo, C. moschata, C. maxima* (pumpkin) and *Vigna unguiculata* (black-eyed pea) prefer well-drained, medium-textured soil, grow optimally in temperatures above 15˚C and are drought tolerant. All these TAV responded well to limited irrigation, except for *Corchorus olitorius* (Jew's mallow), *Solanum nigrum (nightshade)* and *Brassica rapa* subsp. *Chinensis (Chinese cabbage)* require adequate water availability without prolonged dry spells (Jansen van Rensburg et al., 2009). *Cleome gynandra* (spider flower) grows optimally in the hotter, northern parts of South Africa, where it is preferred above Amaranth (Jansen van Rensburg et al., 2009). *Brassica rapa* subsp. *chinensis* (Chinese cabbage) is a cool-season crop.

Extensively used crops in South Africa, harvested from the wild and unproduced commercially, include the *Cleome gynandra* (spider flower) and the genus Amaranthus. These include *Amaranthus thunbergii, A greazicans, A spinosus, A. defelexus, A hyprochondriacus, A. viridus* and *A. hybridus*. These species show potential for development as food crops in South Africa due to accessible collection and availability (Jansen van Rensburg et al., 2009; Fox et al., 1982; Oelofse and Van Averbeke, 2012). *Amaranthus* spp. (Amaranth) and *Cleome gynandra* (spider flower) are pioneer plants and usually not cultivated, as they grow naturally in disturbed soils. These crops are C_4 plants, which entail

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more efficient photosynthesis and reduced water loss than other plants, resulting in these plants being tolerant to hot, arid environments with extreme water and temperature conditions (Hughes and Ebert, 2013). The extensive use of *Amaranthus cruentus* (purple amaranth), *A. hybridus* (amaranth), *Cleome gynandra (*spider flower), *Corchorus olitorius* (jute mallow), *Bidens pilosa* (blackjack), *B. biternate* (yellow-flowered blackjack), *Corchorus tridens* (horn-fruited jute), *Chenopodium album* (fat hen) and *Tribulus terrestris* (puncture vine), is confirmed through case studies in Limpopo, KwaZulu Natal and the Eastern Cape Provinces of South Africa, although not commercially produced, but harvested from the wild for home consumption (Jansen van Rensburg et al., 2009). The genera of Amaranthus were also found to be popular amongst the Vhavenḓa, a cultural group living in the Vhembe District, Limpopo Province of South Africa, and the Solanum genera second in terms of popularity, with 12 Amaranthus species and 10 Solanum species used (Magwede et al., 2019). This was confirmed in other studies with *Amaranthus thunbergii* (Theepe), which proved to be the most consumed in Limpopo, together with *Corchorus* spp (jute), *Cleome gynandra (spider flower*), *Cucurbita maxima (mokopu)* (Nyarai et al., 2018).

Commercially grown TAV include *Vigna unguiculata* (black-eyed pea), cultivated on 12.3 million hectares in Niger, Nigeria and Burkina Faso (Tadele, 2019). *Vigna unguiculata* (black-eyed pea) is cultivated as a grain and fodder crop to control weeds and address erosion. However, the green seeds, young fresh leaves and immature green pods have also proved to be nutritious vegetables with high protein, iron and zinc content (Gerrano et al., 2019). Two broad-leaved varieties of African nightshade, “Nduruma“ and “Olevolosi“, which are softer, sweeter and also require less cooking than Nightshade, have been developed, with seed available at companies in East Africa (Ojiewo et al., 2015). CFF research focuses on *Amaranthus tricolor (Chinese spinach)(Gregory et al., 2019).* Leaves of pumpkins (*Curcubita maxima, Curcubita pepo*), which are commercially grown (Hart, 2011), are nutritious and edible. *Cucurbita* spp (Pumpkin) are cultivated as an intercrop with maize, mainly for weed control and their fruit. Although *Brassica rapa* subsp. chinensis (bok choy) is grown, agronomic strategies are required for improved production (Maseko et al., 2017). Agronomic studies on fertilisation have shown that manure and nitrogen improved production (Maseko et al., 2017).

In the savanna zones of Africa, *Xanthosoma mafafa* (cocoyam leaves), *Hibiscus sabdariffa* (bra), *Amaranthus* spp. (alefi) and *Corchorus* spp (ayoyo) were the most preferred TAV based on a study completed in 2009 based on buying behaviour in Ghana (Quaye et al.,

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2009). In West Africa, *Amaranthus cruentus* proved essential due to its health benefits, short cultivation cycle, nutritional value and resistance to nematodes (Sogbohossou et al., 2015). *Amaranthus viridis* is also widely used by Afro-descendent communities in tropical America (Vandebroek and Voeks, 2018).

Table 2.2 includes the most prominent warm-season TAV crops based on the literature (Quaye et al., 2009; Sogbohossou et al., 2015; Hart, 2011; Ojiewo et al., 2015; Nyarai et al., 2018; Tadele, 2019; Maseko et al., 2017; Jansen van Rensburg et al., 2009; Fox et al., 1982; Oelofse and Van Averbeke, 2012; Welcome and Van Wyk, 2019).

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Table 2.2: Based on the literature review, the most prominent warm-season TAV crops in South Africa for household production and consumption

Specie	Common name/s	Family	Most prominent areas
Amaranthus cruenthus	pigweed	Amaranthaceae	Limpopo, KwaZulu Natal and Eastern Cape Province
Amaranthus hybridus	smooth pigweed, Theepe (Sesotho)	Amaranthaceae	Limpopo, KwaZulu Natal and Eastern Cape Province
Amaranthus thunbergii	Thunberg's pigweed/ poor man's spinach, Theepe-ea-bokone (Sesotho), Bonongwe/ Mowa/ Mbowa (Shona) Imbuya (Ndebele) (Shona), Teka (Hlengwe), Umbhida (Ndebele) (Hyde, 2022)	Amaranthaceae	Limpopo
A greazicans, ***A spinosus,*** ***A. defelexus,*** ***A hyprochondriacus,*** ***A. tricolor***	amaranth	Amaranthaceae	Sub-Saharan Africa
A. viridus	slender amaranth	Amaranthaceae	Tropical America
Bidens pilosa ***B. biternate***	blackjack, yellow-flowered blackjack, Mokolonyane (Sesotho), Muchize (Northern Sotho), Mushiji (Venda), Ucucuza/ Ugamfe/ Umesisi /Umhlabangubo/ Uqadolo (Zulu), Ucucuza (Ndebele), Umhlabangubo (Xhosa) (SANBI, 2020a)	Asteraceae	Limpopo, KwaZulu Natal and the Eastern Cape Provinces
Chenopodium album	fat hen, Serue (Sesotho), Umbikicane (Swati) (SANBI, 2020b)	Amaranthaceae	KwaZulu Natal and the Eastern Cape Provinces
Cleome gynandra	spider flower, morotho (Northern Sotho), murudi (Venda) (SANBI, 2011)	Capparaceae	Limpopo Limpopo, KwaZulu Natal and the Eastern Cape Provinces
Corchorus* olitorius and *C. tridens	jew's mallow, delele (Tshivenda), thelele (Sepedi), gushe (Xitsonga) (SANBI, 2021)	Malvaceae	Ghana Limpopo Limpopo, KwaZulu Natal and the Eastern Cape Provinces Sub-Saharan Africa
Cucurbita maxima	pumpkin	Cucurbitaceae	Limpopo
Solanum retroflexum	Nightshade, Seshoa-bohloko Limomonyane/ Lintsontso/ Mofukuthoane (Sesotho), Ugqumugqumu/ Umsobo/ Umsobosobo (Zulu), Wesinja (Xhosa) (Foden, 2005)	Solanaceae	East Africa
Vigna unguiculata	Black-eyed pea	Fabaceae	Niger, Nigeria and Burkina Faso

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2.4.7 [1]Factors affecting the potential of AOC and TAV

African orphan crops and TAV have numerous advantages over exotic food crops due to their tolerance to local climate conditions, their high nutritional value, the short growing season required and the low maintenance requirements for irrigation and agrochemicals (Araya, 2014). African vegetables are more resistant to pathogens than exotic vegetables (Aworh, 2018). However, the utilisation of TAV is hampered by several factors (Botes and Breed, 2022).

Taste is argued to be the most crucial criterion for selecting wild or semi-wild TAV for cultivation, followed by marketability, biomass yield, and ease of collection and processing, based on a study in Ethiopia (Kidane et al., 2015). In South Africa, the value of TAV is still limited to trade in informal markets and foraging from the wild (Jansen van Rensburg WS et al., 2012). Exotic vegetables are preferred over local vegetables in South African urban areas. This is due to several reasons. Traditional African Vegetables were replaced by exotic crops in post-colonial South Africa, which resulted in the relegation and neglect of traditional TAV and AOC species (Mabhaudhi et al., 2018). Research to enhance exotic crops and their genetic enhancement has surpassed that of TAV, which resulted in a decline in the use of TAV (Schippers R.R., 2002). Availability, recipes, ease of preparation, taste, consistency and appearance play a significant role in accepting TAV (Oelofse and Van Averbeke, 2012; Gregory et al., 2019; Botes and Breed, 2022).

The development of improved genetic traits to improve the quality and quantity of yields and efficient agricultural and processing practices is imperative in the development of TAV (Dawson et al., 2019; Tadele and Assefa, 2012a; Tadele, 2019; Ribaut and Ragot, 2019). The absence of policy to guide decisions for food production with AOC also impacted the potential of these crops in Africa (Tadele, 2019). Additional undesirable constraints of some AOC species that need to be altered include toxic compounds in some species (Tadele, 2019; Tadele and Assefa, 2012a). Moreover, climatic factors, soil salinity and acidity, diseases, insects, and weeds impact the productivity of AOC (Tadele, 2019; Botes and Breed, 2022).

[1] Botes, K. L. & Breed, C. A. 2021. Outdoor living wall systems in a developing economy: A prospect for supplementary urban food production? *Acta Structilia* [Online], 28

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i. Taste and preparation

Taste preferences differ in different geographic areas. The northern parts of South Africa prefer the bitter tastes of Spider flower (*Cleome gynandra*) and Nightshade (*Solanum retroflexum*), compared to preferences of sweet Amaranth in the southern parts of the country (Jansen van Rensburg et al., 2009; Oelofse and Van Averbeke, 2012). Studies conducted to determine the taste preferences of young consumers suggested that canned Amaranth and Cowpea leaves have potential as commercial products and that Cleome leaves needed further research (Onyeoziri et al., 2018; Botes and Breed, 2022).

Recipes and relevant TAV preparation methods are also essential to improve the taste. New ways of preparing Amaranth should be investigated to address the popularity of Amaranthus (Hiscock et al., 2018; Botes and Breed, 2022).

ii. Social perception

A study conducted in 2019 on the availability, cost, and popularity of TAV in Accra markets in Ghana showed that six TAV crops were sold fresh throughout the year at four markets surveyed (Asase and Kumordzie, 2018). Also, that popularity was regarded as high among 88% of the respondents (Asase and Kumordzie, 2018). These vegetables included Purple Amaranth (*Amaranthus cruenthus*), Jute Mallow (*Corchorus olitorius*), Roselle (*Hibiscus subdariffa*), African Eggplant (*Solanum macrocarpon*), Waterleaf (*Talinum triangulare*) and Cocoyam (*Xanthosoma sagittifolium*) (Asase and Kumordzie, 2018; Botes and Breed, 2022).

However, trade is still limited in South Africa, although TAVs play a vital role in the economy and subsistence of poor communities (Schippers R.R., 2002). The urbanised South African youth negatively perceive TAVs as old-fashioned and “poverty crops” (Vorster et al., 2008; Jansen van Rensburg et al., 2009; Shackleton et al., 2009). However, a survey conducted in 2011 on a sample group of 64 respondents in Nomathiya village, KwaZulu Natal showed that rural residents disagreed with the perception of TAVs as “poverty crops” (Thandeka et al., 2011). This study concluded that communities and the youth should be educated on agronomy, nutrition value and modernized healthy preparation methods to enhance the taste of TAVs and encourage their consumption (Thandeka et al., 2011; Botes and Breed, 2022).

Another factor hampering the potential of TAV is the lack of knowledge of the genus Amaranthus and local beliefs amongst African people that consumption of reddish or purple leaves can lead to insanity. This is despite its nutritional benefits due to high protein,

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minerals and Vitamin C (Mnkeni et al., 2018). In addition, high levels of nitrates in Amaranth, which are carcinogenic and can make anaemia sufferers susceptible to methemoglobinemia (blue baby syndrome), also affect consumption levels of Amaranth. The recommended daily intake (ADI) by the Council on Science and Public Health (CSPH) is 0.07 mg nitrate ion per kilogram of body weight (Mnkeni et al., 2018; Botes and Breed, 2022).

iii. Marketability

TAV was foraged from the wild or semi-cultivated before the 21st century, with a recent resurgence in popularity. This is evident in the availability in markets, some supermarkets and informal traders, which has initiated the commercialisation of some TAV (Ojiewo et al., 2015; Botes and Breed, 2022).

The South African market is limited to mainly dried products and by street traders at informal markets, and Amaranth leaves at informal markets. However, in KwaZulu Natal and Gauteng provinces, the municipal fresh produce market and selected greengrocers also sell fresh leaves (Jansen van Rensburg et al., 2009; Vorster et al., 2008). In the Limpopo province, Chinese cabbage and Pumpkin leaves were traded, with Nightshade (*Solanum retroflexum)* sold in supermarket outlets in the Vhembe district (Juma et al., 2007; Botes and Breed, 2022).

In rural and lower-income communities, consumption of TAV is higher than in urban areas (Gido et al., 2017) (Jansen van Rensburg et al., 2009), especially during periods of drought and unemployment (Jansen van Rensburg et al., 2009). Indigenous knowledge (IK) of TAV in these communities impacts consumption preferences (Vorster et al., 2008), with elderly decision-makers having a preference for vegetables with medicinal benefits (Gido et al., 2017). The South African Venda and Southern Sotho cultural groups, with 265 and 203 used food plant species recorded, respectively, are the two most prominent cultural groups preferring TAV, based on literature studies (Welcome and Van Wyk, 2019). However, figures for other cultural groups could be underestimated (Welcome and Van Wyk, 2019; Botes and Breed, 2022).

The indirect benefits of income generation through crop production amongst small-scale family farmers should not be underestimated (FAO et al., 2018; Mabhaudhi et al., 2018; Botes and Breed, 2022).

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iv. Research to improve genetic traits

The shortage of quality seeds and improved cultivars significantly limits the demand for TAV and commercial use. Improved seed production and cultivars are endorsed by the World Vegetable Center (AVRDC) (Hughes and Ebert, 2013). The Agricultural Research Council (ARC), Vegetables and Ornamental Plants (VOPI), Water Research Council (WRC), Medical Research Council (MRC) and Department of Agriculture, Forestry and Fisheries (DAFF) are role players role in the promotion of TAVs in South Africa, (Maseko et al., 2017; Botes and Breed, 2022).

Genetic improvement relating to the impact of the planting date, water and nutrient supply to optimize the production of TAV is required, following studies on Chinese cabbage (*Brassica rapa* subsp. Chinensis) and Nightshade (*Solanum retroflexum*) (Van Averbeke et al., 2018; Botes and Breed, 2022).

v. Cultivation procedures

Environmental factors such as drought, soil acidity and salinity, pests, diseases and weeds contribute to significant losses in quality and quantity of the yield (Tadele and Assefa, 2012b). Traditional African vegetables require water, nutrients, sunlight, well-drained soil, ventilation, and specific temperature ranges, preferably no frost (Jansen van Rensburg WS et al., 2012). Soils must be well fertilised in terms of macro and micronutrients, comprise an organic material such as animal manure or compost and have a loose, stable and crumb structure (Jansen van Rensburg WS et al., 2012), and soil salinity and acidity impacts on the yield (Tadele and Assefa, 2012a; Botes and Breed, 2022).

vi. Pests and disease management

Pests and diseases impact TAVs, with the leading indicators being damaged, misshaped, wilted, spotted or discoloured leaves (yellowing), stunting, fruit rot, stem damage and the presence of ants (Jansen van Rensburg WS et al., 2012). Typical pests include cutworms, aphids, blister beetles, ladybirds, stem borers, and red spider mites, and symptoms of diseases include powdery mildew, mottle and blight (Jansen van Rensburg WS et al., 2012). Mitigatory or preventative measures include weeding, mixed cropping, establishing trap crops, which are more favoured by insects around the vegetables and push crops with a strong smell, such as garlic and marigolds, to act as deterrents (Jansen van Rensburg WS et al., 2012; Botes and Breed, 2022).

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vii. Policy and governance

Mabhaudhi et al. (2016) determined that non-major crops contribute to food and nutrition security, human health and well–being, climate change adaptation, the environment, and employment creation in poor rural communities following a review of their potential and hence proposed the development of a regional approach. This should include individuals with indigenous knowledge of non-major crops to rank and compare these crops to expand their potential use to address SDGs instead of alternative strategies to support SDGs.

There is great potential for promoting TAVs in urban areas due to TAVs not being utilised as much in urban households compared to rural households, where there is better access to natural locations of these vegetables (Oelofse and Van Averbeke, 2012). Mabhaudhi et al. (2018), however, maintain that South African policies need to promote underutilized indigenous and traditional crops to support all food system stages and represent the interests of all role players, including smallholder farmers and women as producers of TAV to counteract existing inequalities (Botes and Breed, 2022).

2.4.8 Concluding remarks on the potential contribution of TAV to address food security in South Africa

This section of the literature review considered the status of TAV in terms of their contribution to household food security, the eight connected SDGs globally, and factors hampering household-scale food production.

Regarding the potential contribution that TAV can make to address hunger and related SDGs, the literature points out that reliance on exotic vegetables compromises the resilience of food systems and the vulnerability of especially marginalised communities like SSA. Should indigenous knowledge be utilised to enhance the potential of non-major crops, TAV could contribute to food security, human health and well-being, climate change adaptation, biodiversity, and employment creation in poor rural communities.

Considering local SSA climate conditions, entailing mainly semi-arid to arid conditions with intense weather extremes due to climate change, TAV are a resilient option to address food security. They provide critical nutrients and are rich in vitamins, minerals, trace elements and essential amino acids. However, awareness of the nutritional value of TAV needs to be increased amongst SA urban communities.

However, despite their tolerance to local climate conditions, high nutritional value, short growing season required and low maintenance irrigation and agrochemical requirements,

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the literature highlights aspects that negatively impact the potential use of TAV and need improvement. These factors include a lack of research on TAV seeds and cultivars to ensure higher yields and improve negative traits, affecting TAV's marketability. The social perceptions of TAV as “poverty crops” and preparation methods to enhance their taste and make preparation easier also affect their potential. The lack of policies addressing inequality and including all role-players in small-scale agriculture also affects TAV production, especially in marginalised countries. Moreover, there is a lack of research on the correct soil, water, sunlight, ventilation and specific temperature ranges for optimum production to successfully cultivate TAV and control pests and diseases.

Based on the review, the most prominent warm-season TAV are *Amaranthus* spp. (Amaranth, Theepe), *Bidens pilosa, B. biternate* (blackjack, mokolonyane), *Chenopodium album* (fat hen, serue), *Cleome gynandra* (spider flower), *Corchorus olitorius* and C. *tridens* (Jew’s mallow, thelele, gushe), Cucurbita *maxima* (pumpkin), *Solanum retroflexum* (nightshade, Seshoa-bohloko) and *Vigna unguiculata* (black-eyed pea).

2.5 Current knowledge gaps and research focus

Peer-reviewed literature was assessed for studies with a research focus to evaluate the productivity of food plants in outdoor modular LWSs to determine the current knowledge gaps and research focus. Criteria included 1) household scale vertical food production, 2) vegetables as food crops, and 3) empirical field research.

The most similar and comprehensive study on this research topic includes an empirical field study by Nagle, Echols and Tamminga (2015) to determine the productivity of a small-scale modular LWS with vegetable crops in Pennsylvania, United States of America (USA). Like this study, the productivity of the vegetable crops in the LWS is measured during a growing season, with a drip irrigation system installed (Nagle et al., 2017). Mainstream vegetable crops were assessed in the study over three months (Nagle et al., 2017). For the research study by Nagle et al., the climate classification subtype is Humid Subtropical (Cfa) according to the Köppen-Geiger Climate Classification (Peel et al., 2007). The study by Nagle et al. (2015) comprises one typology modular LWS with 64 planter boxes, each containing ten cells with a growth medium of 1.5 litres. The scale of the LWS, 7.5m^2 in extent, is focused on household consumption, similar to the focus of this study. The outcomes of the study by Nagle et al. (2015) demonstrate that urban edible LWS are efficient as EGI, with the most productive crops assessed. Although the study entailed a comprehensive list of variables, including soil pH and nutrient levels, cumulative fresh mass

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yield, irradiance levels, soil moisture content, and irrigation frequency, the results faced limitations such as the considered variables measured over different time frames, varying between 2 and 12 weeks, and inconsistent quantities of crops included in the fresh mass calculations. The limitations render the results from the above study arguably less exact. Economic feasibility evaluated in the study by Nagle et al. contains the monetary value of the weight of crops, which effectively measures the social benefits. However, no other economic considerations or technical characteristics affecting the system's functioning to contribute to food security were considered.

Similar to the research conducted by Demling (2018), the second study aimed to determine the potential of vegetable plants in LWSs and rooftop gardens for urban food production. The study in Veitshöchheim, Germany, compares the performance of four irrigated and fertilised LWS typologies of 6m^2 each, comprising edible plants. The climate classification subtype for the study area is temperate oceanic (Cfb), which implies warm summers below 22℃, with an insignificant precipitation difference between seasons, according to the Köppen-Geiger Climate Classification (Peel et al., 2007). The research study was conducted in the summer season of 2017. The LWS covered the spectrum of geotextile bags, plastic boxes with substrate and rock wool, gabions with substrate and gutters comprising 8-cm pots and substrate. Vegetable species included Roman lettuce, beans, strawberries, beetroot and dill. Although the study states that measurable variables include yield and vitality, no yield results and information on the methods and instruments are provided to verify results. The report on the crop vitality seems to be measured on the lettuce only, with vitality ratings determined on observations ranging between 1 for a “dead plant” and 9 for a “very vital plant”. Although the study concludes that the geotextile and gabion LWS are more productive for vegetable crop production, limited information on the aspect, growth medium, number of crops, technical details of the LWSs and methods are provided. The study fails to convincingly demonstrate the potential of the LWS for food production since several variables are unknown.

Similar to this research, the third study entailed an edible living wall of 30,88m^2 in extent in Yogyakarta, Indonesia, comprising Chinese cabbage, lettuce, water spinach, chilli red and lemon, guava, mango and passion fruit. The modular LWS type was regrettably not specified, although the study was conducted on the Centre for Land Resources rooftop garden at the Gadjah Mada University. The climate classification for Yogyakarta is tropical monsoon (Am), with an average annual temperature of 25℃ and an annual precipitation of

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over 2500mm (Peel et al., 2007). Although the monsoon climate differs considerably from the African environment, the Yogyakarta project also assesses the living wall productivity. The study, conducted over 28 days, concludes that the vertical gardening yield for Chinese cabbage exceeds conventional agriculture methods with more than 20 t ha^{-1} (Utami et al., 2012). However, limitations in supporting these results include no specified plant quantities, no technical specifications of the LWS or number of replications, and no information on instruments.

Table 2.3 summarizes the three studies used to develop a comprehensive understanding of limitations and shortcomings to aid the development of the research focus for this study. Based on this, the limitations of the studies are 1) restricted periods of the experiment and variables assessed, 2) absence in reporting of the LWS technical information and its impact on plant performance, 3) absence in reporting on variables impacting plant performance such as daily minimum and maximum temperatures, daylength, precipitation, relative humidity, and the growth medium's moisture, temperature and electrical conductivity; 4) absence in reporting of research on the crop quantities, randomisation of crops, replications, intervals of data collection and instruments, and 5) a research focus on the crops and not on the whole system.

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Table 2.3: Comparison of research studies on living wall systems productivity

	Pennsylvania research study (Nagle et al., 2017)	**Veitshöchheim, Germany (Demling, 2018)**	**Yogyakarta, Indonesia (Utami et al., 2012)**
Aim	To determine the productivity of a small-scale modular LWS with vegetable crops	To assess the potential of vegetable plants in LWS and rooftop gardens for urban food production	to evaluate the productivity of the living wall compared to conventional agriculture
Type of modular LWS and location	LWS comprising 64 black coroplast planter boxes with ten plant cells each, attached to a south-facing concrete wall on the outdoor training yard of the School of Architecture and Landscape Architecture training facilities.	Four irrigated and fertilised outdoor LWS typologies. The different LWS comprise geotextile bags, plastic planter boxes with substrate and rock wool, gabions with substrate and gutters filled with 8-cm pots and substrate. The aspect is unknown.	An edible wall comprising mounted shelves on ten different levels on the rooftop garden of the Centre for Land Resources at the Gadjah Mada University.
Planting Area	7,5m^2	Four typologies of 6m^2 each	Six levels of 4 m^2 and 4 levels of 1.72 m^2, amounting to 30,88m^2 in total
Climate region (Köppen-Geiger Climate Classification)	Humid subtropical	Temperate oceanic	Tropical monsoon
Irrigation	drip	Closed system, 15 minutes of irrigation per day	The system is not specified. Irrigation with wastewater.
Plants	Seventeen species of commercial vegetables, comprising; Cinnamon basil, lemon basil, Sungold cherry tomato, Supersweet 100 cherry tomato, chives, cilantro, collards, dill, Mei Qing Choi, ruby streaks mustard, Amara mustard, radish, salad mix, Malabar spinach, flamingo spinach, sugar snap pea, Swiss chard.	Five species Roman lettuce, beans, strawberries, beetroot and dill.	Eight species Chinese cabbage, lettuce, water spinach, chilli red and lemon, guava, mango and passion fruit
Quantity of crops	640	Not specified	Not specified
Pest control	Hobby gardener (natural) remedies, no netting or pest barriers, companion planting comprising herbs and marigolds	Not specified	Not specified, although the study concluded that crops in LWS are not as accessible to pests
Number of replications	Not specified varies between species	Not specified	Not specified
Period of experiment	Three months, June to August	Three months	28 days (1 month)
Pot size	1,5 litres	Not specified for systems 1 to 3, system 4 calculated at 0,5 litres based on an 8cm round pot size	Not specified
Harvesting intervals	1 to 2 times weekly	Not specified	Once-off at maximum vegetative stage.
Assessed variables	Soil pH and nutrient levels (once-off), cumulative fresh mass (average) 12-week period, irradiance levels and soil moisture content (6-week period), irrigation frequency (2-week period).	Yield and vitality of crops	Soil moisture, soil pH, soil minerals, wastewater quality and fresh and dry mass of Chinese cabbage

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Figure 2.6 depicts the relationships of themes which serve as a roadmap for this research study.

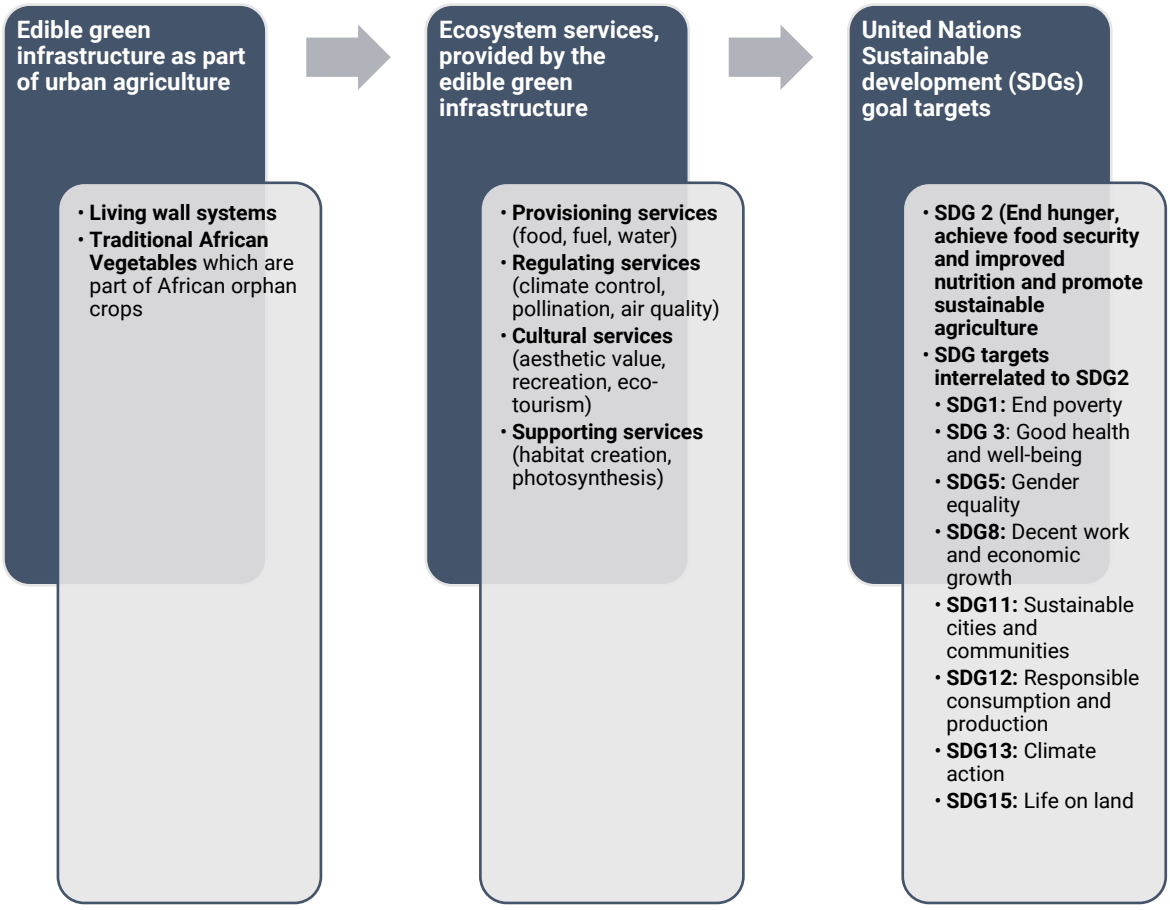


Figure 2.6. Theoretical framework of the study on the performance of traditional African vegetables in outdoor urban modular living wall systems for food security in Gauteng, South Africa

2.6 Concluding remarks on urban agriculture, living wall systems and traditional African vegetables

Regarding the status of living walls as a form of urban agriculture contributing to global household food security, gaps exist in current urban agriculture systems. Urban small-scale food production involving LWSs and leafy TAV shows the potential to contribute to household food security and associated SDGs in South Africa. These projects need to consider SDG targets holistically, addressing not only food security (SDG 2) but also poverty (SDG 1), gender equality (SDG 5) and decent work and economic growth (SDG 8) through employment opportunities through the involvement of the local community and females as subsistence producers. Moreover, urban agriculture projects entailing LWSs with TAV offer

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provisioning ecosystem services through providing local food, regulating ecosystem services through cooling through evapotranspiration of crops and air purification, supporting ecosystem services through absorbing carbon dioxide and producing oxygen through photosynthesis of the crops and cultural ecosystem services through its biophilic value. Edible living wall systems further contribute to climate action (SDG13) and sustainable cities and communities (SDG 11) through decreased GHG emissions due to reduced food miles and waste (SDG 12). Urban agriculture through living walls with edible crops also optimises interstitial spaces to provide habitat and conserves land by lowering pressure on conventional agriculture and addressing biodiversity loss (SDG 15). Although LWS as a form of urban agriculture can contribute to the SDG targets and ecosystem services, more research is necessary to determine how urban agriculture contributes to these SDGs. Policy by national and local governments can support edible green infrastructure through incentives and empowerment of females and small-scale producers. Practice-initiated projects can address current challenges experienced following research on performance improvement of LWSs and TAV.

Modular LWSs offer a more viable solution than continuous LWSs, as EGI in developing countries such as South Africa. This is mainly due to their resilience in interrupted electricity and water provision, low technology requirements, and effective disease control. Factors negatively affecting modular LWSs' performance in contributing to food security can be mitigated through research to address the high installation and maintenance costs, big carbon footprint and environmental burden, low resilience, increased reliance on technology and electricity, limited social benefits and crop performance. This can be a combined effort between government, researchers and practice, with projects rolled out at community facilities and schools. However, the positioning of edible LWSs in polluted urban environments must consider the possible health risks resulting from the contamination of crops. LWSs must be viewed as integrated systems, comprising the wall, water harvesting, irrigation, and plant palette. Using locally produced systems with components manufactured from recycled or reused materials and reducing reliance on high technology, water, and electricity can enhance performance. Based on the literature review findings, criteria to select the LWSs were finalised to include that they must 1) be locally produced, 2) contain components that are manufactured from recycled material/ must be recycled to limit the carbon footprint, 3) have a drip irrigation system to minimise potable water consumption, 4) be cost-effective, and 5) involve uncomplicated assembly.

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Regarding the status of TAV in terms of their performance in contributing to household food security globally, the factors hampering the household-scale production and utilisation of TAV need to be addressed. Factors affecting the potential of TAV include limited research to develop quality seeds and cultivars, pest and disease control to ensure higher yields and improve negative traits, and negative social perceptions relating to their consumption. Government policies in marginalised countries must protect all role-players involved in urban agriculture. Lastly, the lack of policies to address inequality and include all role-players in marginalised countries affects TAV production. Research can improve the popularity of TAV through improving growth by studying the agronomy of these crops, and developing easy-preparation recipes for attractive and tasty dishes

Although empirical research has been done on edible LWSs, research is limited, and knowledge gaps exist. Limitations in previous studies include restricted data collection periods of a maximum of three months, limited variables assessed, limited information reported on the LWS technical information and crop quantities, randomisation, replications, data collection intervals, and instruments. Lastly, the research focused mainly on the crops, not the whole system. No research that was conducted on LWSs with TAV could be found.

In conclusion, the literature confirms a need for edible city landscapes, such as living walls. Food production, particularly TAV in modular LWSs, can offer a solution to increase agricultural productivity and income, combined with other advantages such as biophilia, cooling and air purification. The technical characteristics of modular LWSs to improve their efficiency for growing TAV in urban conditions aimed at household food security need further assessment. This can be a combined effort between practice, research and government. Lastly, TAV species with the potential for small-scale vertical food production in SSA outdoor urban environments must be identified through further research.

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Chapter 3

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3. RESEARCH DESIGN

3.1 Introduction

The first part of the chapter provides an overview of possible research designs for consideration as an approach to the quantitative empirical stage of this study. After that, the rationale for the proposed research design method is discussed.

The study area and methods considered most relevant for this research are then presented. The study area and context, population and sample sizes are described, followed by a justification of the research methods, including a clarification of the variables and research instruments in the study. Sampling and data collection methods are elaborated, after which the data analysis and presentation are deliberated. Finally, the researcher reflects on the rigour and validity, strengths and limitations of the selected research design and ethical considerations before concluding the chapter. Figure 3.1 contains a diagram of the structure and content of the chapter.

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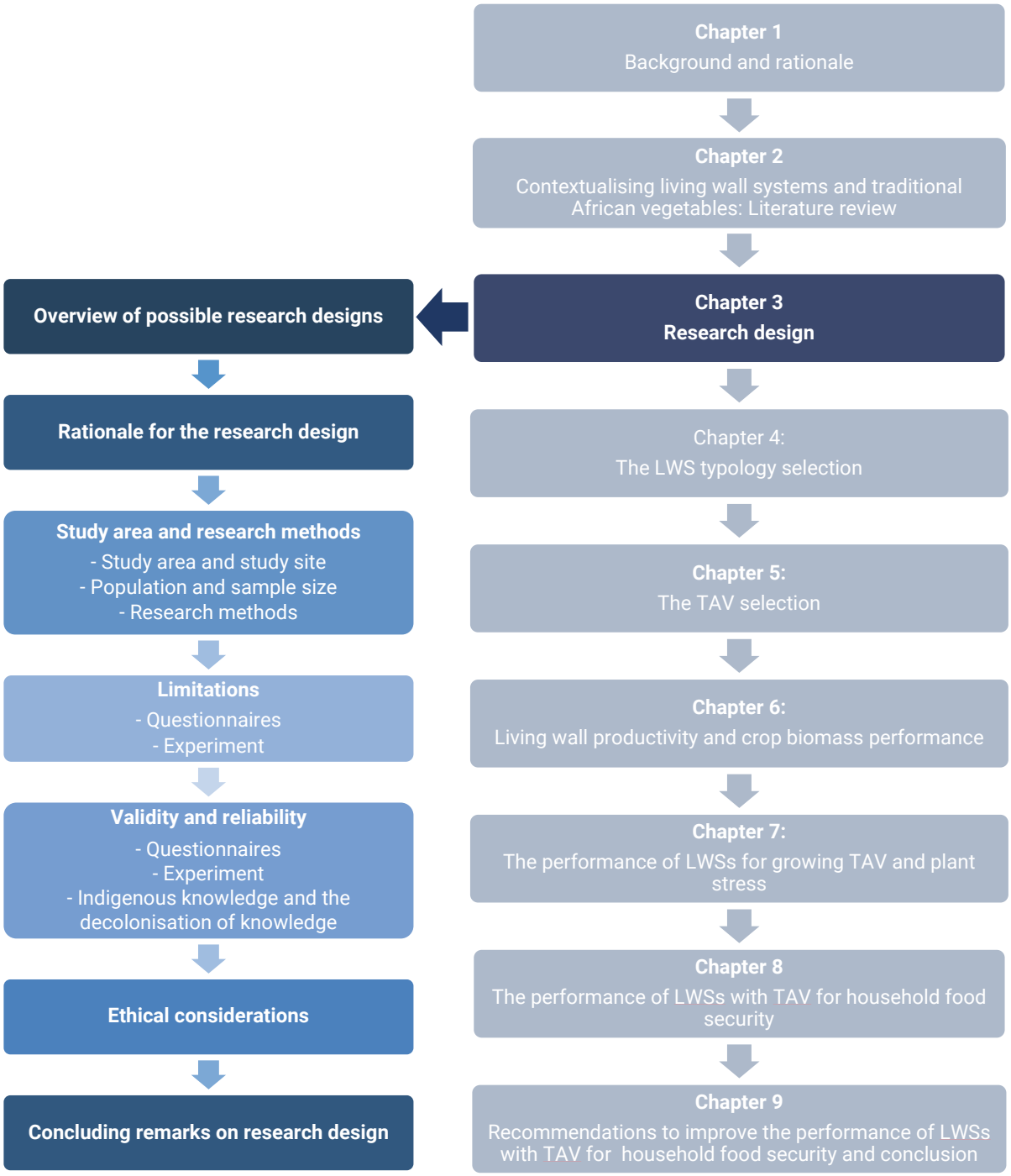


Figure 3.1: Diagram of the research design chapter structure and content

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3.2 Overview of possible research designs

Empirical research involves studying causal relationships where cause and effect are determined depending on certain variables (Falk and Heckman, 2009). This approach is best suited for this study, which entails measuring the performance of LWS typologies with TAV for household-scale food production. The first stage of this study was to select LWSs and TAV for the empirical study, after which the quantitative empirical research followed to measure the performance of the LWS typologies and TAV species as the second stage.

The review of the three studies considered in the literature review in 2.5 Current knowledge gaps and research focus was extended, focusing on the research design and methods followed, instruments used and associated strengths and weaknesses. Literature was first assessed to assist this study in determining criteria for a) selecting LWSs and the TAV crops, b) measuring the performance of the LWSs for growing TAV sustainably, and c) for successful food production. The point of departure for the literature search was to find empirical research studies involving the performance of LWSs with food plants, after which the search was broadened to include the efficiency of LWSs with plants for social benefits and the performance of plants in agriculture.

The three most relevant studies relating to the research methods found in the literature are listed in Table 3.1. This study found inspiration in the productivity analysis of small-scale edible LWSs (Nagle et al., 2017). The Nagle et al. study measured fresh yield mass, relative humidity, soil moisture and radiation levels. As the study by Nagle et al. (2017) did not elaborate on the selection process of the LWSs and crops, the study by Razzaghmanesh and Razzaghmanesh (2017) was selected as an additional example for this study. Similarities of the Razzaghmanesh and Razzaghmanesh study to this study include comparing two LWS typologies. The Razzaghmanesh and Razzaghmanesh study, which compares the microclimate qualities of a LWS and bare wall, is valuable as an example for this study, as it describes a method for selecting the LWS. The variables measured included relative humidity and temperature and the offset of temperature loggers (Razzaghmanesh and Razzaghmanesh, 2017). The study by Riley (2017) was included as an example due to its extensive list of variables considered in assessing the LWss' cost and sustainability. The Riley (2017) study aimed to optimize the design of LWSs to improve perceptions of LWSs as only serving a decorative function, being costly and not sustainable. Although of value for this study due to the variables and its contribution to research on LWSs, the qualitative

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process holds limited value. Table 3.1 provides an overview summarising the above three empirical research designs as a guide for evaluating LWSs with crops. The method, variables, instruments, and research period were important for this study. The Nagle et al. study guided this research regarding variables and instruments. The Razzaghmanesh and Razzaghmanesh study added additional value by describing the decision-making process and criteria for selecting the LWSs. Lastly, the Riley study added value through the variables to guide the research.

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Table 3.1: Overview of empirical research designs evaluating living wall systems with crops

Source	Research period	Purpose of study	Study area	Methods	Instruments	Contribution
(Nagle et al., 2017)	Three months	To determine the productivity of a small-scale edible LWS relating to the system and the scale.	Pennsylvania, USA	Field experiment	Calibrated electronic scale, pyranometers, water data loggers, soil moisture sensors, and soil tests.	Proof that productive commercial vegetable crops (collard, basil, Mei qing Choi, Swiss chard and radishes) have harvest rates (HR) of 3 to 5 times the average Rutgers Agricultural Experiment Station productivity rate for mixed-stand, small-scale conventional agriculture.
(Razzaghmanesh and Razzaghmanesh, 2017)	Six months	To compare the microclimate effects (temperature and relative humidity) of a living wall with a bare wall in dry climates during two seasons (cold and warm).	Adelaide Australia	Field experiment Decision-making process and criteria: positioning of LWS Wall with the best sun exposure Size of wall Prototype LWS Local LWS suppliers (3) for suitability to project Plant species: No selection processes. Criteria: indigenous	Temperature and relative humidity sensors, loggers (30-minute intervals). Temperature loggers at 500mm offset from each wall. Four replications	The study identifies the cooling advantages of LWSs. LWSs had no cooling effect on the surrounding micro-environment at offset distances of 0.50 and 1.0 m. However, the LWSs improved indoor temperatures.
(Riley, 2017)	Twenty-four months	To optimize the design of LWSs to address criticism regarding cost and sustainability, they are prone to failure and are too decorative and superficial.	Japan, France and England	Integrative review (includes an examination of case studies with interviews, observation and literature)	Observations, interviews, scientific articles	The study identifies requirements for viable LWSs (complete systems considering water harvesting, support structure, maintaining correct light, water, oxygen, nutrient and pH levels, comprising a plant palette tolerating climate and seasonal changes, and considering affordability, sustainability and longevity).

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3.3 Rationale for the research design

The literature review supports the need for empirical research on the efficiency of modular LWSs and TAV species to contribute to household food security. Therefore, the research study aims to determine the technical characteristics of modular LWSs and which TAV would perform best for food production in modular LWSs for improved performance as EGI in local urban conditions to improve local household food security (SDG 2). The study focuses on the following;

1) Two locally manufactured modular typologies of living walls are selected, comprising physiognomy that would promote viable growth of selected leafy traditional African vegetable species as per the recommendations from experts.
2) One test site, located in Pretoria, Gauteng Province, South Africa that is representative of typical urban environmental conditions with potential for food growth, i.e. easily accessible, north aspect, with external dimensions 6 (length) x 2 (height) meters and minimum influence of light intensity by nearby or canopy architecture.
3) Nine TAV species that were selected by experts in the field of botany and TAV.

A quantitative methodology was employed to determine the potential of selected TAV species for vertical food production and the technical characteristics of two locally produced typologies of LWSs in Gauteng, SA.

The study conforms to an applied research context, intending to improve food security in practice following knowledge gained regarding the performance of the TAV and LWSs to resolve a real-world problem. Applied research aims to resolve real-world issues with findings that can offer practical solutions and are flexible in research design (Silva, 2015).

This research is positioned in the pragmatist paradigm. Pragmatism is based on the tenet that an investigation is a working hypothesis with practical results or consequences, focusing on “what works” instead of using a single scientific method to categorise an inquiry as “true” or “real” (Frey, 2018). Also, the pragmatist paradigm was deemed the most appropriate, as this research entails a field experiment with less control of variables due to real-world conditions (Falk and Heckman, 2009). Moreover, the active and realistic problem-solving approach of pragmatism (Frey, 2018) resonates with this study, which attempts to address household food security through LWSs with TAV. Also, the flexibility of pragmatism by not committing to a single system in terms of ontology (“nature of reality”) and

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epistemology ("nature of knowledge") (Frey, 2018) made this the preferred research paradigm.

Concerning the inference, the study followed a deductive reasoning approach, where a conclusion is drawn from the general to the particular (Salkind, 2010). The outcomes of the study, which include technical characteristics of an outdoor modular LWS and a list of TAV species that have the potential for small-scale vertical food production, are indicative of deductive reasoning.

Following the comprehensive literature review described in Chapter 2 to address research objectives 1,2 and 4, the research was conducted in two phases in line with research objectives 3 and 5, listed below:

> *Research objective 3: To define the technical characteristics for improved performance of modular LWSs as EGI for growing TAV in local urban conditions (Gauteng, South Africa) based on their performance in an empirical study.*
>
> *Research objective 5: To identify TAV species that have the potential for household vertical food production in outdoor urban environments in Gauteng, South Africa.*

As illustrated in Figure 3.2, the design for the first phase entailed: 1) expert consultation involving questionnaires to select LWS typologies for the experiment; 2) expert consultation involving questionnaires to select TAV species for the experiment; 3) selection of a suitable site for the experiment. The design for the second phase involved step 4), which entailed the experimental study as a true field experiment with quantitative measurements, and stage 5), the data analysis.

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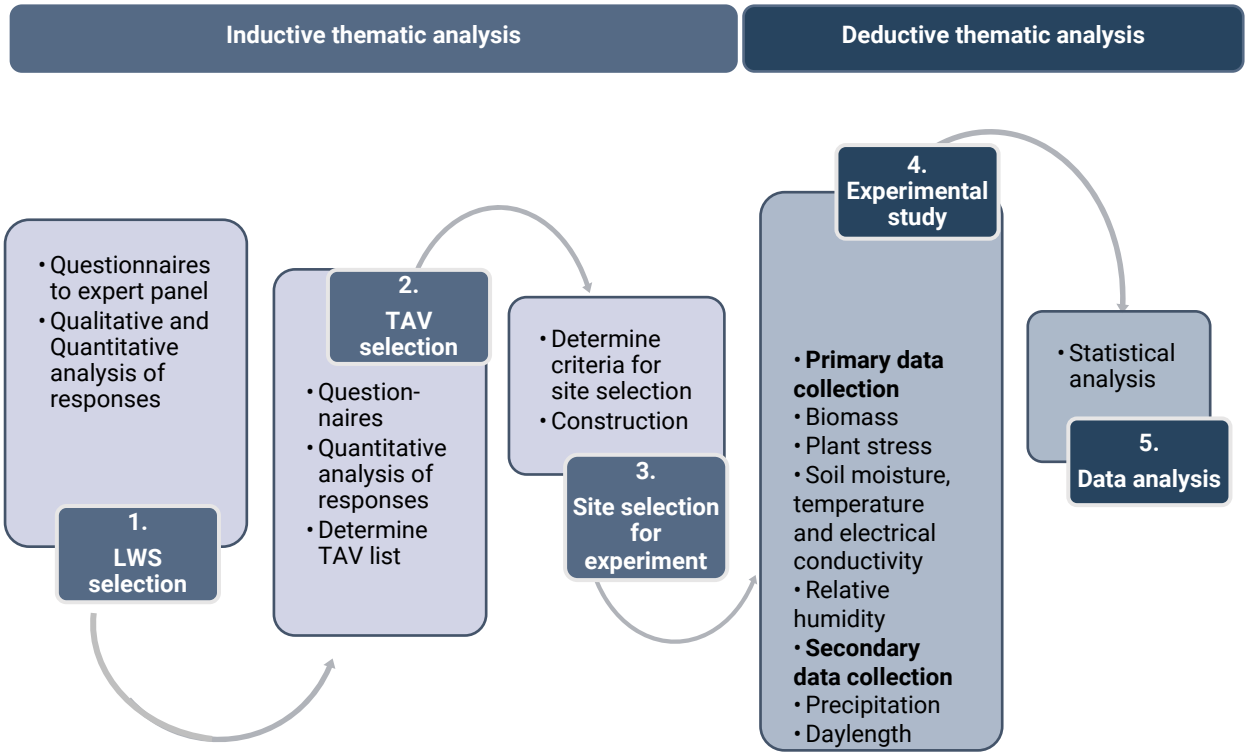


Figure 3.2: Diagram of the research design

A true experimental design process was deemed the most appropriate to address the practical core of the research question, and the research aims unambiguously (Silva, 2015). True experimental design is also known as randomised experimentation, with the experimental subjects randomly assigned and a control group (Salkind, 2010) to determine the cause-and-effect relationship between variables using statistical analysis (Banaszak, 2022). As advocated by Salkind (2010), "randomisation, experimental control(s), experimental treatment(s), hypothesis testing, experimental and control group(s), and standardized research instruments" were applied as research design criteria. A quantitative research method was selected for the experimental study due to its rigour and the numerical nature of the data to provide explanations and causal relationships (Salkind, 2010). The main advantages of true experimental design are its ability to provide causal inferences and its increased validity due to the control group providing counterfactual evidence (Salkind, 2010; Frey, 2018). Additional advantages of true experimental research include that the results are specific and objective and that the data from this study can form a foundation for future solutions and further research to improve household food security through LWSs with TAV.

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The researcher used hybrid data sources by mainly capturing primary data, with secondary data collected from the nearby climate station. Primary data were collected through the questionnaires and the experiment. Although this strategy was costly and time-consuming, data collection was tailored to address the research questions and objectives. Secondary data, such as climate data, typically have the disadvantage that data are collected for a general context. However, this data collection approach holds advantages such as cost-effectiveness and fast access to data. Secondary data was limited to precipitation and daylength, combined with site-specific data comprising relative humidity and temperature to address the risk of generalised data not being context-specific for the research.

Finally, the fifth phase of the research design entailed statistical analysis as a tool to analyse the experimental research data. Written descriptions, graphs and tables presented data to report on and summarise the data findings.

The sections below discuss the research methods for each of the five phases.

3.4 Study area and research methods

3.4.1 Study area and study site

i. Study area and context

The study context is the Gauteng province, the most urbanised and densely populated South African province (Statistics South Africa, 2019a), as the study area. A study comprising 13,616 respondents was conducted in 2020 and 2021, using a sampling frame from the Gauteng City-Region Observatory Quality of Life (Mazenda et al., 2022). This study indicated that 87% of the households that participated in the survey in the three metropolitan municipalities of Johannesburg, Tshwane and Ekurhuleni depended on food support and experienced food insecurity (Mazenda et al., 2022). Food insecurity was an important motivation for the selection of the Gauteng region.

As shown in Figure 3.3, Gauteng is located in the northeastern interior of South Africa and falls in the summer rainfall region (Engelbrecht and Engelbrecht, 2016).

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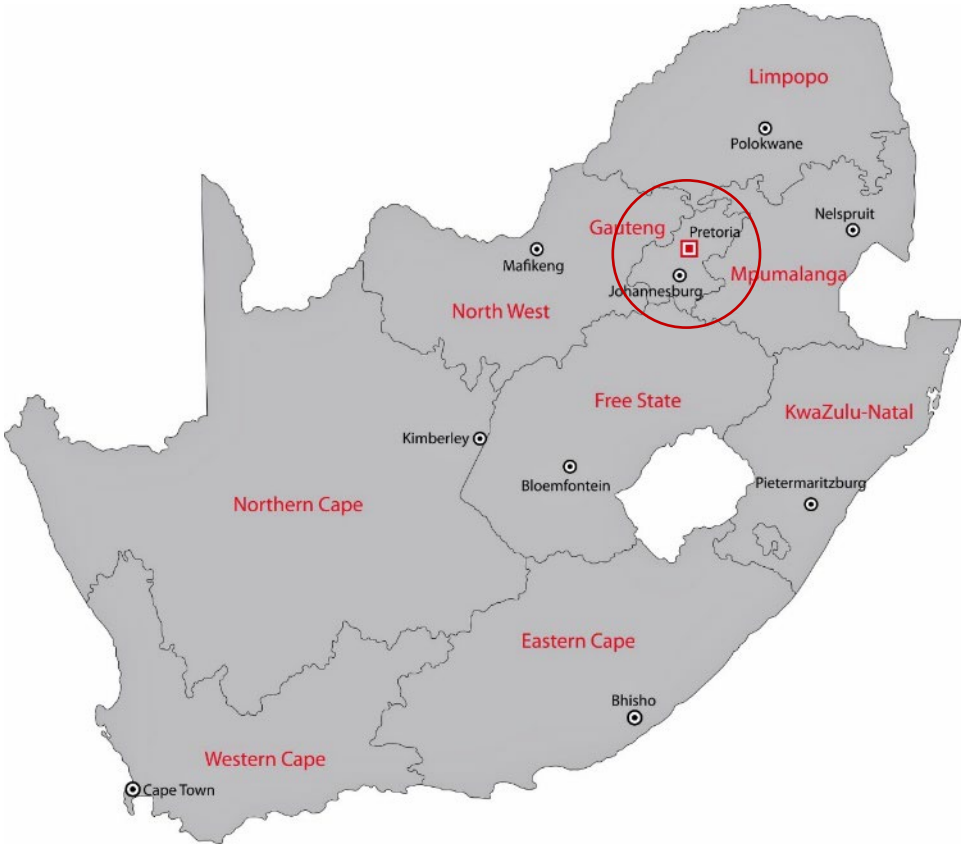


Figure 3.3: Location of the Gauteng province and Tshwane area, which includes Pretoria (source: https://www.orangesmile.com/common/img_country_maps_provinces/south-africa-map-provinces-1.jpg)

The City of Tshwane Metropolitan Municipality (Tshwane) was regarded as a good case study area. The reasons for this decision were first that the Tshwane area, indicated in Figure 3.4, is grappling with urbanisation, with households experiencing poverty, unemployment, and poor education and health. These are significant contributors to food insecurity in the Gauteng City Region (Mazenda et al., 2022).

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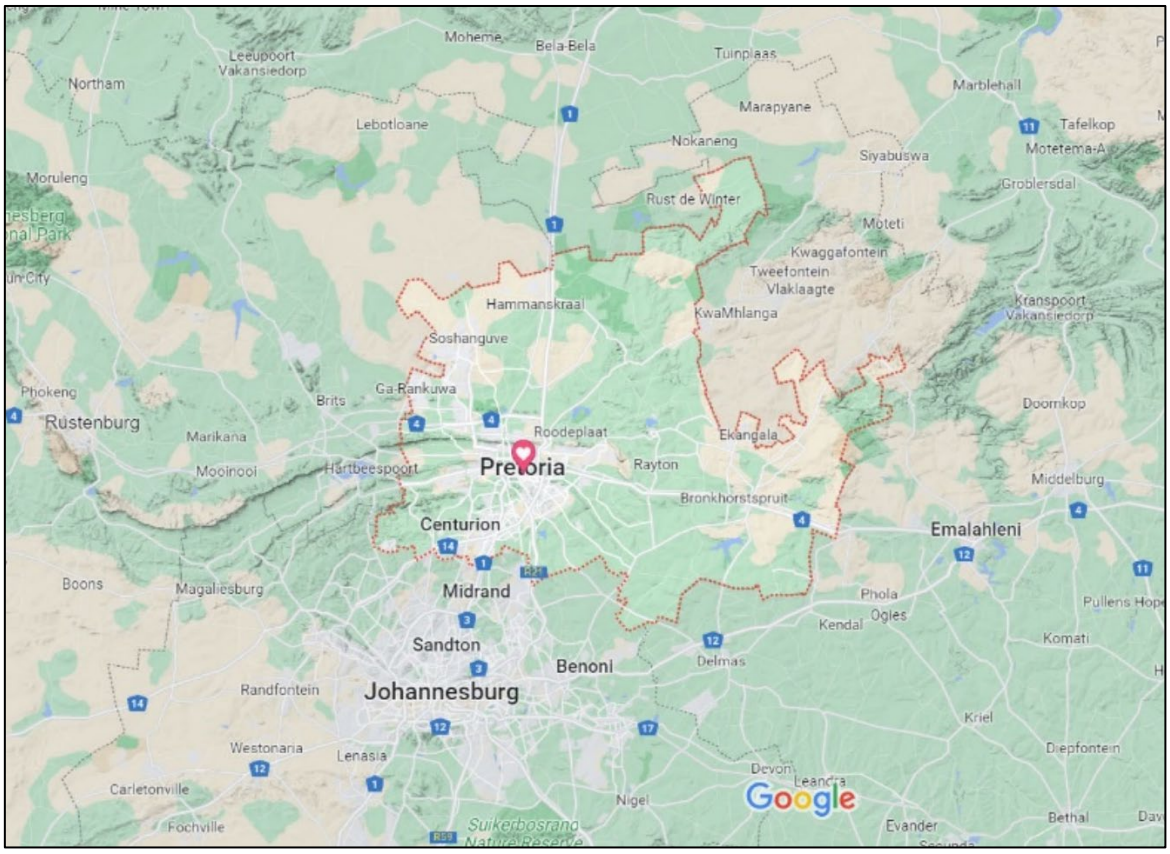


Figure 3.4: The City of Tshwane Metropolitan Municipality (Tshwane) boundaries (that include Pretoria), indicated in the red dotted line (Source: Google Maps)

Tshwane falls within the monsoon-influenced humid subtropical climate area (Cwa), according to the Köppen-Geiger climate classification (Engelbrecht and Engelbrecht, 2016). The South African Weather Service developed more detailed climate regions based on biomes (SA Weather Service, 2021). The vegetation-based climate regions map of South Africa indicates that the study area falls in the Central Bushveld and Moist Highveld grassland climatic regions (SA Weather Service, 2021). Tshwane has an annual precipitation of around 580mm, with mean minimum temperatures between 5 and 7℃ and mean maximum temperatures between 28 and 30℃ based on data between 1991 and 2020 (SA Weather Service, 2021).

ii. Study site

The experimental study entailed determining the performance of outdoor modular LWS typologies with TAV species in an urban environment as the intervention. An area representative of urban conditions had to be selected for the experimental study. This study

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defines urban areas (Schneider et al., 2010) as areas with 50% or more unvegetated, built-up coverage comprising manufactured structures, including buildings, paved surfaces and roads.

An opportunity arose at the Future Africa campus, which is well aligned with African Innovation and urban food gardens (refer to https://www.up.ac.za/future-africa), to house and fund the experiment construction through Innovation Africa.

The Future Africa campus of the University of Pretoria comprises more than 50% built-up cover, representing a typical urban area (Schneider et al., (2010). It was therefore considered as a study site for the experimental study. The Future Africa campus is located on the Hillcrest campus experimental farm (25.7515° S, 28.2608° E), 8,8 kilometres from the centre of Pretoria, situated in the Tshwane area. Further considerations for this study site included being near and easily accessible but with security and surveillance for monitoring and data collection. Moreover, the objective of the Future Africa campus, which entails creating a multi-disciplinary pan-African research platform, including agriculture and edible landscapes, aligns with the research objectives of this study. Site selection must be practical regarding regular accessibility for the researcher (Meter Group Inc., 2021). Therefore, the study site was chosen based on practical considerations, such as ownership of the site by the university, which enabled the researcher to control the construction and installation of the electrical and water points and maintenance. Another advantage included security offered by the University to protect research instruments and unrestricted access for the researcher to collect primary data. For secondary data, a weather station is located on the experimental farm, with the added benefit of accurate and context-specific data for the research. Funding was also made available to construct the experiment on this site, which also gave the experiment a home and ownership for future use.

After considering various possibilities and discussing these with the campus Facilities management that needed to approve the location, the north-facing kitchen yard wall of the campus was selected as the study site for the experiment. This site adhered to the final selection criteria, which entailed the following: must include a minimum sufficient wall area of 12m^2 on the northern aspect of a building plus a natural soil area of 12m^2 in the direct vicinity of the LWSs for the experiment with no interference of building overhang or other elements in terms of shade; water and electrical connection points must be available; must be easily accessible for construction, maintenance and data collection; there must be

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minimal chances of interference of irrigation or maintenance of the LWSs by anyone else than the researcher and must comply with legal and campus facility requirements. Figures 3.5 and 3.6 depict the site location on the Future Africa campus.



Figure 3.5: Locality of the kitchen yard as selected study site at the Future Africa campus (Source: Google Maps)



Figure 3.6: The north-facing kitchen yard wall at the Future Africa campus that was selected as the experimental study site (Photograph: Author).

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iii. Experimental study

The objectives of the experimental study were to compare the performance in terms of the production of TAV for household food production of a) a local soil cell system representative of leading all-in-one high technology as the first intervention and b) a local system representing simple technology as the second intervention, and c) a control, which was represented by a natural soil area, watered manually through irrigation standpipes activated by the campus maintenance team (as the third intervention). Selected TAV species were compared with a mainstream crop, representing a second level of control, to rate performance for household food security in Gauteng, SA.

The intervention entailed the LWS typologies and planting of TAV seedlings, as illustrated in Figure 3.7. The natural soil area comprising TAV planted in soil and located directly adjacent to the LWSs at the Future Africa campus served as control.



Figure 3.7: The experimental study at the Future Africa campus of the University of Pretoria entailed the Vicinity system, the Eco Green Wall system, and the natural soil area (Photograph: Author).

The LWSs were constructed in October 2020. Before planting, the researcher determined the growth medium and watering schedules. The TAV crops were established between October 2020 and September 2021, and the crops in the natural soil area, which served as the control site, were planted in September 2021. Apart from the *Vigna unguiculata* (black-eyed pea), which were grown from seed, all the other species were planted as plugs, which

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can be described as rooted seedlings of equal size within species. As randomisation is a tenet of true experimental design and vital for statistical data analysis, TAV crops were randomised in each LWS through a pseudo-random number generator using a complex algorithm (Urbaniak and Plous, 2013). One plug per pot was planted in the top three rows of each system. All plants were fully established before the data collection commenced. Data were collected from the top three rows in each system for six months, from 1 November 2021 to 30 April 2022.

An aerated growth medium is vital in the case of potted plants to protect the roots from oxygen deficiency, which is defined as hypoxia (Passioura, 2006). The pots of each system were filled with a soil mixture comprising potting soil, river sand and perlite (ratio 1:4:1) to ensure sufficient aeration, optimal pH and nutrient levels. The soil mixture was slightly acidic, with a pH of 7.6. Wonder rose and flower 8:1:5 (17) + C (8) SR, a granular slow-release nitrogen fertiliser comprising four macro-nutrients, nitrogen, phosphate, potassium and carbon, was added at the onset of the experimental study in October 2020. Twelve months later, in October 2021, Culterra vita flora 5:1:5 (33), a slow-release nitrogen fertiliser comprising three macro-elements, nitrogen, phosphate and potassium, was applied.

In addition to the growth medium, water content also impacts aeration. In contrast with freshly watered, drained natural soil, with suction of all pores larger than 0.3 mm, pots with lower heights have small suctions, with much smaller pores filled with water, resulting in aeration problems (Passioura, 2006). This is because the growth medium only drains when it is saturated at the bottom of the pot, and when draining has stopped, the water content is at hydraulic equilibrium, with the water suction linked to the pot height (Passioura, 2006). Therefore, the water amount for each pot should aim to achieve a water content that produces a similar suction to natural soil, which ranges between 10 and 30 kPa (Passioura, 2006). Therefore, the amount of irrigation applied needs to be calculated per growth medium weight, which is 1.6 kg for the Eco Green Wall and 3kg for the Vicinity Wall. Another determining factor for defining irrigation intervals is the root depth. Shallow rooting depths reduce access to available water, with more regular irrigation intervals required than deeper rooted crops. Therefore, for the Eco Green Wall (depth of planters = 50 mm), the volume of irrigation water was applied more regularly than for the Vicinity system (depth of planters = 200mm). Pots deeper than 200mm, reduce risks for hypoxia, also known as oxygen deficiency (Passioura, 2006).

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The Future Africa gardens involve automated and manual irrigation areas fed by harvested water stored in a retention dam on the campus. The LWSs are, therefore, more sustainable in terms of water usage due to minimal potable water usage, used only in the case of failure of the harvesting system. The study site for the experiment falls in an irrigated area, which is not linked to a controller but activated by manually turning the solenoid valve. The campus maintenance team watered the natural soil area thrice weekly for 15 minutes. An automated drip irrigation system irrigated the LWSs. The Vicinity system was connected to a digital programmable timer and watered four times weekly. The Eco Green Wall system was watered daily by an automated battery-operated controller for the data collection period. The irrigation volumes were set to adapt to the soil volume of each system to achieve the correct water content balance at hydraulic equilibrium like natural soil conditions. The soil volumes of 3 kg for the Vicinity system and 1,59 kg for the Eco Green Wall system implied 218 litres of water weekly on the Vicinity system and 116 litres on the Eco Green Wall system.

The researcher removed weeds manually during the establishment and data collection periods since they might compete and interfere with the plant's performance.

3.4.2 Population and sample size

Selecting the most appropriate sampling technique is critical, as it impacts the research findings' reliability, validity and accuracy (Turner, 2020). As few professionals in South Africa know LWSs and TAV, purposive snowball non-probability sampling was deemed the most appropriate sampling technique for this study. When individuals are not randomly selected to represent a population but decided upon based on specific criteria that the researcher considers representative of the population, sampling is categorised as purposive (Turner, 2020; Lavrakas, 2008). A rare population comprises 10% or less of the total population and complies with specific criteria (Lavrakas, 2008), such as professionals specialising in LWSs and TAV. Non-probability sampling entails that subjects of a population do not have a known or equal chance of selection (Turner, 2020). Snowball sampling is applied as a technique in the case of rare or unknown populations to the researcher and entails referral to other members of that population (Lavrakas, 2008; Turner, 2020). Therefore, participants were requested to point out other professionals or projects that would contribute to the study.

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i. Questionnaire 1 relating to LWSs

Experts can be defined as professionals whom their peers regard as authorities in a field based on qualifications, skills and experience. The study entailed purposive non-probability followed by snowball sampling. The researcher focused on including experts who have completed at least 3 LWS projects in Gauteng, South Africa. For the study population, Gauteng members of the Institute of Landscape Architecture South Africa (ILASA) (membership n = 63) and South African Landscapers Institute (SALI) (membership n = 90), regarded as experts based on three projects successfully completed in the field of LWSs were approached.

A total of 6 experts were identified in the first round. Based on the initial consultation, the researcher visited at least 15 LWSs projects in Pretoria and Johannesburg, Gauteng, in 2019, extending the sample population (n = 9). The researcher is confident that all known commercial projects with edible LWSs in Gauteng were identified and visited. Following referrals from the initial panel of experts through snowball sampling, the sample was further extended (n =11) in the third and final rounds. Of the population of 11 experts identified in Gauteng, seven respondents participated in the study.

The respondent profile, indicated in Table 3.2, illustrates that the sample size, although small, included more than 50% of landscape contractors. Still, it also represents the various other professionals involved in the supply, design, and installation of LWSs. This includes multiple perspectives and expertise and ensures generalisability regarding the population.

Table 3.2: Respondent profile for questionnaires relating to living wall systems

Respondent	Field of expertise/ skills	Years Experience
1	Indigenous Vegetation Grower & advisory consultant for LWS plant palettes	>45
2	Landscape architect	>10
3	Landscape contractor	>25
4	Landscape contractor	>35
5	Landscape contractor	>30
6	Landscape contractor	>30
7	Supplier of LWSs	>35

The researcher considered the small respondent sample group sufficient and representative of experts in LWSs, as snowball sampling was implemented through 3

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rounds. The expertise of the participants/ experts was diverse, covering the supply, design and construction of LWSs. All participants/ experts on the referral lists were included in the population. Finally, the participant's experience in the sample group ranged between 10 and 45 years.

ii. Questionnaire 2 relating to TAV

The second questionnaire, relating to knowledge of TAV, required a different population group from the first questionnaire on LWSs. Through purposive non-probability snowball sampling, the researcher identified the population sample through publications and known specialists in TAV from various areas. These fields included horticulture (cultivation and construction), botany, agriculture, ecology and indigenous knowledge in TAV.

The first round of questionnaires entailed a sample population of 8. The list was extended during the second round (n = 16) based on referrals through snowball sampling from the first round. All subjects on the referral lists were approached. However, not all the experts who were approached responded. The researcher aimed for a minimum sample size of 10. The researcher considered the small respondent list (n = 12) sufficient and representative. The subjects' backgrounds covered indigenous knowledge, agriculture, agronomy, horticulture, ecology and botany. An effort was made to involve respondents with geographical representation, as including a broad selection of TAV would benefit the study. Although only three of the nine provinces in SA, including Gauteng, KwaZulu Natal, and the Eastern Cape province, were represented, the respondents' involvement covered southern Africa, with the majority of experts from Gauteng, where the study took place. Table 3.3 reflects the respondents' profiles.

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Table 3.3: Respondent profile for questionnaires relating to traditional African vegetables

Respondent	Field of expertise/ skills	Employment classification	Geographical region
1	Agriculture	Research	Gauteng
2	Agronomy	Research	Kwazulu Natal
3	Botany	Research	Gauteng
4	Botany	Industry	Gauteng
5	Curator	Industry	Gauteng
6	Ecological horticultural installation	Industry	KwaZulu Natal
7	Ecology	Research	Eastern Cape
8	Grower	Industry	Gauteng
9	Grower	Industry	Gauteng
10	Grower	Industry	Gauteng
11	Grower	Industry	Gauteng
12	Traditional healer (indigenous knowledge of edible plants)	Industry	Gauteng

iii. Experimental study

Two living walls were installed as part of the experiment with nine TAV species (refer to Chapter 5). The LWSs were selected based on an analysis of five systems identified by the experts through the questionnaires. The five systems were compared based on the selection criteria developed from the literature and questionnaire findings. The analysis was done by calculating a definite yes for each criterion to 2 points, yes to 1 point, and no to 0. Only two systems complied with all criteria. Two walls were considered sufficient for this study, as one typology represented low technology, and the other represented an all-in-one high technology system.

Furthermore, funding and the study site's space capacity were considerations and limitations in the selection and quantity of LWSs. The sample size for each living wall comprised 80 plants, covering 10 species (8 plants per species). The experimental study was limited to nine TAV species, with one mainstream leafy dark green vegetable crop as control, to accommodate the study site's area and the researcher's capacity.

Conventional food production, such as the natural soil typology, utilises green space. In city environments, "green space", which refers to "urban vegetated spaces" (Payen et al., 2022), is limited and an essential consideration in assessing crop performance. On the other hand, LWSs use "grey space", which involves zero-acreage agriculture and includes façades and

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rooftops by preserving green space for urban vegetation or natural environments (Payen et al., 2022). The LWSs areas and footprints were compared to the natural soil to assess the yield production and green space utilisation. The natural soil, as the control, represented a conventional food production area as the control.

The natural soil area, which serves as the control for the experiment, included 30 plants, three plants per species of each selected TAV and the mainstream crop. Therefore, 90 plants from 10 species were included in the data collection, with three replications of each plant species.

The top 3 rows of each LWS were included in the data collection, with a plant from each species positioned in a randomised pattern in each row, amounting to 90 plants comprising 10 species, including 30 plant crops per LWS typology and 30 plant crops in the control, the natural soil area. The mean and standard errors were calculated from three plants for all measurements.

3.4.3 Research methods

Similar research studies were considered a baseline for this study, after which the variables, methods and research instruments were determined based on the research questions and objectives. This section first discusses the variables, after which the methods and their associated instruments are elaborated.

i. Variables

The recommendations for reporting experimental conditions relating to plant experiments by Poorter et al. (2012) were considered valuable for guiding this research. Poorter et al. (2012) deliberate on eight critical environmental factors for plant growth: light quantity and quality, CO_2, nutrients, air humidity, water, temperature and irrigation salinity. Also, the importance of including parameters related to the growth medium, such as nutrients, temperature and the correlation between plant growth and the pot volume, is stressed (Poorter et al., 2012). An excerpt of the recommended checklist for experimental research with plants, focusing on abiotic factors impacting plants, developed by Poorter et al. (2012), is included in Table 3.4.

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This recommended checklist, together with similar research projects summarised in Table 3.1 in par. 3.2 Overview of possible research designs was considered to guide the selection of variables, data collection methods and instruments for this study.

Table 3.4: Excerpt of recommended checklist of variables for soil experiments to be included in experimental field research with plants

	Minimum	Extended
Timing of experiment	Start of the experiment (month and year) Duration (days/ months/ years)	
Experiment location	Geographic indication	Latitude and longitude
Type of growth facility	Experimental garden/ field	
Light intensity (PAR)	Average daily integrated PPFD measured at plant canopy level (mol m^{-2} day^{-1}) The average length of the light period (h)	Range in peak light intensity (μmol^{-2} s^{-1})
CO_2		Average CO2 during light and dark periods (μmol mol^{-1})
Rooting medium	Soil type Container volume Number of plants per container pH Frequency and volume of replenishment and addition	Container height Other container dimensions Penetration strength (Pa m^{-2}), water retention capacity (g g^{-1} dry weight), organic matter content (%), porosity (%) Rooting medium temperature
Nutrients	Total N before fertiliser added The total amount of fertiliser added per container or m^2	Total extractable N at the end of the experiment
Air humidity	Average VPD air during the light period (kPa) or average humidity during the daylight period (%)	Average VPD air during the night (kPa) or average humidity during the night (%)
Water supply	Per pot: volume (l) and frequency of water added per container or m^2 Average day and night temperature (°C)	Range in water potential (MPa) Irrigation type Changes throughout the experiment
Salinity	Composition of nutrient solutions used for irrigation	Electrical conductivity (dS m^{-1})
Seed source	Origin, pre-treatments	Age, conservation conditions

Source: Reproduced from Poorter H et al. (2012) with permission from CSIRO Publishing

Table 3.5 provides an overview of variables identified that had to be monitored to answer the research sub-questions and objectives and achieve the study outcomes. Instruments are listed in Table 3.7.

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Table 3.5: Methods and variables identified for monitoring to address the research questions, objectives and outcomes

Research sub-question	Objective	Outcome	Method	Variable/s
1. What is the status of UA in terms of their efficiency in contributing to household food security globally?	To determine the status of urban agriculture in terms of its contribution to household food security and related SDGs globally and SSA. To explore SDGs related to household food security. To define the status of urban food production to contribute to household food security and related SDGs. To identify the potential contribution of LWSs as EGI to address food security (SDG 2) and related SDGs	A synthesis of the status of urban agriculture in terms of its contribution to household food security and related SDGs globally	Integrative literature review	N/A
2. Which factors negatively affected the performance of modular LWS in contributing to food security (SDG 2) in the recent past?	To define factors affecting the performance of modular LWSs negatively in contributing to food security (SDG 2) in the recent past.	A synthesis of the status of LWS in terms of their contribution to household food security and related SDGs globally.	Integrative literature review	N/A
3. How can the technical characteristics of modular LWS improve their performance as EGI for growing TAV in local urban conditions (Gauteng, South Africa)?	To define the technical characteristics of modular LWSs for improved performance as EGI for growing TAV in local urban conditions (Gauteng, South Africa). To list and identify the different LWS typologies. To list and elaborate on factors affecting the efficiency of modular LWSs. To determine criteria for modular LWS	Performance guidelines to improve the technical characteristics of outdoor modular LWS as EGI in local urban environments (Gauteng, South Africa).	Experiment (data of species survival, stress, and biomass yield of selected species)	**Independent** Daily maximum and minimum temperatures Relative humidity **Dependent** Biomass (per LWS) Plant stress (per LWS) Cost efficiency, Resilience & maintenance

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	efficient for food security.			
4. To what extent do TAV contribute to household food security in SSA, and which factors hampered household-scale food production and consumption utilising TAV in addressing food security recently?	To determine the status of TAV's efficiency in contributing to household food security globally and related SDGs in sub-Saharan Africa, and to identify factors that hampered household-scale food production and utilisation of TAV in addressing food security in the recent past.	A synthesis of the status of TAV in terms of their contribution to household food security and related SDGs globally	Integrative literature review	**Dependent**: Taste and preparation, Social perception, Marketability, Research to improve genetic traits, Cultivation procedures, Pests and disease management, Policy and governance
5. Which TAV species have the potential for small-scale vertical food production in South African exterior urban environments in Gauteng, South Africa?	To identify TAV species that have the potential for household vertical food production in outdoor urban environments in Gauteng, South Africa. To identify a shortlist of the most prominent TAV species based on the literature review and expert consultation for growth in the two LWSs typologies for empirical research. To monitor and analyse the performance of the TAV crops by comparing data on the survival, stress, growth and yield of selected species to that of a commercial crop. To provide a list of TAV species that have the potential for cultivation in exterior living walls in Gauteng, South Africa.	A list of TAV species with the potential for small-scale vertical food production in outdoor urban environments in Gauteng, South Africa.	Questionnaire Experiment (data of survival, stress, biomass yield of selected species) Experiment (data survival, stress, biomass yield of selected species)	**Independent:** Daily maximum and minimum temperatures Relative humidity **Dependent:** Biomass (per TAV specie and control crop) Plant stress (per TAV specie and control crop)

The conceptual framework, defined as an illustration of the relationship between the different variables, which include independent, dependent, moderating and mediating

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variables (Swaen, 2022), is shown in Figure 3.8. Mediating variables are significant where correlational relationships between variables need to be clarified, as they explain the process between related variables, and moderating variables indicate the impact and direction of the relationship between the variables (Bhandari, 2022e).

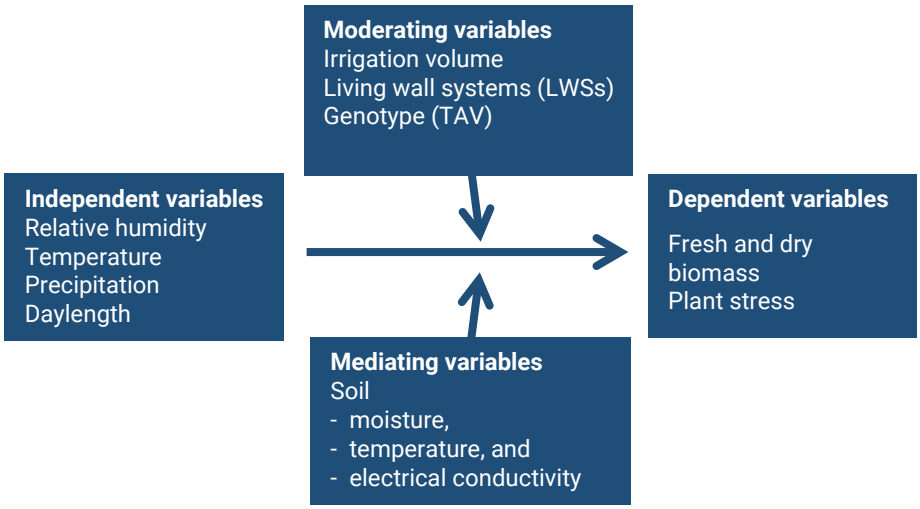


Figure 3.8: The study's conceptual analysis indicating the relationship between the different variables

The study employed primary and secondary data. Primary data were collected via questionnaires to select a shortlist of LWSs and TAV for the empirical research. For the quantitative data, primary data included biomass, thermal and relative humidity and soil temperature, water content and electrical conductivity. Primary data for irrigation were also calculated based on irrigation times and volumes. The South African Weather Service provided the secondary data (daily maximum and minimum temperatures, precipitation and average daylength).

Data collection methods and instruments applied for the questionnaires to select the LWSs and TAV are discussed, after which the experimental study's data collection methods and instruments are elaborated.

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ii. Questionnaires

Questionnaires were deemed the most appropriate method to obtain standardized answers for the LWS and TAV selection and data compilation. Compared to interviews, questionnaires have the benefit that respondents have sufficient time to consider their solutions, and interviewer influence is eliminated. However, a lower response rate is a known disadvantage of questionnaires.

The questionnaires were circulated electronically via email to experts. Emails included an introductory explanation of the project and a self-completion questionnaire attached, with a request to be returned to the researcher within three months.

a. Data: LWS selection (primary data)

Data were collated between June 2019 and March 2020. Questionnaires were administered to the sample group through a cross-sectional design on a single occasion (Lavrakas, 2008).

A questionnaire (refer to Appendix A) was designed to capture expert opinions on LWSs currently used for projects in SA and their specific qualities and technical specifications. This enabled the researcher to gain insight into maintenance and other challenges presently experienced with LWS projects.

The questionnaire consisted of three sections and 20 questions. Questionnaires included open-ended and closed-ended questions. Closed-ended questions entailed selecting an answer from a fixed number of responses, whereas open-ended questions entailed the participants formulating their solutions (Lavrakas, 2008). The first section comprised open-ended questions relating to TAV to determine respondents' knowledge of AOC. The second section focused on LWSs. Open-ended questions listing LWS qualities and specifications that would optimise growing conditions for urban food production were also obtained, including the size or dimensions of LWSs. Respondents were requested to list preferred systems and describe the maintenance required and challenges related to these systems. A closed-ended question about the recommended orientation for LWSs with TAV was also included. The third section requested names and contact details of further LWS experts in LWSs who might contribute to the study.

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Responses were analysed and codified regarding the preferred systems currently used for SA projects and described specific qualities, technical specifications, maintenance and other challenges experienced. The LWSs for the experimental research were qualitatively and quantitatively selected for the empirical study based on a checklist developed following the identification of criteria from the literature review and the experts to ensure optimal resilience. Criteria added by the respondents based on questionnaires were added to the checklist, which was developed from the literature review in section 2.3.6 Concluding remarks on the factors affecting the efficiency of modular living wall systems.

It was important for the researcher to attempt a novel approach to LWSs as a response strategy to the resilience and sustainability issues associated with LWSs identified through the literature review (Saldaña, 2021). This was achieved through identifying a shortlist of nine of the most prominent TAV species based on the literature review and expert consultation for growth in the LWS typologies for experimental research. The researcher, therefore, set the criteria for the LWSs in line with her literature review combined with the expert consultation through questionnaires.

b. Data: TAV selection (primary data)

The TAV were qualitatively and quantitatively selected by administering questionnaires to the purposively selected sample group. The researcher collated data through questionnaires between November 2019 and March 2020.

Closed-ended questions required that participants select TAV on the shortlist for suitability in LWSs by selecting yes or no. Respondents were also requested to choose the preferred aspects/ orientation. Responses were grouped and qualitatively analysed in the case of open-ended questions. Responses to closed-ended questions were analysed in Excel by giving answers numeric values, and graphs were developed to determine the selected TAV and orientation of the LWSs. For the third consultation round, two experts in horticulture and botany were consulted, focusing on the market availability of seeds and seedlings for growing crops for the experimental study.

Appendix B contains the questionnaire for the TAV selection. The questionnaire included three sections, with the first comprising a closed-ended question relating to the selection of the list of TAV for use in the study and an open-ended question for any other TAV suggestions. The second section focused on maintenance and species requirements,

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whereas the third section requested specialists' names and contact details of those who might contribute to the study. The TAV selection aimed to select a shortlist of nine TAV species for comparison with a mainstream dark green leafy vegetable, *Spinacea oleracea* (spinach), for assessment as part of the experimental study. The outcome entailed a list of nine TAV species with the potential for small-scale vertical food production in South African outdoor urban environments in Gauteng, South Africa.

Participants were requested to assess the list of TAV in the questionnaire regarding the potential suitability of the TAV species for growth in living walls. This question included a two-choice question (yes = 1/ no = 0). Respondents were also requested to add TAV to the list indicated in Table 3.6 should they regard other species as suitable for growth in LWSs.

A shortlist of 31 TAV species was compiled based on the most prominent warm season TAV, as concluded in the literature review, with TAV added from the most recent list of TAV in South Africa (Moteetee and Van Wyk, 2006). The following criteria were applied for the selection of TAV for the shortlist: 1) can be annual/ perennial, 2) must be commercially available, 3) must be suitable for growth in LWSs in terms of size and shape, i.e., groundcover/ climber 4) must be prominent in the literature review based on utilisation and production in southern Africa 5) must grow in full sun 6) must be able to tolerate drought, 7) must be frost-hardy 8) must be suitable for the Gauteng climate conditions, and 9) must be ornamental. Refer to Table 3.6 for the shortlist of TAV identified by the researcher with two experts in TAV and LWS.

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Table 3.6: Shortlist of traditional African vegetables for inclusion in the questionnaire

	Botanical name	Common name
1	*Aervia leucera*	aambeibossie
2	*Amaranthus spp*	Amaranth, theepe
3	*Ancylobotrys capensis*	wild apricot, morobe (Northern Sotho), umdongwe (Zulu)
4	*Asystasia gangetica*	creeping foxglove, isihobo (Zulu)
5	*Asystasia schimperii*	longevity spinach
6	*Athrixia elata*	daisy tea bush
7	*Centella asiatica*	pennywort
8	*Corchorus confusus*	Jute plant, Ungibonisele (Zulu)
9	*Cucumis metuliferus*	horned melon, African horned cucumber, mokapana (Tswana)
10	*Cucumis zeyheri*	wild cucumber, inhlakahlela, iselwa-lenja (Zulu), lerakana, monyaku (Sesotho)
11	*Cynanchum virens*	Liane Calle
12	*Cyperus esculentus*	Nutsedge, tiger nut, indawo, insikane (Zulu), manakalali (Sesotho)
13	*Dicliptera clinopodia*	pink ribbons
14	*Diclis reptans*	dwarf snapdragon, isinama (z), koenana, ponye (Sesotho)
15	*Diospyros austro-africana*	Firesticks, star-apple
16	*Gazania krebsiana*	terracotta gazania
17	*Hilliardiella oligocephala*	bicoloured-leaved Vernonia, ihlambihloshane (Zulu)
18	*Hypoestes aristata*	ribbon bush uhladlwana olukhulu, uhlonyane, uhlalwane (Zulu)
19	*Hypoxis argentea*	yellow stars, African potato, inkomfe, ilabatheka (isiZulu)
20	*Imperata cylindrica*	cogon grass, umthente (Zulu)
21	*Lantana rugosa*	bird's brandy, sekwebetane (isiNdebele); utyani-bentaka, utywala bentaka (isiXhosa), impema, ubukhwebezane, ubungungundwane, uguguvama, umkhukhuthwane, utshwala benyoni (isiZulu), mabele-mabutsoa-pele, molutoane (Sesotho) (SANBI, 2019)
22	*Mentha aquatica*	water mint, amabunu, imbozisa, umaliwane, umayime, umnuka (isiZulu), ityaleba, icholachola, inxima, inxina (isiXhosa), koena-e-nyenyane, koane-ya-lidiba (Sesotho)
23	*Mentha longifolia*	wild mint, koena-ya-thaba, bohatsu (Southern Sotho); inixina, inzinziniba (Xhosa); ufuthana lomhlanga (Zulu)
24	*Nemesia fruticans*	wild nemesia
25	*Coleus amboinicus, previously known as Plectranthus amboinicus*	Indian borage, Indian mint, soup mint
26	*Portulaca oleracea*	Purslane, pigweed, Igwanitsha (Xhosa), lenjana (Zulu)
27	*Portulacaria afra* prostrata	pork bush, isAmbilane, iNdibili, isiCococo (isiZulu); iGqwanitsha (isiXhosa).
28	*Rhoicissus tomentosa*	wild grape, isaQoni, iDiliya (Xhosa), isiNwazi (Zulu), Moaparo (Sotho); isiNwati (Swati); Dyathoho, Makhulu-wa-khundwi (Venda)(Metalobomix, 2012)
29	*Rhoicissus tridentata*	bushman's grape, isaqoni, umnxeba, ulatile, uchithibhunga (isiXhosa); isinwazi, umthwazi (isiZulu); lumbu (Xitsonga); morara-oa-thaba (Sesotho); murumbula-mbudzana (Tshivenda)
30	*Vigna unguiculata*	Black-eyed pea, cowpea
31	*Vigna subterranea*	bambara nut

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The researcher also gained insight into TAV, with a high nutritional value and health benefits, from the questionnaires. Finally, respondents were asked for referrals to other TAV experts whom they would recommend to participate in the survey.

For the questionnaires, which entailed the first stage of the study, an adapted inductive thematic analysis was applied to determine LWSs that were the most prominent in responses and select TAV for the experiment. One of the advantages of thematic analysis, which involves identifying, analysing, and reporting themes in data, is its flexibility as a research tool, resulting in a detailed data account (Braun and Clarke, 2006). Also, another consideration to selecting thematic analysis as most appropriate was that participants were collaborators, and this method allowed for the generation of unanticipated insights. The researcher approached the study by grouping responses to questions from open-ended questions and grouping similar responses into clusters through hard-copy coding (Saldaña, 2021). For closed-ended questions, binary nominal values were allocated to yes and no answers to capture the data. Data were organised in tables and charts using Microsoft Excel to assess the frequency distribution, defined as the "number of observations for each possible value of a variable" (Turney, 2022).

iii. Experimental study

As experimental studies measure causation (Silva, 2015), data collection and recording of variables are vital for the research. In the case of empirical field studies, as opposed to laboratory studies, the various external influences cannot be controlled (Abdul Ghani, 2014). Therefore, differentiation between observation and experiment data collection methods based on the research objectives is essential, as the independent variables cannot be controlled (Abdul Ghani, 2014). Measurement and instrument invariance is critical in research. This was achieved through time, multimethod evaluation, reliability replication and calibration, as Frey (2018) advocated.

Data were collected after establishing all TAV and control crops during the growing season. The data collection stage of the study was conducted over six months, commencing 1 November 2021 to 30 April 2022. Table 3.7 provides an overview of the data collection intervals for each variable and associated instruments included in the study.

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Table 3.7: Summary of variables, data collection methods and research instruments used for the experiment

Data measured (variable)	Data collection method, Instrument & unit of measurement	Quantity of instruments	Frequency of measurements	Manual measurements
1. Timing and duration	Observation	n/a	Start and end of the experiment	Twice
2. Experiment location	Observation	n/a	Start of experiment	Once
3. Daily minimum and maximum temperatures	Observation: Future Africa Weather station (°C)	secondary data, instrumentation unconfirmed	daily	n/a
4. Precipitation	Observation: Future Africa Weather Station (mm)	secondary data, instrumentation unconfirmed	daily	n/a
5. Average photoperiod/ daylength	Observation (h:m:s) Sunrise and sunset recordings as per https://www.timeanddate.com/sun/south-africa/pretoria?month=1	secondary data, instrumentation unconfirmed	daily	n/a
6. Daily temperature at LWS	Experimental: Hobo U23 Pro v2 (°C)	3 (1 per LWS & natural soil)	hourly	n/a
7. Relative humidity at LWS	Experimental: Hobo U23 Pro v2 (%)	3 (1 per LWS & natural soil)	hourly	n/a
8. Growth medium (Macro and micronutrients)	Experimental: Laboratory tests (Total extracTable nitrogen (N) before adding fertilizer)	1	Start of experiment Quarterly	Once
9. Soil volumetric moisture content (VWC)	Experimental: Teros12 (m^3/m^3)	3 (Each LWS and natural soil)	hourly	n/a
10. Growth medium electrical conductivity (EC)	Experimental: Teros12 (mS[EC])	3 (Each LWS and natural soil	hourly	n/a
11. Growth medium temperature	Experimental: Teros12 (°C)	3	Hourly	n/a
12. Crop yield (Fresh biomass)	Experimental: Calibrated digital scale (g)	1	Monthly	6
13. Crop yield (Dry biomass)	Experimental: Calibrated digital scale (g)	1	Monthly	6
14. Plant stress (chlorophyll fluorescence)	Experimental: JIP test with Plant Efficiency Analyser (PEA)(Fv/Fm) ($PI_{absorbed}$ and PI_{total})	1	Monthly	6
15. Irrigation duration (minutes per day as indicated on a timer)/ quantity of irrigation	Observations (irrigation settings)	n/a	End of the experiment	Once

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a. Variables 1 and 2: Timing and duration (primary data)

Irrigation duration and volumes were controlled; however, these variables were dependent on the water supply for the study site, which was connected to the main irrigation system of the campus. The researcher recorded the experiment's timing, duration, and location manually. The researcher also recorded observations on pests, diseases and mammals that grazed the crops.

b. Variables 3 and 4: Daily maximum and minimum temperatures and precipitation (secondary data)

Regarding air humidity and climatic conditions, extremes in temperature and moisture or humidity and rainfall that might cause interference with plant health were monitored through secondary weather station data. The climate data was collected from the closest weather station, the Future Africa Weather Station, on the University of Pretoria experimental farm.

c. Variable 5: Photoperiod/ Average daylength (secondary data)

The photoperiod impacts the biomass during vegetative growth (Meki et al., 2017). However, during flowering or kernel development, the daylength or photoperiod is not correlated with biomass (Villegas et al., 2016). The average daylength was collected from the source https://www.timeanddate.com/sun/south-africa/pretoria?month=1., after ensuring its validity and reliability.

d. Variables 6 and 7: Temperature and relative humidity (primary data)

Temperature and RH impact all vegetative growth stages by affecting biochemical and physiological processes (Rabbi et al., 2019). These include photosynthesis, transpiration, and enzymatic activities (Rabbi et al., 2019). Increased temperatures associated with low humidity lead to increased transpiration, which is ideal for growth, and high RH extremes can enhance disease (Rabbi et al., 2019). Temperature extremes can impact plant performance negatively, worsened by the cumulative impact of water deficits (Hatfield and Prueger, 2015).

Relative humidity and temperature sensors were, therefore, installed for the experimental study to monitor these critical parameters. Concurrent temperature and relative humidity

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(RH) were measured hourly at each LWS and the control site by Hobo U23 pro v2 weatherproof data loggers with built-in temperature and RH sensors (Onset Computer Corporation, 2022). The researcher installed three loggers (see Figure 3.9). The loggers were placed 500mm above natural ground level in front of each LWS and the natural soil area. Data logging intervals were set to 60 minutes, with the temperatures measured in degrees Celsius (℃) and the RH in percentage (%).

As the sensors are sensitive to direct sunlight, the accuracy of readings can be affected. Protective housing with vents was therefore constructed from plastic plant containers (diameter = 170mm) with holes on the side for ventilation, covered with foil, and serving as housing for the loggers in an upside-down position. Plastic plant trays (diameter = 185mm) were fixed to the top of each shield.



Figure 3.9: The temperature and relative humidity (RH) measurements were taken at each LWS and the control site by Hobo U23 pro v2 weatherproof data loggers with built-in temperature and RH sensors (Photographs: Author)

e. Variable 8: Growth medium macro and micronutrients (primary data)

Concerning the growing/ rooting medium and nutrients, this variable was controlled and remained consistent for the study. The soil health (soil structure and biological activity) was monitored regarding erosion, acidification and salinity, and soil fertility for nitrogen, phosphorus, potassium, and micronutrients. Soils contain nutrients, minerals, and organic matter of different sizes, which affect the porosity and ability to anchor plants' roots, which impacts growth (Voroney, 2019).

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f. Variables 9,10, and 11: Soil water content, temperature, and electrical conductivity (primary data)

Besides the soil texture, structure, and nutrients, soil also provides available water, which impacts plant growth and yields through nutrient availability and aeration status (Voroney, 2019). The impact of soil water content on root growth is significant for agriculture, as it also affects photosynthesis, carbohydrate activity, and oxygen availability in the soil (Lynch et al., 2012). Poorter et al. (2012) confirm the importance of soil water content as an essential variable to measure. The soil water content is the amount of water per total unit volume or mass of soil (Meter Group Inc., 2021; Voroney, 2019).

Soil temperatures impact root length and surface, affecting water and nutrient uptake (Kaspar, 1992). Increased soil temperatures speed up root development and absorption of water and nutrients, microbial activity, organic matter decay, and seed germination (Abou-Hussein, 2012). Moreover, soils with high temperatures have been shown to release more CO_2 than cooler soils, stressing the importance of measuring the soil temperature (Howell et al., 2019). Passioura (2006) reports that, despite the significant differences between air and soil temperatures, especially in the case of dark pots, which are often significantly higher than air temperatures, there is a research gap in pot experiments, where soil temperatures are seldom measured.

Soil electrical conductivity (EC), measured in units of milli-Siemens per cm (mS/cm), is the ability of soil particles to conduct electrical currents and increases with moisture content (Grisso et al., 2009). Soil electrical conductivity (EC) is a widely accepted indicator of soil salinity and affects crop yields in agriculture (Corwin and Lesch, 2005). EC correlates with soil properties that affect crop productivity, such as soil texture, organic matter levels, salinity, and cation exchange capacity (CEC) (Grisso et al., 2009). As EC affects nutrient uptake and indicates the moisture content (Grisso et al., 2009), values below 0.200 mS/cm indicate insufficient available nutrients, with values above 1200 mS/cm indicating saline conditions unfavourable for plants (Nistor et al., 2014). Values above 1200 mS/cm indicating saline EC should be monitored for pot experiments, as the accumulation of ions in pots can lead to a salt build-up, resulting in saline soil conditions not conducive for plants (Poorter et al., 2012).

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For soil temperature, moisture, and electrical conductivity, three Teros12 soil moisture, temperature, and electrical conductivity sensors were installed and positioned in the top row of each LWS and the natural soil control area (see Figure 3.10). The logger was set to log automatically at 60-minute intervals. The volumetric water content is measured through capacitance technology, which measures the polarity of water molecules by creating an electromagnetic field in the soil with the sensor (Meter Group Inc., 2021).

Data was downloaded onto a computer using the ZENTRA Utility software by connecting with a port on the Zentra data logger via a cable. Sensors were connected to a ZL6-data logger via 5-meter cables.

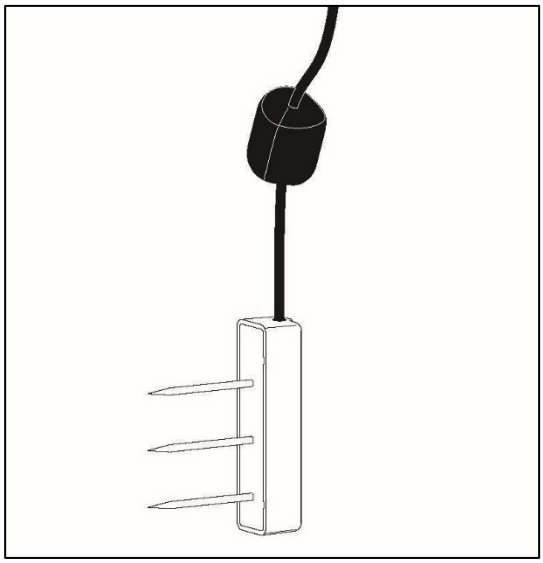


Figure 3.10: The Teros12 soil moisture, temperature, and EC meter (Meter Group Inc., 2022).

g. Variables 12 and 13: Fresh and Dry Biomass yield (primary data)

Biomass yield, as the primary attribute of TAV, indicates the productivity and profitability of the LWS/ natural soil area. Plant tissue can be measured as fresh or dry weight (Huang et al., 2019a; Hort Americas, 2022). Plant weight is an essential indicator of crop performance and yield (Wei-Tai et al.; Huang et al., 2019a).

According to Poorter (2012), assessing a small number of four replicates for experiments is well in the acceptable range with a 65% statistical difference between populations, as any difference in values of more than 50% between two populations can safely be considered as statistically significant when the standard deviation is 0.15. Three replications per variable were therefore taken for yield measurements. Crops were harvested once a month

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to determine the biomass. The researcher separated leaves from stems with a hand pruner, placed them in labelled brown bags, and weighed the fresh mass within 3 hours of harvesting to ensure consistent data. Nagle et al. (2017) assessed crop performance with a calibrated scale. As performance indicators, crop yields (g FW plant−1) were therefore monitored at harvest with a calibrated laboratory Mettler 4400 balance (refer to Figure 3.11) with a 5 to 4400 g weight capacity and a measurement accuracy of 0.01g readability. The fresh leaf contents of each labelled bag were placed into a 500ml glass beaker and weighed. The monthly weights of three plants per species per typology were recorded manually in a notebook and carried over to Excel.

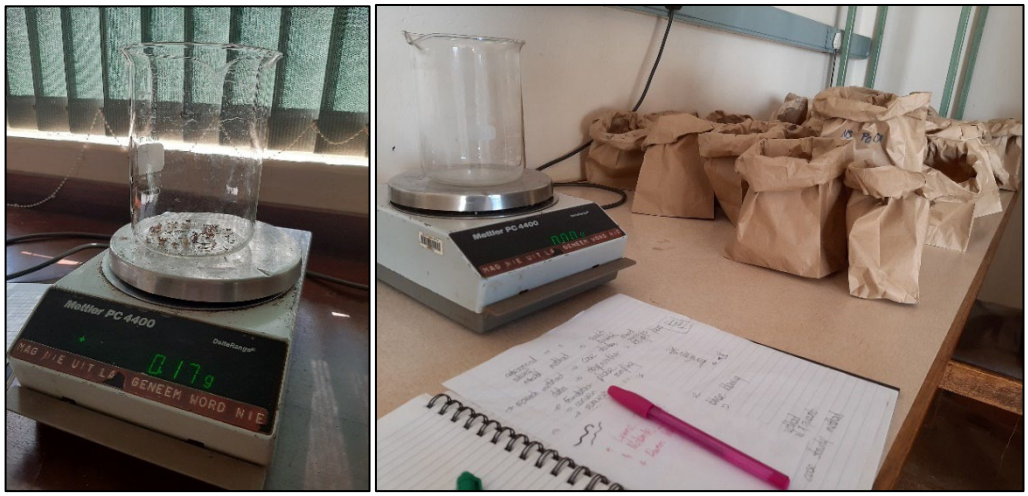


Figure 3:11: The Mettler PC4400 balance that was used to measure fresh and dry biomass

Dry weight is considered a more reliable and accurate indicator of leaf biomass, as fluctuations resulting from the water content are eliminated when leaves are dried for a defined period at a constant temperature higher than the ambient temperature (Huang et al., 2019a; Hort Americas, 2022). Controlled variation of decision environments, as one of the tenants of experiential research, is one of the benefits of laboratory heating ovens (Falk and Heckman, 2009). As the water concentration in fresh mass fluctuates, dry mass levels are more accurate for determining plant performance (Hort Americas, 2022). They are used to measure mass as a yield indicator (Strasser et al., 2018). The drying oven method entails a dry process loss at a uniform temperature for a defined period (Mettler Toledo, 2022). A 72-hour drying period was considered sufficient to ensure a constant dry weight, based on recommended times of 72 hours for drying plant tissue in their specific ovens by the

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laboratory of the University of Pretoria and the objective of achieving a constant dry weight for the plant tissue (Mettler Toledo, 2022) (refer to Figure 3.12).



Figure 3.12: Fresh leaf samples were dried for 72 hours in Labotech digital eco-therm industrial drying ovens at the University of Pretoria laboratory on the experimental farm

After measuring the fresh weight of the leaves, the leaves were placed back in labelled brown bags for the drying process. Leaves were dried in the University of Pretoria laboratory on the experimental farm. Similar to the weighing and recording of the fresh weight, the dry leaves of each plant per species per typology were placed into a 500 ml glass beaker and measured using the electric balance after drying the plants at a constant temperature of 60 °C for 72h in the laboratory drying ovens. Dry weights were recorded manually, after which information was carried over to Excel. Dry leaves were discarded after the dry weights were recorded.

h. Variable 14: Plant stress (primary data)

Photosynthesis, which entails the absorption and conversion of light energy into chemical energy, is affected by environmental factors, including light, water, CO_2, nutrient availability and temperature [Salisbury and Ross,1992; Strasser and Tsmilli-Michael, 2001 in (Little and Rolando, 2003; Kalaji et al., 2014)]. Photosynthesis is highly sensitive to stress caused by extreme temperatures and, therefore, is suppressed before other cellular functions are affected (Yamane et al., 1998). Plants exposed to high temperatures exhibit two

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opposite effects in the electron transport chain of photosynthesis (Tóth et al., 2007). During high-temperature periods, the photosystem I (PSI) is stimulated (as measured by the rate of P700+reduction) (Tóth et al., 2007; Martinazzo and Marcos, 2012). In contrast, photosystem II (PSII), and mainly the oxygen-evolving complex (OEC), is deactivated even at slightly elevated temperatures (Martinazzo and Marcos, 2012; Yamane et al., 1998), indicating that this process is susceptible to temperature stress (Martinazzo and Marcos, 2012; Pushpalatha et al., 2008). PSII, a protein complex that is the first link in the photosynthesis chain, uses light energy for electron extraction from water molecules (Barber, 2003). The JIP test, which analyses the polyphasic fluorescence transient (OJIP), is a fast and informative test widely used for analysing plant performance to indicate plant stress caused by environmental conditions (Bussotti et al., 2010). Photosynthetic parameters are efficient plant stress indicators [Salisbury and Ross,1992; Strasser and Tsmilli-Michael, 2001, (Little and Rolando, 2003; Kalaji et al., 2014)]. Therefore, measuring chlorophyll fluorescence with a portable fluorimeter has been reported as an effective measuring tool of chlorophyll fluorescence to indicate plant adaptation and stress (Little and Rolando, 2003; Kalaji et al., 2014).

The plant efficiency analyser (PEA), the Handy-Pea from Hansatech Instruments Ltd., was used for the study (See Figure 3.13). The Handy-Pea is a portable fluorometer that works on the principle of inducing a red LED light for 1 second on a 4mm diameter dark-adapted leaf surface area at a peak wavelength of 650 nm, which is absorbed by chlorophyll at an intensity of up to 3500 µmol photons m^{-2} s^{-1} (Hansatech Instruments Ltd, 2022). A dark-adaptation period of a minimum of 20 minutes is required for leaves to ensure that the reaction centres of the leaf are fully oxidised and, therefore, available for photochemistry with reduced dormant chlorophyll fluorescence (Hansatech Instruments Ltd, 2022).

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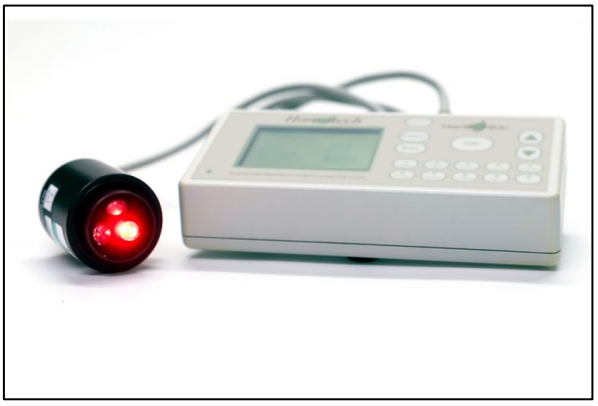


Figure 3.13: The plant efficiency analyser (PEA), the Handy-Pea from Hansatech Instruments Ltd., that was used to measure plant stress (Hansatech Instruments Ltd, 2022)

Parameters measured include the quantum efficiency of the pigment-protein complex, Photosystem II (PSII) (Fv/Fm), which has been reported as an indicator of water stress (Little and Rolando, 2003; Ceusters et al., 2019). Fv/Fm is a popular parameter measure for PSII in photosynthesis studies (Kalaji et al., 2017). The maximum quantum yield of photosystem II declines under most stress conditions and is therefore regarded as a critical plant stress indicator (Kim et al., 2019). It is not sensitive to stomatal changes and, therefore, not recommended for measuring early drought stress, although the Fv/Fm values decrease substantially over extended drought stress periods (Kalaji et al., 2017). Fv/Fm is, however, a good indicator of high-temperature stress or leaf senescence (Kalaji et al., 2017; Lu et al., 2002; Kotakis et al., 2014) before any visual traces of plant stress appear. The quantum efficiency is presented as a ratio of variable fluorescence (Fv) over the maximum fluorescence value (Fm), where values of 0.83 to0.84 in C3 plants and 0.78 in C4 plants indicate optimal conditions, with values below these indicating stress [Björkman and Demmig 1987; Pfűndel 1998 in (Kalaji et al., 2014)]. The literature recommends different Fv/Fm values as stress indicators. An Fv/Fm value range between 0.83 to 0,88 for C3 plants and 0.87 to 0.88 for C4 plants indicates unstressed plants (Kalaji et al., 2014; Kalaji et al., 2017; Wientjes et al., 2013). If the Fv/Fm drops below these threshold values, the plant cannot cope with its environmental conditions and stresses, and its photosynthetic apparatuses start to be damaged. Values below 0.75 were accepted as an indication of photosystem damage for this study (Kim et al., 2019).

The performance index, PI_{total}, was also measured as an indicator linked to plant and drought stress. The PI_{total} is a photosynthetic performance indicator that combines

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biophysical parameters and strongly correlates with plant growth, health, and survival rate (Yusuf et al., 2010; Berner et al., 2021; Maliba et al., 2019). The performance index $PI_{absorbed}$ quantifies the overall electron flow functionality through the pigment-protein complex, Photosystem II (PSII) (Ceusters et al., 2019). The PI_{total} should be measured within the same species to determine trends (Berner et al., 2021) and cannot be measured across species. Therefore, the trend in PI_{total} values should be assessed over a period to determine plant vitality.

Regarding plant stress, the researcher harvested one leaf per plant, three replicates per species per LWS typology and 3 per natural soil control area monthly for the empirical research period. Leaves were adapted to dark conditions for 2 hours, after which three readings each (9 readings per TAV species per LWS typology or natural soil) were taken with the plant efficiency analyser (PEA). The researcher removed inconsistent Fv/Fm values from the readings downloaded in Microsoft Excel before finalizing the datasets for statistical analysis based on the OJIP chart sets to address technical errors.

i. Variable 15: Irrigation (primary data)

Irrigation volumes were calculated according to the irrigation times and settings and recorded manually.

j. Data analysis

The study premise is that outdoor modular LWSs with TAV could contribute to local household food security as EGI in local urban environments (Gauteng, South Africa).

The experimental study can be categorised as deductive, as the process followed general to specific logic through measuring and analysing data (Bhandari, 2022f), following the initial inductive reasoning applied to the questionnaires. As quantitative data was assessed, statistical analysis was selected to determine the cause-and-effect relationship. Statistical analysis is typically used for data analysis in field experiments involving vegetation (Kent, 2012).

The study compared the biomass and plant stress for the two living wall typologies, the natural soil as control, and the nine TAV crops and the control crop. The local maximum (T_{max}) temperatures (T_{min}), relative humidity (RH), soil water content (VWC), soil temperature

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(ST), soil electrical conductivity (EC) and plant stress were compared across groups. There were two LWS typologies and natural soil as control, with nine TAV crops and a commercial crop as control.

For the biomass yield, data were tested for uniform distribution using the numerical method, the Shapiro-Wilk test, before analysis, which showed that data came from a normally distributed population. Results were analysed by following a non-parametric procedure, the analysis of variance (ANOVA), to assess dependent variable changes according to independent variable values (Bevans, 2022). The one-way analysis of variance (ANOVA) and linear regression analysis tests were employed for the inferential statistics. Descriptive analysis was carried out for all numeric variables in the dataset. The pairwise Tukey's multiple comparison post-hoc tests were performed to compare crops and LWS typologies. Significance was set at a threshold of $p < 0.05$ between all genotypes. The analysis was performed using Python software (ver. 3.11, 2021, Santa Clara, California, US), and graphs were developed using Microsoft Excel.

Concerning the post-hoc test results, effect size, which indicates the size of the association between two variables, is important for statistically significant combinations, as it indicates whether an effect is large enough to have practical significance (Bhandari, 2022g). Hedge's g and Cohen's d are two measures of effect sizes with similar interpretations, although Hedges g is unbiased and preferable for small sample groups below 20 (Lakens, 2013; NIST, 2018). Therefore, this study's effect sizes are categorized using Cohen's rule of thumb (Cohen, 1988), where effect sizes of 0.20 are considered small, 0.50 medium, and 0.80 represent a large effect size. The effect sizes for all LWS positions and the natural soil combinations are interpreted as large should Cohen's d rule of thumb be applied (Cohen, 1988).

The researcher obtained Fv/Fm and PItotal values for the plant stress analysis through the HandyPea readings (see Variable 14: Plant stress (primary data) in Experimental study). The daily maximum (T_{max}) and minimum temperatures (T_{min}), relative humidity (RH), precipitation (P), daylength (DF), soil water content (VWC), soil temperature (ST), soil electrical conductivity (EC) and fresh and dry biomass were compared across ten groups to analyse the performance. There were two LWS typologies and natural soil as control, with nine TAV crops and a commercial crop as control. The one-way Analysis of Variance (ANOVA) and the Pearson correlation coefficient tests were employed for the inferential

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statistics to compare groups and to assess the correlation between climatic and soil data and plant stress. Descriptive analyses were carried out for all numeric variables in the dataset. Independent-sample T-tests and pairwise Tukey's multiple comparison post-hoc tests were performed to compare plant stress, crops and LWS typologies. Significant differences were calculated at a threshold of $p < 0.05$ between all genotypes. The analyses were performed using IBM SPSS (version 28) software. Microsoft Excel and IBM SPSS (version 28) were used to produce graphs. Software for the plant stress data differed from the biomass data analysis, as the researcher did the latter under the guidance of Professor Berner (NWU), who has specialised knowledge in plant stress data.

Correlations were analysed by reporting on the type and strength of the relationship, measured by the correlation coefficient or r coefficient (Taylor, 1990), using the Pearson correlation coefficient. A direct relationship between variables is positive, where both variables increase in accordance with each other. In contrast, a negative correlation coefficient indicates an inverse relationship, with one variable decreasing following the increase of the other (Taylor, 1990). Concerning the correlation strength, r coefficients equal to or below 0.35 are considered weak, 0.36 to 0.67 moderate, 0.68 to 1.0 strong, and equal to or above 0.90 very strong (Taylor, 1990).

Findings from the statistical analysis were presented by descriptions, tables, graphs, or Excel charts, guided by the objectives and research questions. Results from the data analysis should illustrate the relationships among variables most clearly and effectively. Graphs must clearly show the data in a simplistic (minimum ink) and consistent manner, focus on the data presented, avoid distorting data, and encourage the reader to compare different datasets (Field, 2018; Tufte, 1983).

Findings related to productivity, installation, costs and maintenance were analysed based on observations and calculations by the researcher. Area and footprint findings were calculated based on the plant's monthly yield per square meter per typology. These were compared to a benchmark average of fresh produce weight of 244g/m^2)(Rabin et al., 2012 in Nagle et al. 2017). The benchmark is based on the average mixed-crop small-scale conventional production rates of 2.44 kg/m^2 at the Rutgers Agricultural Experiment Station.

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3.5 Limitations

3.5.1 Questionnaires

Williams and Webb (1994) identified how experts are defined as a limitation in limited samples. The limited samples for the questionnaires to select LWSs [n=7] and TAV [n=12] could be considered a study limitation. However, few experts on LWSs and local crops in South Africa exist as this is quite a niche market. In defence of this, the criteria for the selection and qualifications of experts were well-defined. The snowball sampling assisted in the composition of the expert panel based on not only the selection by the researcher but also on inputs from experts, which increased the sample sizes and extended the expert panel to a well-balanced group of professionals from different backgrounds to ensure an unbiased selection of LWSs and TAV.

Purposive snowball sampling can pose the risk of bias by the researcher or the initial sampling group, where the probability of respondents with more connections being included in the research is higher (Lavrakas, 2008; Turner, 2020). This risk can, however, be managed. The purposive snowball sampling technique can enhance the population's representativeness by distributing the initial sample group and several rounds of sampling (Lavrakas, 2008), which was the case for this study.

3.5.2 Experimental study

Field experiments have limitations such as uncontrolled temporal environmental variations, including light, temperature, precipitation, and herbivores (Poorter et al., 2012). The advantages, however, outweigh the limitations. These include measuring the actual environmental conditions (Poorter et al., 2012), which is essential for this study as the impact of climatic effects such as heat waves and limited precipitation are determined.

The positioning of the walls at Future Africa was constrained by the existing walls available, the selection criteria of the researcher and the expectations and requirements of the campus management, including the Department of Facilities, the Future Africa campus and the University of Pretoria Garden Committee. After identifying two alternative sites, compromises had to be reached between the researcher and the Department of Facilities Management.

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Moreover, initial flaws in the data measurement include faulty logger batteries, non-randomisation of crops, and no controls such as natural soil crops and commercial crops. These data were excluded from the analysis. The *Procavia capensis* (rock hyrax), also called the "dassie", a small terrestrial mammal whose diet usually consists of grasses, forbs, shrubs and the leaves of trees (Khoza and Hamer, 2013) enjoyed the new prospects of grazing on some of the TAV crops that were established. Significant losses, especially the Portulaca oleracea (purslane), were experienced as the dassies extensively grazed and favoured this species. A 50mm high steel mesh fence was erected around the LWSs to protect crops from the dassies. However, the crops in the natural soil area could not be protected, as this area formed part of a plant bed. The comparative crop yield, therefore, might have been influenced by grazing rather than the environmental and soil conditions.

Regarding the quantitative design, including all the recommended abiotic factors by Poorter (2012) impacting plants in empirical research was challenging due to large data sets, limited capacity of the researcher to include a PAR meter, and limited funding and resources. At the onset of the data analysis stage, the researcher did not have the skills to complete the statistical analyses and relied on funding from the University to liaise with statisticians. Due to the limited hours available, the statisticians had to retain the focus on the research questions relating to biomass and only include variables applicable to the study outcomes. The researcher analysed the plant stress data after gaining knowledge of statistical analysis with the software.

The soil for the two LWS typologies was similar but different from the soil in the natural soil area. This might have impacted the difference in the soil VWC, EC and temperature readings, and crop performance in the different typologies.

The impact of rising atmospheric CO_2 concentrations on agricultural production and photosynthesis is significant, especially during winter with inversion (Abou-Hussein, 2012; Poorter et al., 2012). CO_2 levels should ideally have been included in the variables as recommended by Poorter et al. (2012). However, this limitation is not expected to significantly impact the research findings, as the site criteria include limited air pollution due to low levels of vehicle traffic (the site is only visited by residents, employees and workshop attendees, few busy roads close to the site and ample distance from heavy traffic). Also, the data collection was mainly conducted from November to April in the summer, favouring the crop-growing season.

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Water potential should ideally be measured together with water content, as it provides information about the availability of water for plant uptake and water flow in the soil, which defines the comfort levels of a plant (Campbell and Campbell, 2013). Due to budgetary restrictions, however, it was decided to prioritise the water content as a variable. The main reason was the availability of an accurate all-in-one sensor measuring VWC, temperature and EC. Including the water potential as a variable would necessitate acquiring an additional instrument, the Teros21. The soil water content is more familiar and straightforward to relate to irrigation volumes (Meter Group Inc., 2021). However, including the water potential in the variables would be advantageous, and it should be noted as a limitation.

Also, challenges usually associated with developing countries were experienced, such as unreliable electricity and water availability. These challenges affected the irrigation of the LWSs for intermittent periods ranging between one and four weeks, where the crops received no irrigation for extended periods in November 2021 and January 2022. Emergency interventions had to be taken through hand watering to avoid the loss of crops. Also, the study site for the experiment falls in a manually irrigated area. Therefore, the natural soil area did not always receive the specified water volumes at the specified times and intervals.

3.6 Validity and reliability

Validity and rigour are achieved by preventing potential pitfalls and following the specified process and criteria (Braun and Clarke, 2006). Validity refers to the instrument's accuracy in measuring, whereas reliability refers to the measurement’s consistency (Frey, 2018).

3.6.1 Questionnaires

Possible drawbacks include insufficient data analysis, questions used as themes, inconsistent data interpretations and incorrect statements (Braun and Clarke, 2006). The researcher attempted to eliminate subjective assessments by including relevant, unambiguous, straightforward questions to address validity. Moreover, closed-ended responses were analysed quantitively to ensure objective scoring of responses (Frey, 2018). The sample was also purposefully selected with snowball sampling to represent different professions for the LWSs and TAV selection, with a geographical representation of TAV experts.

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3.6.2 Experimental study

Internal validity, defined as the credibility of the causal relationship between an independent and dependent variable by the research methodology (Lavrakas, 2008), depends on three conditions. A high internal validity can only be achieved when the independent and dependent variables change together after the treatment, with no external influences (Bhandari, 2022d). The dependent variables changed in accordance with the independent variables, and external influences such as the irrigation malfunctioning and shade by trees impacted all the dependent variables equally. Also, randomisation is critical for comparing groups to ensure maximum validity for statistical tests (Kang et al., 2008). Therefore, randomisation of the crop positions in each LWS typology and the control site as a method of experimental control increased the internal validity and credibility of the results, as independent variables were balanced between crops. External influences are part of the real-world environment and preferred over a laboratory environment for the purposes of this research, and internal validity was achieved. The use of a control group, the natural soil, and a control crop, *Spinacea oleracea* (spinach) also increased the internal validity, for comparison purposes with the treatment typologies and crops.

External validity refers to the generalizability of the findings to other real-world situations (Lavrakas, 2008; Bhandari, 2022a; Kalaian and Kasim, 2008). External validity can be ensured through field experiments and replications (Bhandari, 2022a). Due to the true experiment method and the repetitions of crops measured for the data collection, a high external validity has been achieved. A study to measure abiotic plant stress on plants used three leaves per genotype and three evaluations per leaf, resulting in 9 measurements per genotype (Markulj et al., 2014). Therefore, three replications were measured for plant stress and biomass yield, whereas hourly measurements were logged for RH, temperature, soil temperature, water content and EC. Moreover, the 6-month data collection period and monthly plant stress and biomass yield measures further increased the external validity.

Reliability was achieved by ensuring that measuring instruments yielded accurate, consistent, and reproducible results during data collection (Knapp, 2008; Middleton, 2022). The researcher calibrated the balance before measuring fresh and dry mass weights. Also, reliable instruments and loggers were used for the experiment, widely used in similar research studies. Human error can also impact reliability when transferring raw data from

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a field notebook in experimental research (Kent, 2012). To ensure reliability, the biomass data was verified by an independent person to ensure correct transfer.

For the statistical analysis, precautions were taken by selecting a statistical significance threshold value of $p < 0.05$, and outliers or extreme values were also identified and excluded (Bhandari, 2022c; Bhandari, 2022b). For non-normal distributions, where the standard deviation is a less reliable measure of variability, the range, which entails the data spread from the lowest to the highest distribution values, was determined (Bhandari, 2022c; Bhandari, 2022b).

3.6.3 Indigenous knowledge and the decolonisation of knowledge

Although Latin binomials are fundamental and especially of value in addressing confusion about common names, the vernacular names given to plants by indigenous people may convey in-depth information relating to the plant's form, uses, distribution and ecology (Gillman and Wright, 2020). This is especially important in the case of edible and medicinal plants. To ensure the study's validity for indigenous people of SSA and the decolonisation of knowledge, the researcher included indigenous vernacular plant names, where available. Research approaches that include indigenous knowledge systems are crucial in understanding context-specific issues relating to fruit and vegetable consumption (Stadlmayr et al., 2023). Disseminating knowledge in such a manner to retain and enhance indigenous knowledge is, therefore, vital (Moteetee and Van Wyk, 2006).

3.7 Ethical considerations

The ethical protocol was adhered to per the University of Pretoria Faculty of Engineering, Built Environment and Information Technology (EBIT) requirements for administering questionnaires as the main instrument for collecting data for the LWS and TAV selection. Respondents' identities or personal information were not required for the study and remained anonymous. Study participants were informed that participation is voluntary, privacy assurances were made, and participants were provided with a background to the study and research. The ethics application included preliminary questionnaire wording, and the EBIT Research Ethics Committee granted conditional approval. Appendix C consists of the approval letter from the EBIT Research Ethics Committee (Reference no EBIT/84/2019).

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3.8 Concluding reflections on the research design

The initial inductive approach followed for the first phase, involving the selection of the LWSs, TAV and study site, and the subsequent deductive approach for the second phase, involving the experimental study, are considered successful. Existing knowledge from similar research studies, including Nagle et al. (2017), Razzaghmanesh and Razzaghmanesh (2017), Riley (2017) and Poorter (2012), was influential in guiding the design and method for experimental strategy. This assisted the researcher in selecting variables and research instruments to address the research sub-questions, objectives, and the required outcomes for the study in a targeted and precise manner to increase validity.

Validity and reliability were achieved despite the limitations of small sample sizes for the first phase of the study, which entailed the LWS and TAV selection through questionnaires. This was done through purposefully selected snowball sampling to represent different professions. Moreover, the sample group represent views from various fields of expertise. Furthermore, validity was increased by including relevant, unambiguous and clear questions and a mixed method of quantitative and qualitative analysis of responses.

The north-facing kitchen yard wall of the University of Pretoria's Future Africa campus in the City of Tshwane Metropolitan Municipality (Tshwane) is deemed a representative study site for typical urban conditions in Gauteng. The site also complies with the selection criteria for the experimental study site.

The study's second phase, the experimental research, entailed comparing the performance of a local soil cell system representative of mainstream high technology as the first intervention and a local system representing simplistic low technology as the second intervention to the control, represented by the natural soil area. As the third intervention, the selected TAV species were compared, and a mainstream crop was chosen as the control to analyse their performance for household food security in Gauteng, SA. Dependent variables, including yield biomass and plant stress, were statistically analysed for the two living wall typologies, the natural soil as control, the nine TAV crops, and the control crop. Independent variables included climate, soil temperature, moisture and EC.

The experimental design achieved a high external validity and reliability, although internal validity was affected by external causal influences. Limitations included time delays, crops affected by irrigation failures, crops eaten by dassies and exclusion of variables such as

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CO_2 levels, water potential and PAR. However, internal validity was still considered satisfactory because all independent variables were exposed to the same causal inferences. True experimental research includes specific and objective results, which can serve as a foundation for future solutions and further research to improve household food security through LWSs with TAV. Accurate, consistent, and reproducible results were achieved through measures taken in the selection and calibration of instruments during the data collection process. Validity was also increased owing to the 6-month data collection period. Statistical validity was achieved by developing a comprehensive and relevant database to measure the intended constructs. Moreover, an appropriate statistical approach was applied, excluding outliers and extreme values, considering the effect size and determining the data range of datasets to ensure correct interpretations and conclusions.

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Chapter 4

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4. THE LWS TYPOLOGY SELECTION

Growing plants on a vertical surface gives the appearance of natural simplicity. However, achieving a successful living wall is a complex problem with many factors. These include: ensuring an appropriate support structure, maintaining the proper amount of water, oxygen, nutrients and pH levels, choosing plants which can survive seasonal climatic changes, and establishing the appropriate lighting conditions; not to mention affordability, sustainability and longevity. Satisfying these complex needs - mastering all of these factors - will be essential for living wall systems to mature beyond their use as vanity projects and gain acceptance by the construction industry. (Riley, 2017)

4.1 Introduction

This chapter discusses the findings of the LWS selection process. The first research focus area of this study is the performance of outdoor modular LWS as EGI, Research outcome 3 of the study entails;

> *Performance guidelines for improving outdoor modular LWSs' technical characteristics as EGI in local urban environments.*

Therefore, selecting LWS typologies as an inference for the true experimental study was necessary to measure the efficiency of exterior modular LWS as EGI. The discussion on the LWS typology selection for the empirical research is grouped into the criteria developed for the LWS typologies, the LWS selection, and the description of the two selected typologies and the natural soil area. Figure 4.1 provides a graphical diagram of the layout of the chapter.

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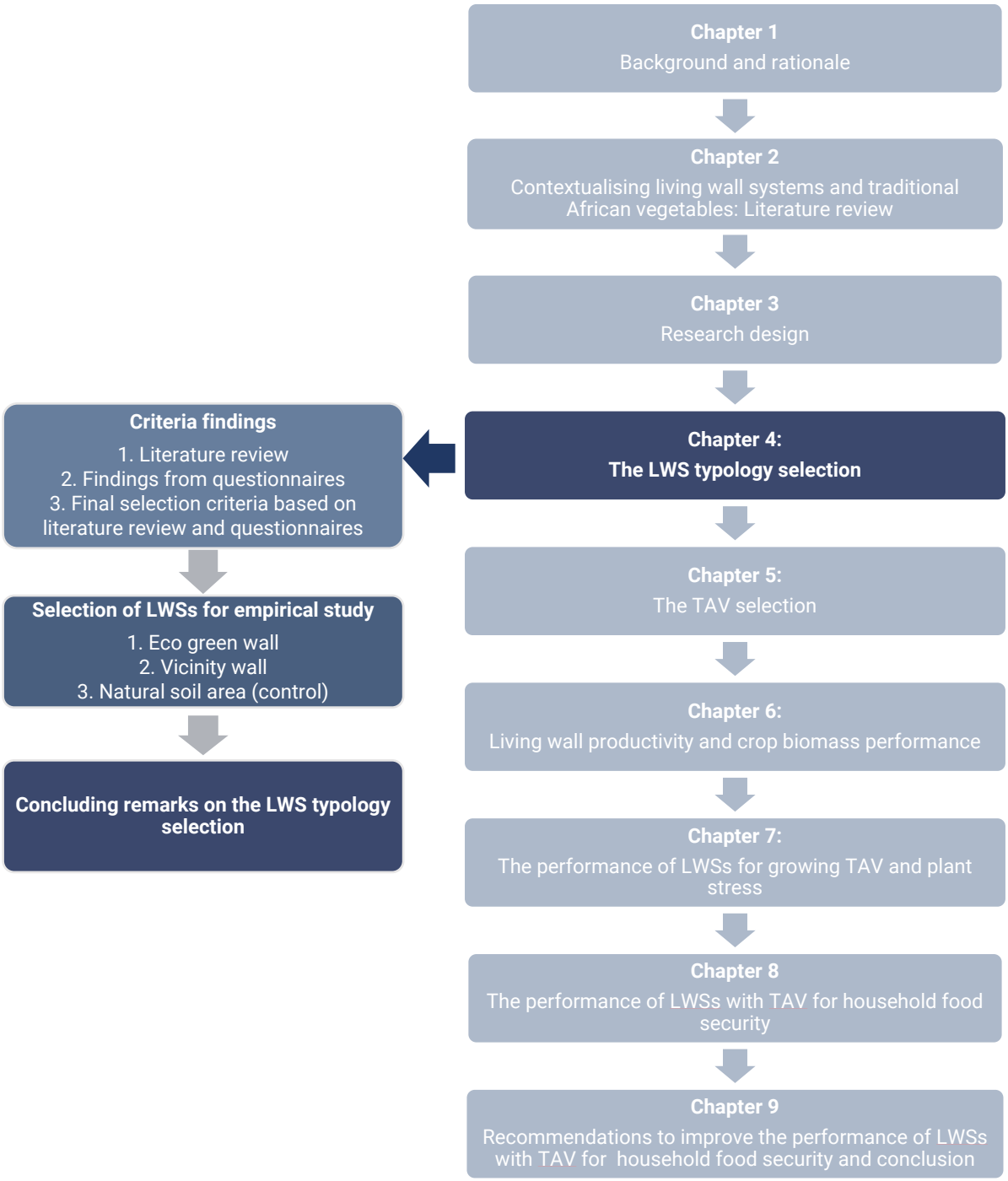


Figure 4.1: Graphic illustration of the layout for Chapter 4

The criteria development section summarises the literature review findings on LWSs and the criteria developed following the literature review. The results from the questionnaires to select LWSs are then described. The final selection criteria are listed based on a combination of the criteria developed from the literature review and questionnaires.

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4.2 Criteria findings

Based on the project applications, different criteria are currently applicable for utilising LWSs in urban environment projects. An important consideration for the inclusion criteria was that the LWS should maximize the generalizability of the findings to ensure external validity. Secondly, it was essential to develop selection criteria for this study based on different viewpoints and perspectives, such as construction, supply and planning or design.

Please refer to 2.3.6 Summary of the characteristics of LWSs for improved performance

4.2.1 Findings from Questionnaires

The researcher identified six main themes concerning essential considerations for LWS selection based on the analysis of responses from the questionnaires, namely: 1) qualities and technical specifications of LWS for optimal growing conditions of TAV, 2) Existing brands or types of LWSs utilised and recommended, 3) maintenance required for LWSs, 4) challenges associated with LWSs, 5) recommended dimensions, and 6) most practical orientation of LWSs for growing TAV in Gauteng. These themes are elaborated below.

i. Qualities and technical specifications of LWS for optimal growing conditions for TAV

Two divergent rationales were captured in response to the first theme: criteria focusing on LWSs as its entity and the second criterion concentrating on the plants in the system. A shared view among five participants was that cost-effectiveness and uncomplicated installation were crucial in selecting LWSs. Other considerations for LWS, which were expressed, included modular expandable components that are flexible for different-scale installations. Recycled or recyclable and robust material for the LWS components and local manufacturing, which was crucial in limiting the system's ecological footprint, was a recurrent factor. Systems with [1]bigger capacity plant containers were proposed. One respondent identified lightweight systems (pots and soil) as a criterion. At the same time, another suggested that a system should be able to function on a free-standing basis

[1] Referring to soil or growth medium over 1,5 litres

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without relying on walls and building facades and should have good insulation properties to mitigate the UHI effect.

Regarding the second focus, which entails plant selection, participants recommended that the positioning of plants should consider grouping species with similar water and light requirements. One participant indicated that root size should be considered, and another participant recommended against plants with spreading root systems and underground parts used as vegetables. The weight of the growth medium, water and nutrient-holding capacity was also raised, while another respondent listed sufficient natural light for optimal plant growth. Respondents expressed concern that TAV's low water requirements should be considered when selecting an irrigation system, with manual irrigation added as an option.

ii. Recommended LWS produced or supplied in SA

The 15 visited LWSs projects in Pretoria and Johannesburg, Gauteng, comprised mainly the Growall, Vicinity, Modiwall and custom-made systems. Figures 4.2 to 4.5 show the systems of four visited projects composed of edible plants.



Figure 4.2: Edible living wall, comprising the Australian-manufactured Atlantis Growall, at the Hobart Doppio Zero restaurant in Bryanston, Johannesburg
(Source: Author)

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Figure 4.3: Edible living wall, comprising the locally manufactured Modiwall, at the 86Public Restaurant in Randburg, Johannesburg. Edible plants were unsuccessful due to insufficient sunlight and were gradually replaced with aesthetic plants
(Source: Author)



Figure 4.4: Edible living wall, comprising the Vicinity system, at the Mix Cocktail Bar in Rosebank, Johannesburg

(Source: Author)

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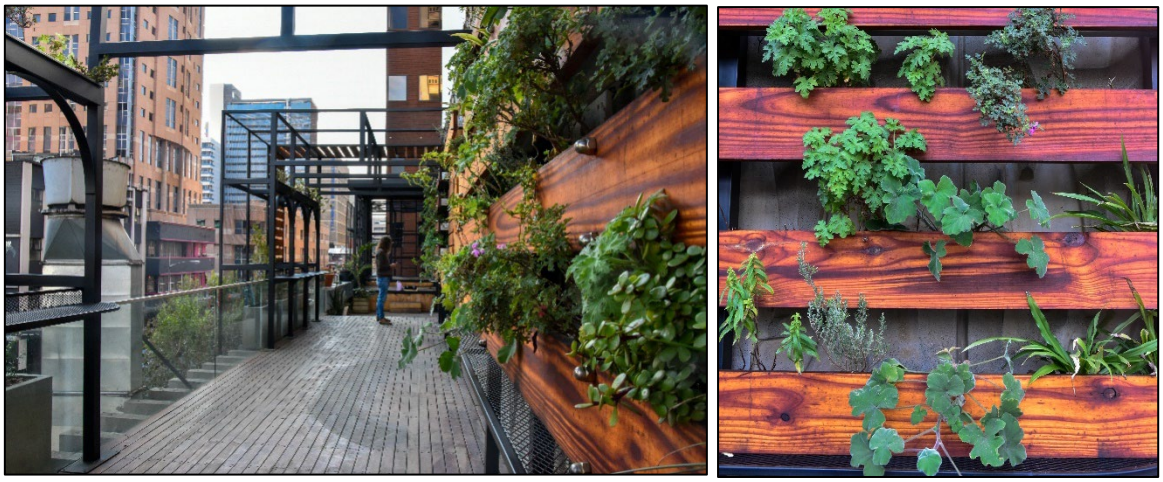


Figure 4.5: Custom-made edible living wall with galvanised steel gutters fixed to steel frames and cladded with timber slats bolted to the frames at the Neigbourgoods Market, Braamfontein (Source: Author)

The respondents reported five systems successfully used for growing crops in local projects. Five respondents proposed the Vicinity system, which is widely used for LWS projects in South Africa, while two suggested a newly patented system, the Eco Green Wall. Two respondents listed the Modiwall, Mobilane and Growall systems as well. The Atlantis GroWall and Mobilane are supplied in SA, although they are manufactured in Australia and The Netherlands, respectively. Both systems are utilised for commercial and residential scale projects in South Africa.

The Vicinity and Modiwall are locally manufactured systems comprising recyclable plastic pots for plants and growing mediums. In the Modiwall system, the growing medium is placed directly in modules. In contrast, in the Vicinity system, geotextile bags in hexagonal pots contain the growing medium, comprising 3 litres. The Modiwall system includes wall panels fixed to the building structure of the façade, to which pots with a growing medium capacity of almost 1 litre are clipped in. The Eco Green Wall system is locally manufactured, a local low-technology outdoor system comprising interlocking, lightweight recycled polystyrene aggregate and cement mixture blocks stacked onto each other with seed trays as plant pots.

iii. Maintenance requirements of LWS

In response to the question on the required maintenance of these systems, respondents were unanimous in the view that maintenance is mainly focused on the irrigation system

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and planting, as the systems themselves need limited maintenance due to the basic assembly and robust materials used.

Concerning irrigation, participants reported that maintenance would require checking that the pump does not run dry, cleaning filters and clearing drippers of blockages as needed.

Regarding the plants, weeding, the fast growth rate of TAV species, which requires regular harvesting, the health of the plants, selecting an appropriate growth medium, nutrients, and irrigation for the planting palette were raised as essential considerations. Also, there were suggestions for addressing diseases and pests through companion planting strategies to increase the system's efficiency.

iv. Challenges associated with LWS

The participants identified the most critical challenges associated with LWSs as the limiting factors of plants, including soil, water, light and aspect. Concerning soil, lighter soil mixtures and the inclusion of water retention agents, as well as aeration and nutrient content, were proposed. Regarding water, participants suggested the importance of automated irrigation systems and water harvesting. Most participants agreed that the installation cost of systems was a significant challenge, and one participant raised the challenge of ensuring public safety through the secure fastening of systems.

v. Recommended dimensions

Concerning developing an understanding of the LWS size required to ensure sufficient yields whilst ensuring accessibility for maintenance, suggestions included that crops' nutritional value and user requirements should guide the LWS size. Another critical factor raised is the accessibility for the maintenance and harvesting of crops. One respondent proposed a maximum height of two metres for the top rows of the LWS, with the length dependent on the user preferences and available space.

vi. The most beneficial orientation for growing TAV in Gauteng

Figure 4.6 shows respondents' selections of the most beneficial orientation/s for LWS with TAV in Gauteng. The most recommended orientation for growing TAV in LWS in Gauteng is north, as almost half of the experts advised, with east and west as second options. No respondents selected south. The motivating factor for orientation was sufficient sun exposure for the plants.

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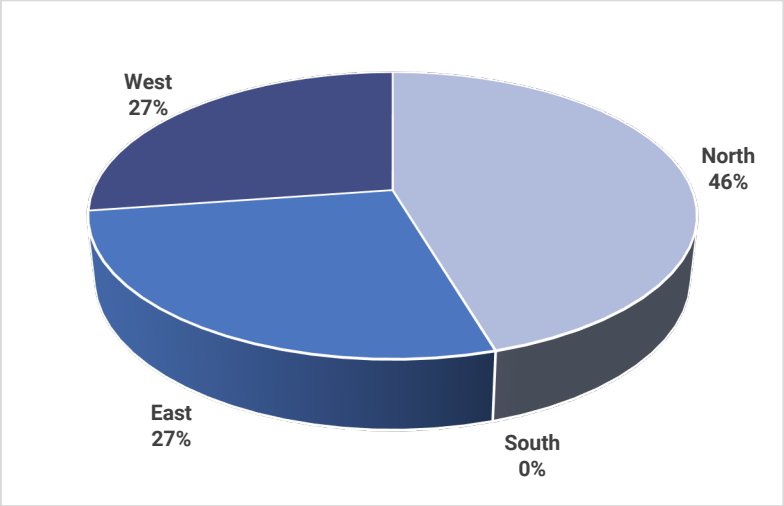


Figure 4.6: Most beneficial LWS orientation for growing TAV in Gauteng according to LWS experts based on the questionnaire findings

4.2.2 Selection Criteria for LWSs based on the literature review and questionnaires

The researcher developed the final criteria for selecting the LWS typologies by combining the findings from the literature review and the questionnaires. Table 4.1 summarises the similarities between the LWS selection criteria of the literature review and questionnaire findings.

Table 4.1: Similarities between LWS selection criteria based on the literature review and questionnaire findings

Criteria from the literature review	Criteria from the questionnaires	The similarity between literature review and questionnaires
Modular LWSs with individual pots are more efficient (Huang et al., 2019b; Botes and Breed, 2022).	The system must be soil-based.	Modular system Must have a structure to support plant density for full vegetation cover and vegetation continuity (easy replacement of plants),
	The Vicinity and Eco Green Wall are the preferred local systems. Modiwall, Mobilane and Growall systems are proposed as the second option.	
The system must be locally produced (Botes and Breed, 2022; Perini and Rosasco, 2013; Akinwolemiwa et al., 2018).	The system must be manufactured locally.	Locally produced.
The system must involve low-skilled, non-specialised workmanship (Akinwolemiwa et al., 2018; Botes and Breed, 2021)	The system must be easy to install	Uncomplicated assembly and technology.
Recycled materials increase the feasibility (Ottelé et al., 2011).	Recycled or recyclable and robust material for the LWS components	Contain recycled or recyclable material components

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	Sufficient natural light should be allowed for optimal plant growth.	North orientation (site selection).
	The system must be lightweight (structure and pots).	Flexible/ adjustable installation.
	The system must have modular expandable components to be flexible for different-scale installations.	
	The system should be able to function on a free-standing basis without relying on walls and building facades.	
	The system's height and size should ensure sufficient yields whilst ensuring accessibility for harvesting and maintenance.	
	Public safety through the secure fastening of the system is required.	
	The system should have good insulation properties.	
The installation and maintenance costs must be reduced (Akinwolemiwa et al., 2018; Botes and Breed, 2021; Huang et al., 2019b).	The system must have a low installation cost.	Be cost-effective.
Plant selection to integrate benefits increases resilience and performance (Russo and Cirella, 2019; Russo et al., 2017; Beacham et al., 2019; Natarajan et al., 2015)	Plants should be grouped and positioned according to water and light requirements.	Plant selection.
	Plants with non-spreading, small, compact roots and above-ground parts used as vegetables should be selected.	
	Plant species without limiting factors must be selected.	
	A lightweight soil mixture should be used, considering water and nutrient-holding capacity, aeration and nutrient content, and the inclusion of water retention agents.	An adequate soil volume of a minimum of 1.5 litres to support optimal growth.
	The system must include plant containers with a sufficient growth medium capacity.	
Reduced potable water usage during the operational phase through water harvesting, drip irrigation and plant selection is essential (Natarajan et al., 2015).	The irrigation system must provide for the low water requirements of TAV, with manual irrigation added as an option.	Must include a drip irrigation system to minimise potable water consumption.
	An automated irrigation system with water harvesting is required.	
	Maintenance of the irrigation system and plants is required.	

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The researcher finalised the criteria selection based on the similarities between the literature and the questionnaire findings in Table 4.1. Therefore, the criteria for the LWS typology selection include that the system must 1) be locally produced, 2) contain recycled or recyclable material components to limit the carbon footprint, 3) have an adequate soil volume of a minimum of 1,5 litres to support optimal growth, 4) must include a drip irrigation system to minimise potable water consumption, 5) must be cost-effective, 6) must involve uncomplicated assembly and technology, 7) must have a lightweight structure, 8) must have a structure to support plant density for full vegetation cover and vegetation continuity (easy replacement of plants), and 9) must be flexible for different scale installations.

4.3 Selection of LWSs for empirical study

Following the identified criteria based on the literature review and the questionnaires, the researcher analysed the locally manufactured 1) Vicinity Wall, 2) Modiwall and 3) Eco Green Wall. The analysis guided the selection of LWS typologies for the experimental research. As only three locally produced systems were available, the researcher also included the imported 4) Growall and 5) Mobilane systems listed in the questionnaire responses.

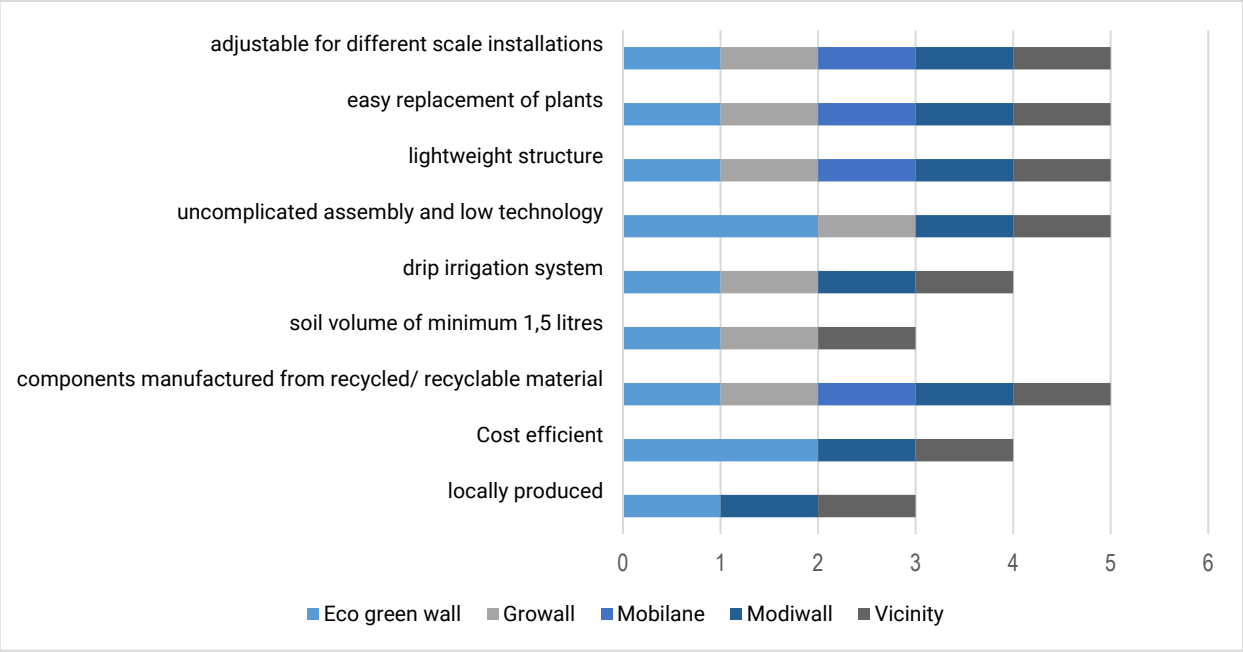


Figure 4.7: Comparison of the Eco Green Wall, GroWall, Mobilane, Modiwall and Vicinity systems in terms of selection criteria

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For the analysis, a definite yes for each criterion was calculated to 2 points, yes to 1 point, and no to 0. It is apparent from Figure 4.7 that the Eco Green Wall and Vicinity systems were the only two systems that complied with all criteria. The researcher, therefore, selected only the Eco Green Wall and Vicinity systems. The researcher deemed these two systems sufficient to analyse the performance of LWSs, as the Vicinity system represents a high-technology system, and the Eco Green Wall represents a low-technology system. Furthermore, the space of the study area and the funding budget made the selection of only two systems possible.

As the control, a natural soil area in which the TAV species were planted in traditional agricultural conditions for comparison with the two LWS typologies was selected as the third option for the growing needs of the TAV species.

The subsections below explain the selected systems and the control area.

4.3.1 Eco Green Wall System

The Eco Green Wall is a local low-technology outdoor system developed to address the economic feasibility and sustainability challenges experienced with modular LWSs. The Eco Green Wall system comprises interlocking, lightweight, recycled polystyrene aggregate and cement mixture blocks (Van der Walt, 2019). These blocks are stacked onto each other and can be fixed onto a building structure or façade with stainless steel brackets or placed back-to-back as a free-standing element. The pots comprise black seed trays containing the growth medium and the plants.

The system aims to limit exposure of the growth medium for enhanced moisture retention by limiting the majority area of the seed tray's sun exposure (Van der Walt, 2019). The growth medium retains moisture for more prolonged periods, protected by the blocks in which the seed trays fit. Seed trays have almost half the capacity of the Vicinity system, with a volume of 1.59 litres for the growth medium and plants.

The system offers two alternatives for irrigation: trunking with a wick or a drip irrigation system (Van der Walt, 2019). An irrigation line irrigates each planter row, and the trays drain into each other.

Figure 4.8 illustrates the Eco Green Wall.

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Figure 4.8a: The Eco Green Wall system, installed at the Future Africa campus of the University of Pretoria

Figure 4.8b: The black seed trays, with dimensions of 150 x 230 x 50mm are fitted into the blocks

Figure 4.8c: The interlocking, lightweight recycled polystyrene aggregate and cement mixture blocks stacked onto each other with the drip irrigation feeder line

(Source: Author)



4.3.2 Vicinity System

The Vicinity system comprises an all-in-one system, with water reservoir tanks at the bottom, a pump and filter, drip irrigation for the top row of pots, gravitating into each row, and circulating back to the top row (Vicinity, 2022). The Vicinity pots are clipped onto an aluminium rail fixed to the building structure or façade. The Vicinity pots with geotextile planter bags have a capacity of 3 litres (Vicinity, 2022).

Figures 4.9 and 4.10 provide a diagram and photos of the Vicinity system.

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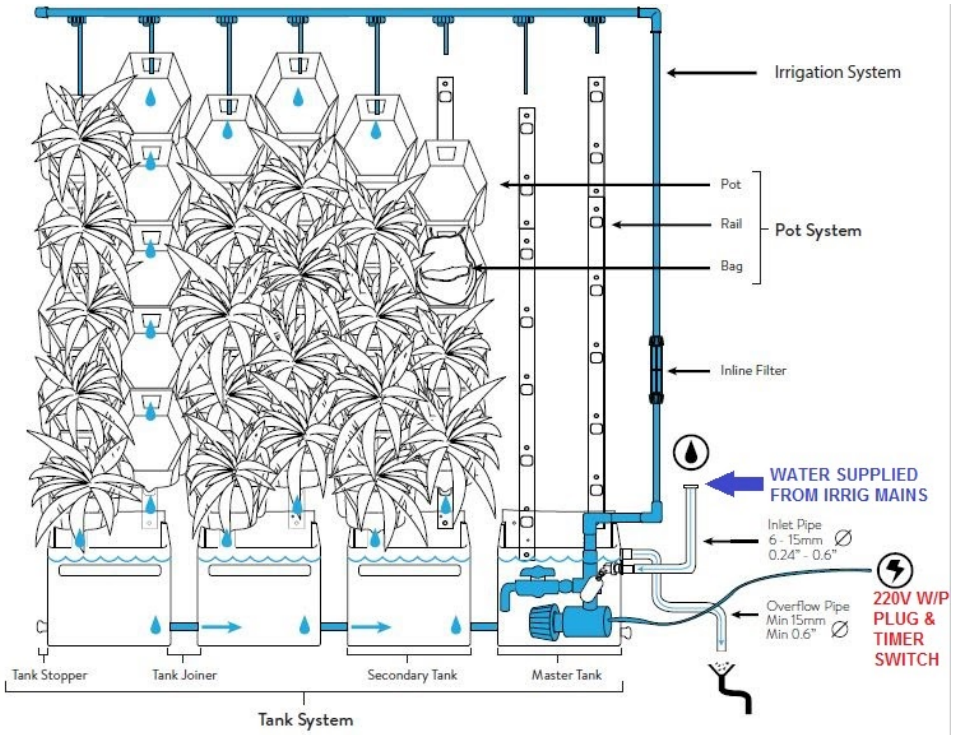
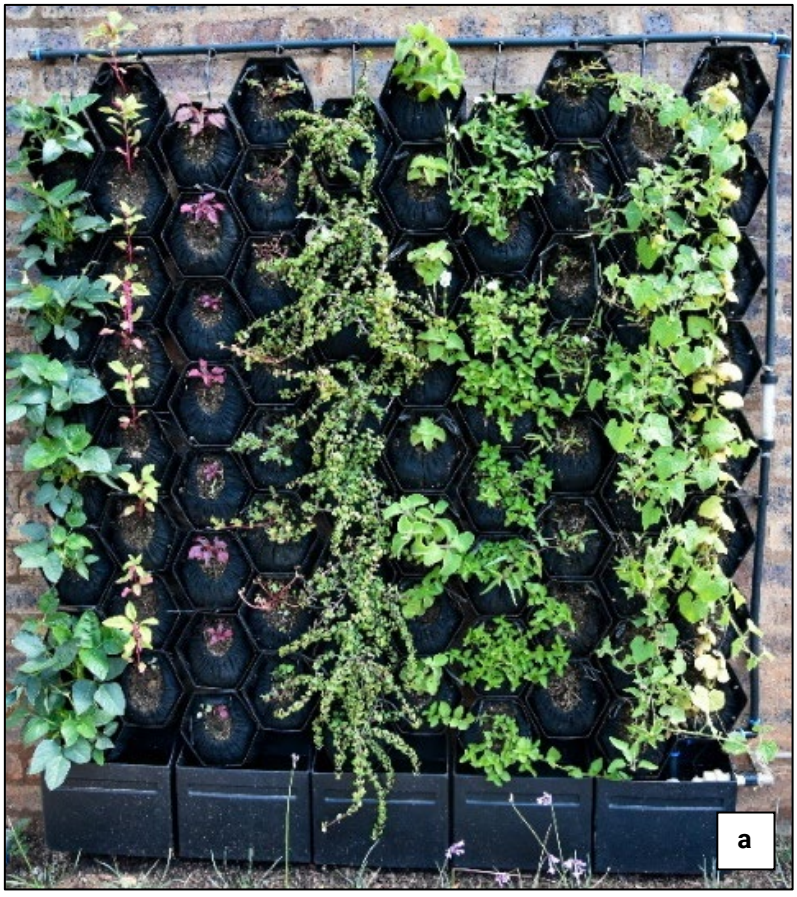


Figure 4.9: Diagram of the Vicinity system
Source: Vicinity (2022)



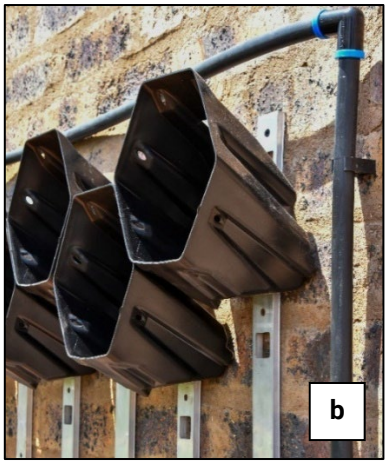


Figure 4.10:

4.10a The Vicinity system, with hexagonal pots containing geotextile bags, the growth medium, plants, and water-reservoir tanks at the bottom feeding the drip irrigation line.

4.10b The pots clip onto aluminium rails, that are fixed to the Future Africa campus kitchen yard wall

(Source: Author)

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4.3.3 Natural soil area

A control area with TAV crops planted simultaneously as the intervention sites, the LWSs, was selected. The control area, the natural soil area, is directly adjacent to and north of the two LWSs on the Future Africa campus area. This area is representative of traditional soil-based urban agriculture. Although space in urban areas is limited, soil-based practices are still the most dominant form of urban agriculture in South Africa (Cilliers et al., 2020). TAV crops were randomly planted in the soil area using conventional subsistence farming methods.

4.4 Concluding remarks on the LWS typology selection

This chapter aims to select LWSs as inferences for the true experimental study. This is the first step in achieving research objective 3. Based on the empirical study findings, it seeks to identify modular LWS technical characteristics to enhance their performance as EGI for growing TAV in local urban conditions (Gauteng, South Africa) to contribute to household food security.

The literature review findings, observations of local LWS projects and the results from the questionnaires provided essential insights into the technical characteristics of LWSs to be included in the criteria list to improve their performance. These criteria include that LWSs must involve low technology, be affordable, uncomplicated, lightweight, adjustable for different scale installations and be locally produced from recycled / recyclable components to limit their carbon footprint. Furthermore, the system must contain pots with an adequate soil volume to support optimal growth, allowing for easy plant replacement.

Based on these criteria, the Eco Green Wall, representing a low-technology system, and the Vicinity Wall, representing a high-technology system, were selected as interventions for this research's experimental study.

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Chapter 5

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5. THE TAV SELECTION

"Worldwide, a multitude of various plant species are assigned to be consumed as grains, vegetables, and fruits, but only a limited number of these species are used as commercial cash crops. Consequently, numerous neglected and underutilized species offer the potential to diversify not only the human diet, but also increase food production levels, and, thus, enable more sustainable and resilient agro- and horti-food systems." (Baldermann et al., 2016: 107)

5.1 Introduction

This chapter describes the findings of the TAV selection process in response to research objective 5, which involves how the production of TAV crops in modular LWS in local urban environments can contribute to household food security.

The first step in achieving this was to develop a shortlist of the most prominent TAV species based on the literature review and expert consultation for growth in the two LWS typologies for empirical research. This list is provided in Table 2.2 in par. 2.4.6 Most prominent traditional African vegetables in South Africa. The second step was the selection of a shortlist of species. This was an essential step to achieve outcome 5, namely, to provide a list of TAV species that have the potential for cultivation in outdoor living walls in Gauteng, South Africa.

This chapter presents the findings of the TAV selection process. The findings on the TAV selection for the empirical study are grouped into the results from questionnaires, the TAV selection, and a description of the final selected TAV and the control crop. Figure 5.1 provides a diagram of the layout of the chapter.

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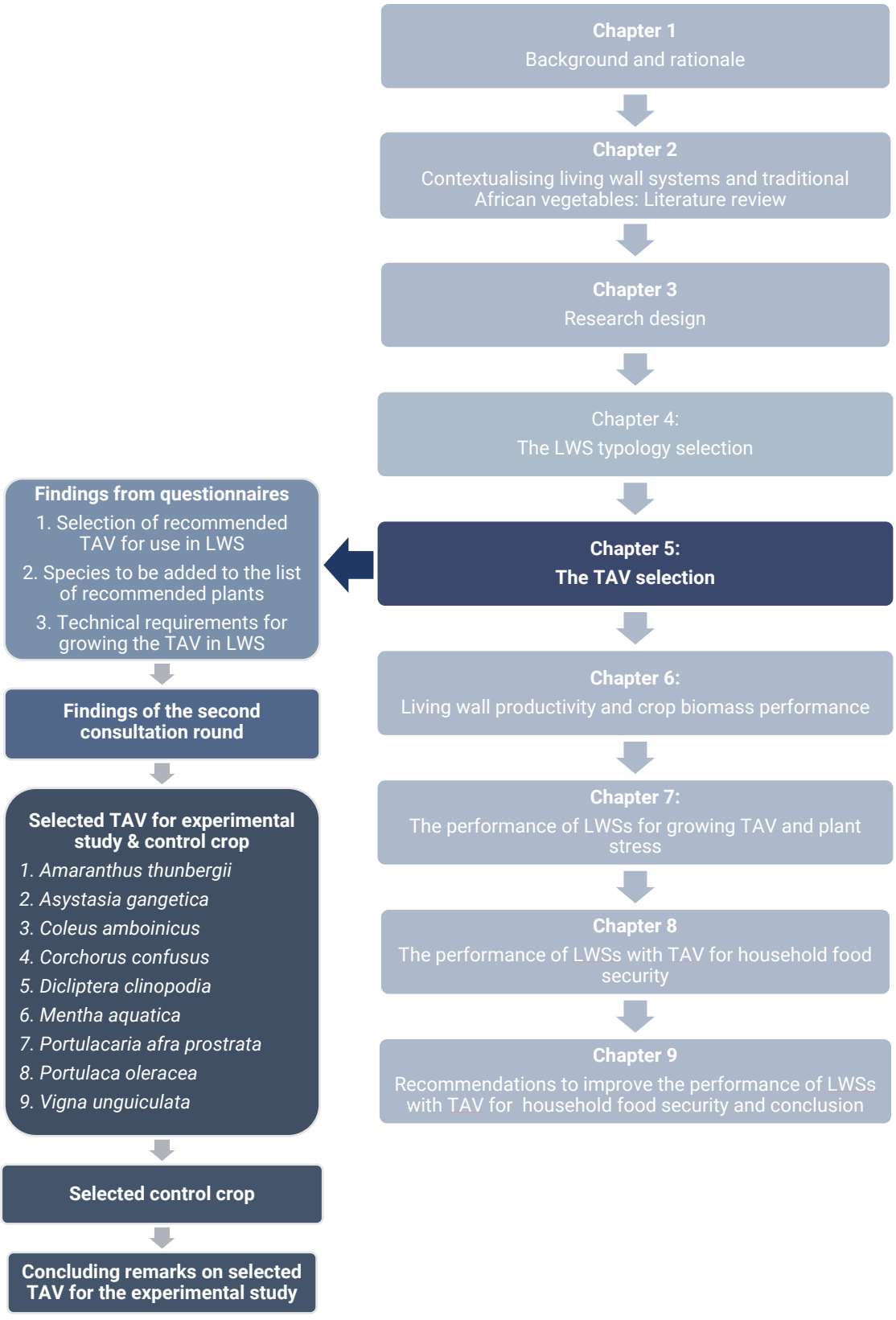


Figure 5.1: Graphic illustration of the layout for Chapter 5

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5.2 Summary of the literature review findings

5.2.1 The most prominent TAV species based on the literature review findings

Based on the literature review, the most prominent warm season TAV included *Amaranthus* spp (Amaranth), *Bidens pilosa, B. biternate* (blackjack), *Chenopodium album* (fat hen), *Cleome gynandra* (spider flower), *Corchorus olitorius* and C. *tridens* (Jew's mallow), Cucurbita *maxima* (pumpkin), *Solanum retroflexum* (nightshade) and *Vigna unguiculata* (black-eyed pea) (Quaye et al., 2009; Sogbohossou et al., 2015; Hart, 2011; Ojiewo et al., 2015; Nyarai et al., 2018; Tadele, 2019; Maseko et al., 2017; Jansen van Rensburg et al., 2009; Fox et al., 1982; Oelofse and Van Averbeke, 2012; Welcome and Van Wyk, 2019). From the literature review findings, the prominence of the Amaranth species should be highlighted (Jansen van Rensburg et al., 2009; Fox et al., 1982; Oelofse and Van Averbeke, 2012; Welcome and Van Wyk, 2019).

These prominent TAV crops form the basis for the expert consultation to select a shortlist of TAV species for the empirical part of the study. The sizes of some of the Amaranth species, spider flower, pumpkin and fat hen, were considered too big for use in LWSs. Yet, all the species were included in the questionnaire sent to participants to select TAV for the experimental study.

5.2.2 Growth Requirements and TAV Cultivation

TAV require sufficient water, nutrients and light for optimal growth. High-temperature ranges are vital for these crops, and they prefer full sun with adequate ventilation (Jansen van Rensburg WS et al., 2012). These crops can typically only tolerate mild frost, and they need to be protected against pests and diseases (Jansen van Rensburg WS et al., 2012)

Soils need to be well-drained and fertilised in terms of macro and micronutrients, include organic material, and have a loose, stable, and crumb structure (Jansen van Rensburg WS et al., 2012). Moreover, the soil pH impacts the yield (Tadele and Assefa, 2012a).

Drip irrigation minimises foliage diseases, and most TAV crops require drier conditions (Jansen van Rensburg WS et al., 2012).

5.3 Findings from questionnaires

Following the analysis of questionnaire responses, the findings were grouped into the selection of recommended TAV crops for use in LWSs and suggested for consideration in

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the empirical study, as well as the growth requirements, habitats, and other recommendations for cultivation. These are elaborated below.

5.3.1 Selection of recommended TAV crops for use in LWSs

Figure 5.2 summarises respondents' selection of TAV species with potential for small-scale vertical production in Gauteng urban environments. Respondents could select from a list of 31 TAV crops. Five TAV crops, *Amaranthus* (amaranth), *Nemesia fruticans* (nemesia), *Coleus amboinicus (previously known as Plectranthus amboinicus)*(Indian borage), *Portulaca oleracea* (purslane) and *Portulacarea afra* Prostrata (dwarf elephant's food) were selected by the majority (n=8) of the respondents. TAV species that were chosen by more than half of the respondents (n=6 and n=7) include *Asystasia gangetica* (creeping foxglove), *Mentha aquatica* (water mint), *Mentha longifolia* (wild mint) and *Vigna unguiculata* (black-eyed pea). Five respondents selected *Asystasia schimperii* (longevity spinach), *Dicliptera clinopodia* (pink ribbons) and *Diclis reptans* (dwarf snapdragon).

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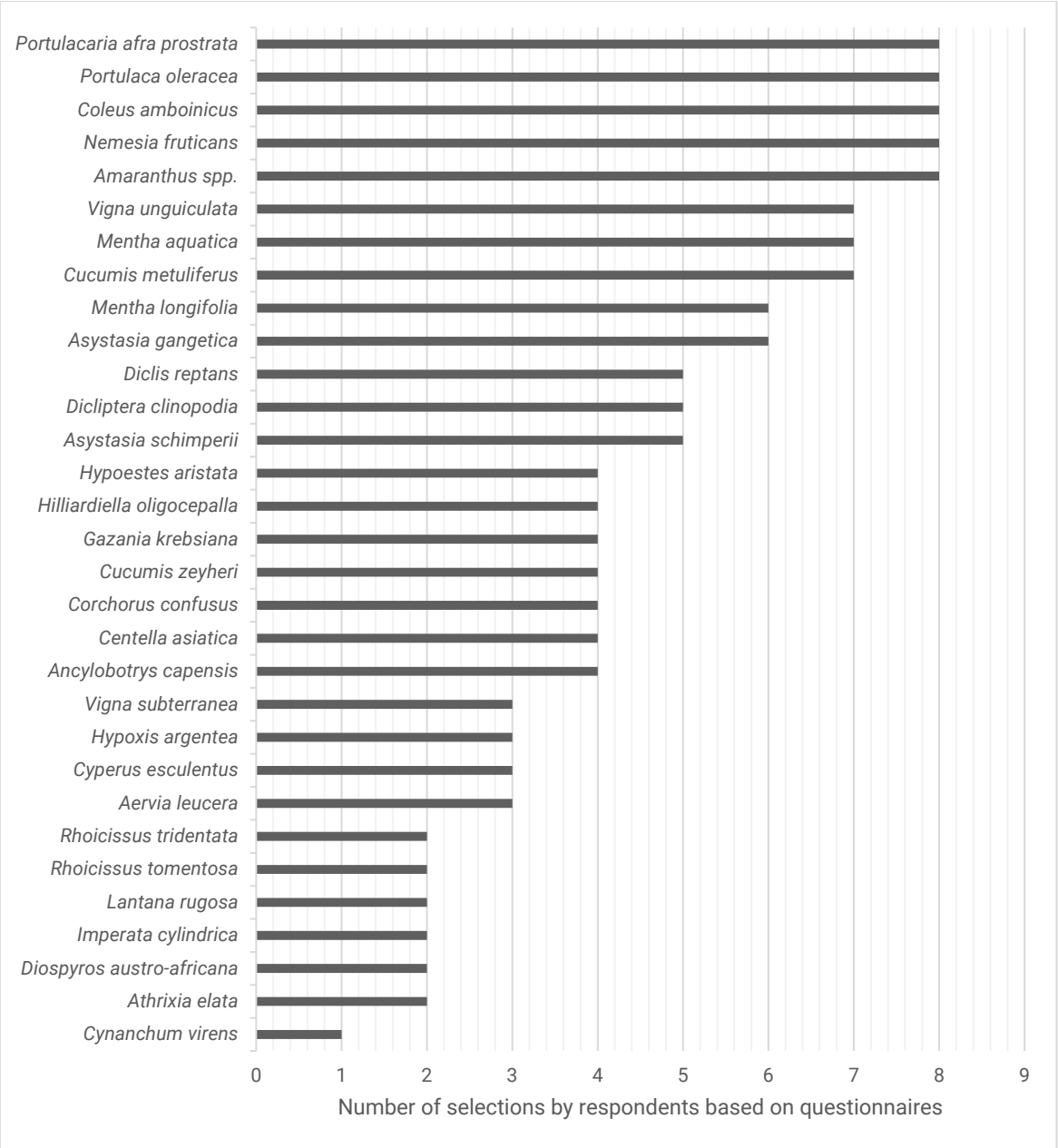


Figure 5.2: Overview of the respondents' selection of [1]traditional African vegetable species with potential for small-scale vertical production in Gauteng urban environments

[1] The edible parts of crops should be verified if used in future studies

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5.3.2 Growth Requirements and cultivation recommendations

This section presents the suggested requirements for optimal TAV growth and production. Experts made four overarching recommendations on light conditions, water requirements, harvesting and replacement, and roots of TAV. Respondents highlighted the importance of sufficient natural light for optimal plant growth.

Concerning their water requirements, respondents highlighted that the growth medium and irrigation should consider TAV's low water requirements. Therefore, a lightweight, well-drained soil medium is required. The irrigation should be phased seasonally, and plants should be grouped according to their water requirements.

Respondents also listed TAV's fast growth characteristics, necessitating regular harvesting to ensure their health and stimulate growth. As most TAV are annuals, they should be replaced annually.

Furthermore, crops with compact root systems should be selected, and the size of the LWS containers should be sufficient for root size. Also, respondents do not recommend crops with underground edible parts (roots, bulbs, tubers, stems, and rhizomes) for LWSs, as the complete plant is destroyed with every harvest.

5.3.3 Species to be tested as part of the empirical study

The researcher developed selection criteria based on her experience and expert opinions from the questionnaire responses. Table 5.1 lists the TAV criteria.

Table 5.1: The TAV selection criteria

Item	Required characteristics
1	can be annual/ perennial
2	must be commercially available
3	must be suitable for growth in LWSs in terms of size and shape
4	must be prominent in the literature review based on utilisation and production in southern Africa
5	must grow in full sun
6	must be able to tolerate dry conditions
7	must be able to tolerate mild frost conditions
8	must be suitable for the Gauteng climate conditions
9	must be ornamental

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Species with the potential for growth in LWS were provided by respondents as TAV that they are familiar with or would recommend. Numerous edible species were suggested. Table 5.2 contains the complete list of 44 species proposed by experts, including binomial, common and family names, for consideration in addition to the TAV species provided in the questionnaire.

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Table 5.2: Edible plants recommended by experts to be considered for inclusion in the empirical study based on the questionnaires

Binomial name	Common name	Family
Abelmoschus esculentus	okra	Malvaceae
Adansonia digitata	boabab	Malvaceae
Bidens spinosa	blackjack	Asteraceae
Brassica carinata	Abbysynian cabbage	Brassicaceae
Brassica nigra	mustard seed	Brassicaceae
Brassica rapa chinensis	Chinese Cabbage	Brassicaceae
Carissa macrocarpa	num-num	Apocynaceae
Chenopodium album	fat hen	Amaranthaceae
Cleome gynandra	African spider flower	Cleomaceae
Crassula ovata, Crassula spathulata, Crassula expansa, Crassula pellucida	Jade plant	Crassulaceae
Cucurbita	pumpkin	Cucurbitaceae
Cynanchum viminale (previously Sarcostemma viminale)	caustic vine	Apocynaceae
Cyrtanthus brachyscyphus, Cyrtanthus mackenii, Cyrtanthus sanguineus	fire lily	Amaryllidaceae
Dicliptera cernua, Dicliptera extenta	false buck-weed	Acanthaceae
Englerophytum magalismontanum	stem fruit	Sapotaceae
Galinsoga parviflora	gallant soldier	Asteraceae
Huernia zebrina, Huernia volkartii, H. hystrix	little owl	Apocynaceae
Hypoestes forskaolii	white ribbon bush	Acanthacea
Justicia flava, Justicia betonica, Justicia capensis, Justicia protracta, Justicia petiolaris	shrimp plants	Acanthaceae
Lablab purpureus	hyacinth bean	Fabaceae
Lannea edulis	wild grape	Anacardiaceae
Momordica balsamina	balsam apple	Cucurbitaceae
Oryza glaberrima	African rice	Poaceae
Parinari capensis	sand apple	Chrysobalanaceae
Pelargonium capitatum, graveolens, inquinans, peltatum	rose geranium	Geraniaceae
Plectranthus esculenthus	African potato	Lamiaceae
Rhinacanthus gracilis		Acanthaceae
Sinapis arvensis	wild mustard	Brassicaceae
Solanum retroflexum	sunberry/ nightshade	Solanaceae

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Many species recommended by the expert panel were not suitable in terms of the selection criteria, as depicted in Table 5.1. Furthermore, crops with fruit and underground edible parts were not considered for the final selection, as the study only focuses on leafy TAV with above-ground edible parts as part of the experimental study.

5.4 Findings of the second consultation round

For the second analysis stage, the researcher consulted a smaller expert panel from the initial respondent list, comprising one agricultural researcher and two growers with expertise in indigenous vegetation. This stage was vital for the study to ensure that the final TAV list would be practical regarding growth and utilisation and commercially available as seed or seedlings for growing the crops for the experimental study. Also, the two selected LWSs and space restrictions at the study site allowed ten crops to be tested. Therefore, nine TAV crops and one control crop, representing a commercial crop, could be selected.

The panel of experts were presented with the TAV list of 31 crops in Figure 5.2 for further reduction of the TAV list for growth in the LWS. This process involved eliminating TAV species selected by less than five respondents in the questionnaire responses (Refer to Figure 5.2 in section 5.3.1). From the list of thirteen TAV species with five or more selections, as shown in Figure 5.2 in section 5.3.1, the *Mentha* and *Asystasia* spp. included two genera. As the research aims to make a difference in real-world environments and therefore needs high generalizability, the panel selected only one species per genus to increase the study's external validity. Concerning the *Mentha* spp, the researcher and second stage panel of two experts chose to exclude the *Mentha longifolia* (wild mint) due to its size and shape, entailing 1 meter compared to the *Mentha aquatica (water mint)*, which has a more compact form and grows up to 500mm. Two species were excluded due to the commercial unavailability of seeds and seedlings. These included *Asystasia schimperii* (longevity spinach) and *Nemesia fruticans* (Nemesia).

The agricultural researcher assisted with the selection of the *Amaranthus* (Amaranth). Two species were proposed due to their compact size and ornamental appearance: *Amaranthus caudatus* (love-lies-bleeding) and *Amaranthus tricolor* (Chinese spinach). These two Amaranth species were planted for a pilot study from October 2020 to October 2021, but neither of these species survived the LWS environment. Due to its compact growth, it was decided to include *Amaranthus thunbergia* (Thunberg's pigweed).

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One species needed to be added to the eight selected species from the second round for the experimental research. Therefore, the TAV species, as shown in Figure 5.2 and selected by four respondents, were investigated for inclusion in the empirical study. These included *Ancylobotrys capensis* (Wild apricot), *Centella asiatica* (Pennywort), *Cucumis zeyheri* (wild cucumber), *Corchorus confusus* (jute plant), *Gazania krebsiana* (Gazania) and *Hilliardiella oligocepala* (bicoloured leave Vernonia). Selection between them was based on the selection criteria listed in Table 5.1 in section 5.3.2. *Ancylobotrys capensis* (wild apricot), which can grow up to 5 metres, was excluded based on size. *Centella asiatica* (pennywort) was excluded due to its use mainly for medicinal purposes. One respondent asked *Gazania krebsiana* (gazania) to be reconsidered as it was not edible and insufficient knowledge of its edible properties was available. Lastly, *Hilliardiella oligocepala* (bicoloured leave Vernonia) was not commercially available.

Based on the former, two TAV species were included as a trial between October 2020 and October 2021. *Cucumis metuliferus* (horned cucumber) was selected as the *Cucumis zeyheri* (wild cucumber) was not commercially available. *Corchorus confusus* (jute plant) was sourced as it was commercially unavailable and initially included as a trial between October 2020 and October 2021. Like the amaranth species, the *Cucumis metuliferus* (horned cucumber) did not survive in the LWS environment, although the *Corchorus confusus* (jute plant) proved successful during the trial period.

5.5 Selected TAV for the experimental study

Table 5.3 lists the TAV crops that were selected for inclusion in the experimental research following the finalisation of the shortlist developed based on expert consultation.

All the chosen crops comply with the criteria listed in Table 5.1 (Section 5.3.2).

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Table 5.3: Final traditional African vegetable selection for the experimental study

Binomial name	Common name	Family name
Asystasia gangetica	creeping foxglove, Isihobo (Zulu)	Acanthaceae
Amaranthus thunbergii	Thunberg's pigweed Thunberg's pigweed/ poor man's spinach, Theepe-ea-bokone (Sesotho), Bonongwe (Shona), Imbuya/ Umbhida (Ndebele), Teka (Hlengwe)	Amaranthaceae
Coleus amboinicus (previously known as Plectranthus amboinicus)	Indian borage, Indian mint, African thyme, broad-leaved thyme	Lamiaceae
Corchorus confusus	Jute plant, gusha, ungibonisele	Malvaceae
Dicliptera clinopodia	pink ribbons	Acanthaceae
Mentha aquatica	water mint, koena-e-nyenyane	Lamiaceae
Portulacaria afra prostrata	dwarf elephant's food	Portulacaceae
Portulaca oleareae	Purslane, Selèlè	Portulacaceae
*Vigna **unguiculata***	black-eyed pea	Fabaceae

Spinacia oleracea (Spinach) was selected as a control crop, as the crop has a short growing period, falls in the Amaranthaceae family and tolerates full sun. It is also a popular food crop species in South Africa. The main characteristics and growing habits of the nine selected TAV species are described below.

5.5.1 *Amaranthus thunbergii* (Thunberg's pigweed/ poor man's spinach, Theepe-ea-bokone (Sesotho)

The *Amaranthus thunbergii* (Thunberg's pigweed/ poor man's spinach, Theepe-ea-bokone (Sesotho), Bonongwe (Shona), Imbuya/ Umbhida (Ndebele), Teka (Hlengwe) (Hyde, 2022), is a widespread weed growing in Ethiopia and Somalia to the Democratic Republic of Congo and Angola, Botswana, Namibia and South Africa (Hyde, 2022).

This compact, erect annual, growing up to 500mm (Fern and Fern, 2022; Hyde, 2022), is usually found in sandy or loamy soils in disturbed areas and near rivers (Hyde, 2022). The Thunberg's pigweed has angular, simple or branched stems with multicellular hair at the top of its elliptic leaves and almost no hair below, and greenish flowers in short axillary clusters (Fern and Fern, 2022; Hyde, 2022).

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5.5.2 *Asystasia gangetica* (creeping foxglove, Isihobo)

Asystasia gangetica (refer to Fig. 5.3), indigenous to South Africa, is a vigorous, spreading perennial herb that can grow up to 2 meters and smother other herbaceous vegetation (Fern and Fern, 2022; Adetula, 2004). Also called Isihobo (Zulu) (Random Harvest Nursery, 2023), it thrives in slightly acid soils with high organic content, sandy loams and clayey soils (Adetula, 2004). It is usually found as weeds in waterlogged and well-drained disturbed areas and river banks below 2500 m altitude and will not survive severe drought conditions (Adetula, 2004).



Figure 5.3: Asystasia gangetica (Creeping foxglove)
Source: Author

The ascending, branched, quadrangular stems carry simple opposite leaves with absent stipules and white funnel-shaped flowers with purple spots inside the lower lobe in spring and summer, which attracts insects (Adetula, 2004).

The young tender leaves, shoots and flowers are edible (Fern and Fern, 2022) and a popular vegetable, mixed with other leafy vegetables, in Kenya and Uganda (Adetula, 2004). The leaves have been reported to have medicinal properties in treating parasitic worm infections, hypertension, rheumatism, asthma and diabetes mellitus (Raji and Mugabo, 2013).

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5.5.3 *Coleus amboinicus* (previously known as *Plectranthus amboinicus*) (Indian borage, Indian mint, African thyme, broad-leaved thyme)

The Indian borage (Figure 5.4), indigenous to South Africa, is a sprawling perennial, usually found in dry river valleys in KwaZulu Natal and southern, eastern and central Africa (Van Jaarsveld, 2020).

This ornamental, lemon-scented, creeping perennial has succulent stems and fleshy, serrated leaves. It can grow to 1 metre (Fern and Fern, 2022) with two-lipped mauve flowers in summer and autumn (Van Jaarsveld, 2020). Leaves of the Indian borage have a strong aromatic flavour similar to oregano and are eaten raw or cooked as a pot herb and for flavouring (Fern and Fern, 2022).



Figure 5.4: Coleus amboinicus (previously known as Plectranthus amboinicus)(Indian borage) Source: Author

5.5.4 *Corchorus confusus* (jute plant, gusha, ungibonisele)

The jute plant (refer to Fig. 5.5) is a compact perennial herb with a woody rootstock and spreading branchlets growing up to 500mm (Hyde, 2022). The jute plant, indigenous to South Africa, is found in woodlands at low altitudes in Southern Mozambique, Zimbabwe, Botswana, Swaziland and the tropical and sub-tropical provinces of South Africa (Hyde, 2022).

The hairy leaves are lanceolate to ovate, rounded at the base, and have yellow flowers that attract insects (Hyde, 2022). Its young leaves are cooked as a mucilaginous vegetable and

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added to dishes to change the texture of vegetables with coarse, older leaves such as cowpea and amaranth.



Figure 5.5: Corchorus confusus (Jute plant)
Source: Author

5.5.5 *Dicliptera clinopodia* (pink ribbons)

This straggly perennial herb (refer to Fig. 5.6) is usually found in forests, forest margins, riparian bush, savanna, and grassy slope areas across eastern South Africa and eastern and tropical Africa (Kamundi, 2010).

In summer, plants have two-lipped glossy leaves with pink, magenta or purple flowers attracting insects and birds (Wentzel, 2022). Young leaves of the pink ribbons are cooked as a spinach and pot herb.

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Figure 5.6: Dicliptera clinopodia (pink ribbons)
Source: Random Harvest Nursery (2023)

5.5.6 *Mentha aquatica* (water mint, koena-e-nyenyane)

The water mint (Figure 5.7) is an indigenous South African perennial typically found in freshwater wetlands and waterlogged areas (Mtshali, 2017). The Sesotho name for the plant means a small (nyenyane) crocodile (koena), referring to the size of the plant (Moteetee and Van Wyk, 2006).

This perennial can tolerate relatively dry conditions and has a creeping rootstock with opposite leaves and white to mauve flowers at the stem tips, attracting insects (Wentzel, 2022). The narrow, opposite, edible leaves are intensely aromatic and minty (Wentzel, 2022).

Culinary uses include using the leaves as a garnish for teas and drinks and flavouring salads and vegetables.

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Figure 5.7: Mentha aquatica (water mint)
Source: Wentzel (2022)

5.5.7 *Portulacaria afra* prostrata (dwarf elephant's food)

The dwarf elephant's food (Figure 5.8) is a form of the spekboom. It is usually found in the arid and semi-arid eastern parts of South Africa, including the Eastern Cape, KwaZulu-Natal, Swaziland, Mpumalanga, the Limpopo Province, and Mozambique (Hankey, 2009).

This succulent groundcover has round, glossy leaves on low-growing, spreading branches (Wentzel, 2022). Besides its excellent carbon sequestration abilities, for which *Portulacaria afra* is well-known, its leaves are edible, with a slightly acidic taste (Hankey, 2009). A dwarf elephant's food sprig adds flavour to a tomato stew, and the leaves have medicinal properties as an antiseptic (Hankey, 2009).



Figure 5.8: Portulacaria afra prostrata (dwarf elephant's food)
Source: Author

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5.5.8 Portulaca oleracea (purslane, Selèlè)

The purslane, known as Selèlè in Sesotho, meaning slippery (Moteetee and Van Wyk, 2006), is an important ethnomedicinal plant widely distributed globally and reported to be indigenous to Mexico (Ajay et al., 2021). Although globally regarded as a noxious weed, purslane is said to have high medicinal and nutritional properties, with an exceptionally high omega-3 and omega-6 fatty acid content (Ajay et al., 2021). The annual succulent has a short lifecycle of 60 to 75 days (Ajay et al., 2021).

The purslane (refer to Figure 5.9) is a compact ascending growing between 200 to 500mm, copiously-branched, annual succulent (Fern and Fern, 2022) with tuberous roots, which enables the plant to adapt to compacted, dry, and less fertile soils (Ajay et al., 2021). It is a C4 photosynthesis plant under normal growing conditions, with reddish, smooth succulent stems, alternate, simple, fleshy oval leaves and yellow flowers (Ajay et al., 2021). The succulent switches to a Crassulacean Acid Metabolism pathway in arid conditions, making photosynthesis more efficient (Ajay et al., 2021).



Figure 5.9: Portulaca oleracea (purslane)
Source: (Backyard forager, 2017)

Leaves are edible with a slightly acidic taste and can be used raw as an addition to salads, cooked as a potherb, and used as a thickener in soups due to their mucilaginous nature (Fern and Fern, 2022). The fruits produce miniature reddish-brown seeds with a high phytochemical content (Ajay et al., 2021).

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5.5.9 *Vigna unguiculata* (black-eyed pea, cowpea)

The black-eyed pea (refer to Figure 5.10), indigenous to South Africa and usually found in dry savanna areas with a range of soil types in the tropics and sub-tropics of Africa, is well-known for its protein-rich grains (Gondwe et al., 2019). This climbing annual, reaching lengths of up to four metres, can tolerate dry spells (Gondwe et al., 2019).

The young, tender leaves are cooked as spinach (Fern and Fern, 2022) and can be kneaded and squeezed into balls and dried or mixed with tomatoes and peanut butter as a relish.



Figure 5.10: Vigna unguiculata (black-eyed pea)
Source: Author

5.6 Selected control crop

Spinacia oleracea (spinach, Sepinichi), a prominent dark leafy green vegetable, was selected as the control crop representative of economically essential and mainstream crops. Although spinach is a cool-season crop, it grows in the study area's temperature range and complies with all the criteria for selecting the TAV species. It is one of the most versatile, commonly consumed, and nutritious vegetables, together with broccoli, consumed globally (Morelock, 2008).

5.7 Concluding remarks on the TAV selection

The aim of Chapter 5 was to discuss the findings of the questionnaires to select TAV crops as an inference in the experimental study for growth in the two selected LWS typologies. The TAV selection was the first step in achieving research objective 5, which entails the

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identification of TAV species that show potential for outdoor small-scale vertical food production in Gauteng, South Africa.

Overall, the results of this chapter provide essential preliminary insights into the required characteristics of TAV for growth in LWSs. Based on the questionnaires, important TAV characteristics include their popularity and prominence in SSA markets, commercial availability, compact size and shape, and plants that must be ornamental to provide a range of ecosystem services. Moreover, these crops must tolerate local climatic requirements.

In addition, the consultation with experts alluded to four critical factors affecting TAV growth. These include TAV's full-sun requirements and the importance of TAV's low water requirements when selecting the growth medium and irrigation system and grouping the plants. Moreover, TAV require regular harvesting and, in the case of annuals, annual replacement. Lastly, crops with compact root systems and no underground edible parts are recommended, with a sufficient container size for roots.

The researcher deems the two-stage process of selecting TAV crops for the experimental study adequate. The first stage involved the crops most respondents chose, followed by a second stage, where a smaller panel refined the crop selection based on the selection criteria and workability. The researcher determined the number of crops according to the space of the study area and the size of the LWSs.

Although basic information relating to edible TAV is available from existing literature, information about their agronomical requirements, preparation, nutritional value and edible parts for consumption is limited. These knowledge gaps must be researched to enhance their use and performance in urban agriculture. Traditional knowledge would be valuable to future generations and research about TAV should be prioritised.

In summary, the final selected list of TAV species for inclusion in the experimental research includes *Amaranthus thunbergii* (Thunberg's pigweed), *Asystasia gangetica* (creeping foxglove), *Coleus amboinicus* (Indian borage), *Corchorus confusus* (Jute plant), *Dicliptera clinopodia* (pink ribbons), *Mentha aquatica* (water mint), *Portulacarea afra* prostrata (dwarf elephant's food), *Portulaca oleracea* (purslane) and *Vigna unguiculata* (black-eyed pea). *Spinacea oleracea* (spinach) has been selected as the control crop.

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Chapter 6

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6. LIVING WALL SYSTEM PRODUCTIVITY AND CROP BIOMASS PERFORMANCE

6.1 Introduction

Chapter 6 elaborates on the yield biomass statistical analysis findings and aims to address research objectives 3 and 5;

> *3.3. monitor and analyse the performance of the selected LWS typologies in providing optimal growing conditions for TAV.*
>
> *5.2. analyse the performance of the selected TAV crops.*

The objectives' measurement and data assessment align with the positivism philosophy and realistic problem-solving approach of pragmatism (Frey, 2018). The outcome entails analysing the efficiency of the two selected LWS typologies in providing optimal growing conditions for TAV to address research objective 3. This outcome was achieved by comparing data on soil water content, soil temperature and soil electrical conductivity, ambient temperature and RH, and the crops' survival and yield for both the LWS typologies to that of natural soil conditions as the control.

In response to research objective 5, the performance of the nine TAV crops was analysed. This was done by comparing data on the crops' yields to that of the commercial crop (*Spinacea oleracea*) as the control to provide a list of TAV species that have the potential for cultivation in outdoor living walls in Gauteng, South Africa.

Chapter 6 is divided into three parts. The first part provides the background by presenting the abiotic conditions applicable to the experimental study under which the LWSs and TAV crops performed. The second part entails the findings relating to the efficiency of the LWSs. The total crop yields for each LWS are compared to the control, the natural soil. Subsequently, the findings regarding the effects of crop positioning and other external factors impacting crop performance are presented. The third part entails the results relating to the performance of the TAV crops (see Figure 6.1). In the third part of the chapter, the crop leaf biomass results in the experimental study period are presented, followed by the crop performance in each typology.

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Figure 6.1: Diagram of the layout for Chapter 6, illustrating Part 1, focusing on the abiotic conditions; Part 2, the efficiency of LWSs; and Part 3, the performance of the TAV crops compared to the controls. The chapter ends with concluding remarks on the LWSs' productivity and crop biomass performance

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6.2 Which abiotic conditions applied to the experimental study?

6.2.1 Climate

The researcher measured concurrent temperature and relative humidity (RH) hourly at each LWS and the control site by Hobo U23 pro v2 weatherproof data loggers with built-in temperature and RH sensors (Onset Computer Corporation, 2022). Precipitation and daylength were obtained as secondary data from the Future Africa Weather Station on the University of Pretoria experimental farm.

i. Local ambient temperature

For warm-season crops, the optimal temperature range is between 13 and 25°C for germination and vegetative growth occurs in temperatures between 21°C and 33°C, with extremes resulting in poor quality leaves and yields (Abou-Hussein, 2012).

The Vicinity Wall displayed the highest mean maximum temperature (31,18℃) compared to the natural soil (30,68℃), and the Eco Green Wall showed the lowest mean (29,66℃) (See Figure 6.2 and Table 6.1). The mean maximum temperatures fall within the acceptable range for vegetative growth, although the maximum temperatures exceeded the allowable range during November 2021.

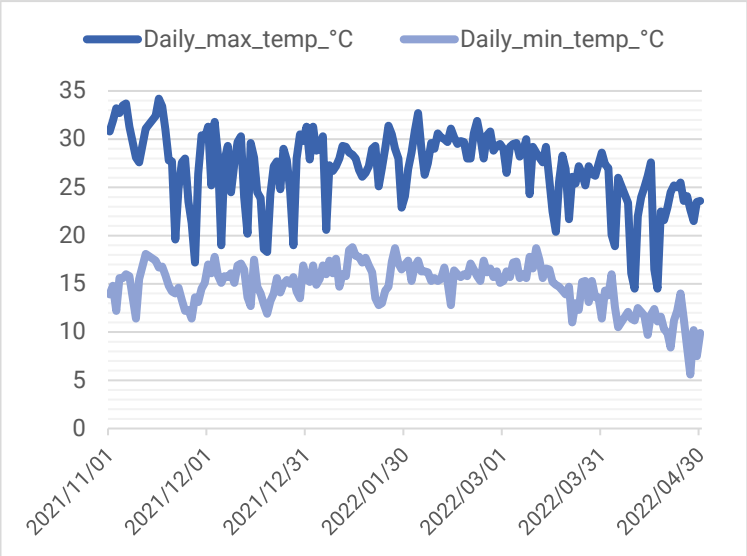


Figure 6.2: Line chart illustrating the daily maximum and minimum temperatures for the experimental study period between 1 November 2021 and 30 April 2022

In the Eco Green Wall, daily maximum temperatures varied between 30.30 and 37℃, with November 2021 and February 2022 being the hottest months. April 2022 showed the lowest

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recorded daily minimum temperatures. In the Vicinity Wall, daily maximum temperatures varied between 29.39℃ and 37.5℃, with November 2021 and February 2022 being the hottest months. The lowest daily minimum temperature was 10.5℃ in November 2021. Refer to Figure 6.3b for the Vicinity Wall's local mean daily maximum and minimum temperatures.

Refer to Figure 6.3 for the Eco Green Wall and Vicinity Wall mean local daily temperatures.

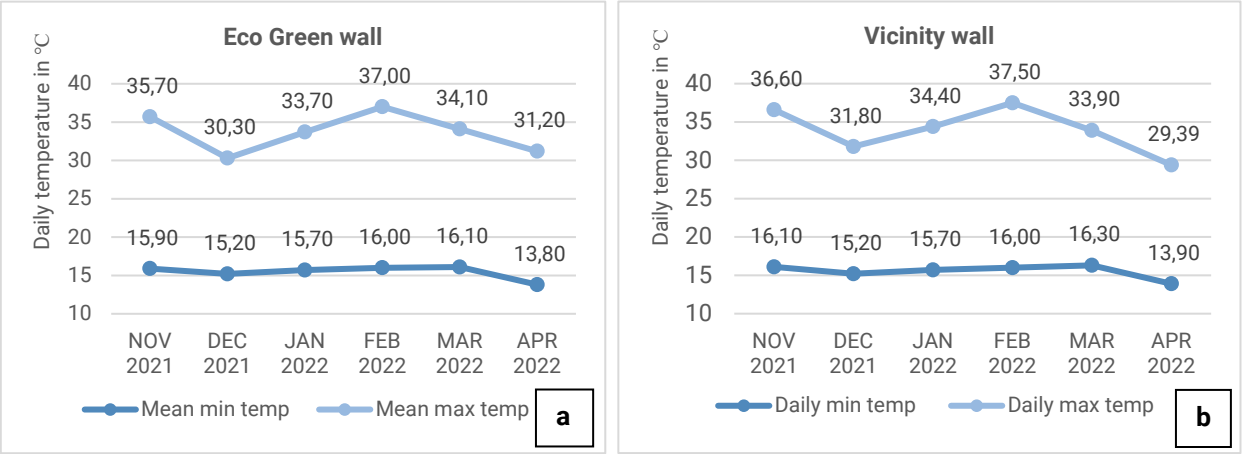


Figure 6.3: The local mean daily ambient maximum and minimum temperatures (℃) of the Eco Green Wall (Fig 6.3a) and the Vicinity Wall (Fig 6.3b) during the 6-month experimental study

In the natural soil, February 2022 had the hottest daily mean maximum temperature (35.6℃), with the lowest minimum temperature (13.3℃) recorded in December 2021 (see Figure 6.4).

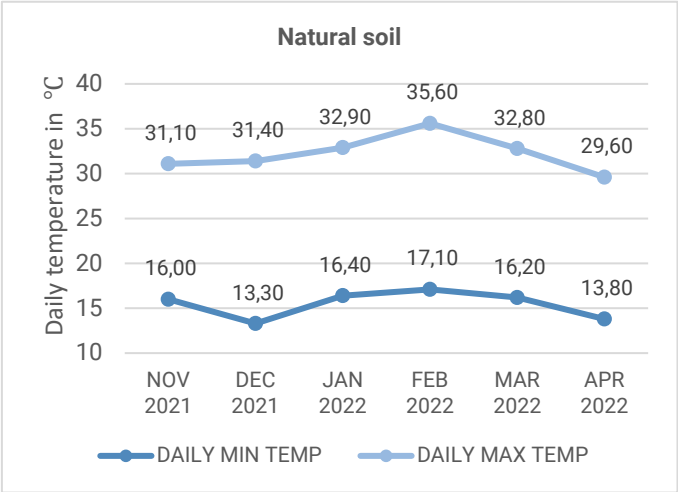


Figure 6.4 The local mean daily ambient maximum and minimum temperatures (℃) recorded in the natural soil area during the 6-month experimental study

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Table 6.1: Local maximum ambient temperature for the two LWS typologies and the natural soil

Typology	Count	Mean	Median	Minimum	Maximum	Standard deviation	Variance
Eco Green Wall	180	29.658333	29.2	24.5	36.4	4.706253	22.148813
Vicinity Wall	180	31.181667	31.1	24.9	37.4	4.405221	19.405975
Natural soil	180	30.676667	29.6	24.8	37.0	3.829831	14.667609

The mean daily minimum temperatures fall within the acceptable range for vegetative growth, although the daily minimum temperatures were below the required range during April 2022 (see Table 6.2).

Table 6.2: Local minimum ambient temperature for the two LWS typologies and the natural soil

Typology	Count	Mean	Median	Minimum	Maximum	Standard deviation	Variance
Eco Green Wall	180	14.616667	15.60	10.4	17.5	2.470214	6.101955
Vicinity Wall	180	14.633333	15.50	10.7	17.4	2.391091	5.717318
Natural soil	180	14.633333	15.55	10.7	17.4	2.386180	5.693855

ii. Precipitation

Water requirements differ across different crop types and growth stages. Moreover, water requirements are also affected by climate factors such as sun, humidity, temperature, and wind, which determine the evapotranspiration rates of plants (FAO, 1986).

The daily precipitation in the experimental study period ranged between 0 and 82 mm, with a median of 7.57mm (see Figure 6.5). It rained from November 2021 to March 2022, with no rainfall during April 2022. December 2021 had the highest rainfall, with a total precipitation of 275.2mm, followed by January 2022, with a total precipitation of 156mm, and February 2022, with a total precipitation of 139mm.

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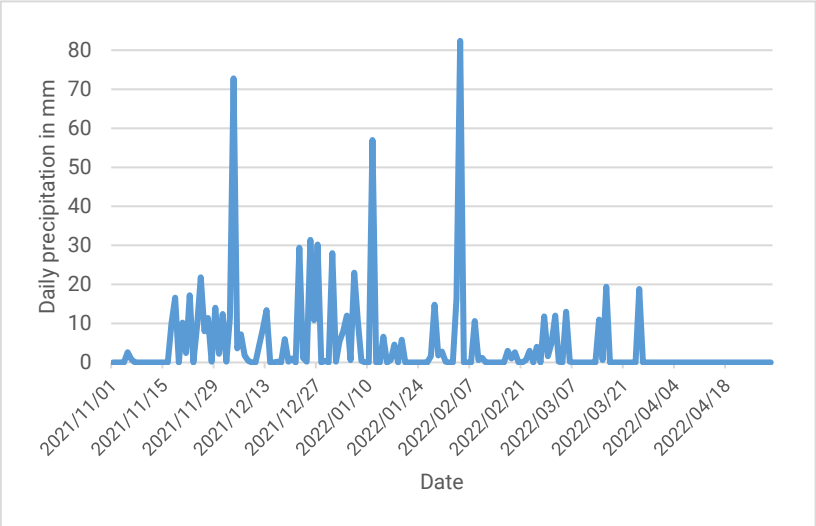


Figure 6.5: Line chart illustrating the daily precipitation for the experimental study period between 1 November 2021 and 30 April 2022

iii. Local Relative humidity (RH)

As shown in Figure 6.6 and Table 6.3, the RH for the three typologies is almost similar, with the lowest RH for the natural soil (mean = 73,22%), compared to the Eco Green Wall (mean = 74,22%) and the Vicinity Wall, which displayed the highest RH (mean = 74, 25). The RH for all three typologies used in the experimental study is in the required range for the TAV and control crop.

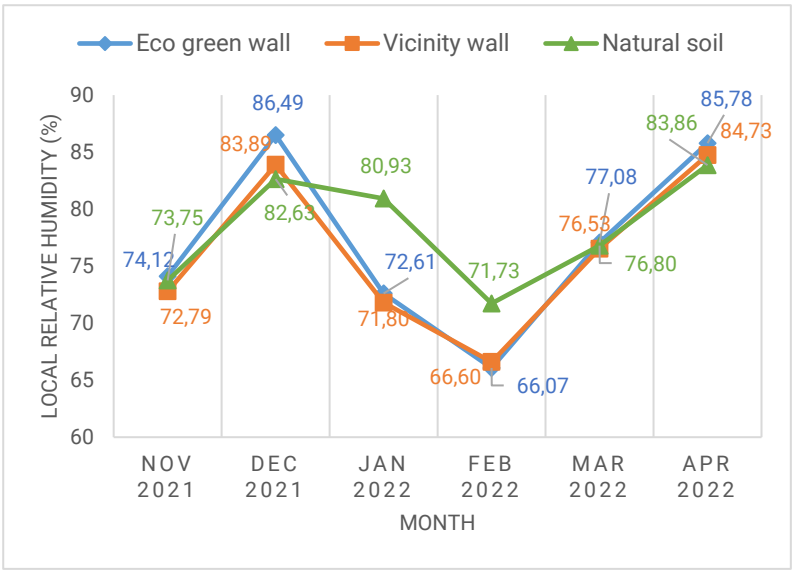


Figure 6.6: Line chart illustrating the local relative humidity for the three typologies during the experimental study period between 1 November 2021 and 30 April 2022

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Table 6.3: Local RH for the two LWS typologies and the natural soil

Typology	Count	Mean	Median	Minimum	Maximum	Standard deviation	Variance
Eco Green Wall	180	74.216667	78.70	52.7	89.3	12.429117	154.482961
Vicinity Wall	180	74.250000	80.30	51.2	88.4	12.728416	162.012570
Natural soil	180	73.216667	78.25	50.3	87.9	12.638385	159.728771

iv. Daylength

For the experimental study period, the daylength ranged between a maximum of 13:45:00 in December and a minimum of 11:08:37 in April (see Figure 6.7 and Table 6.4).

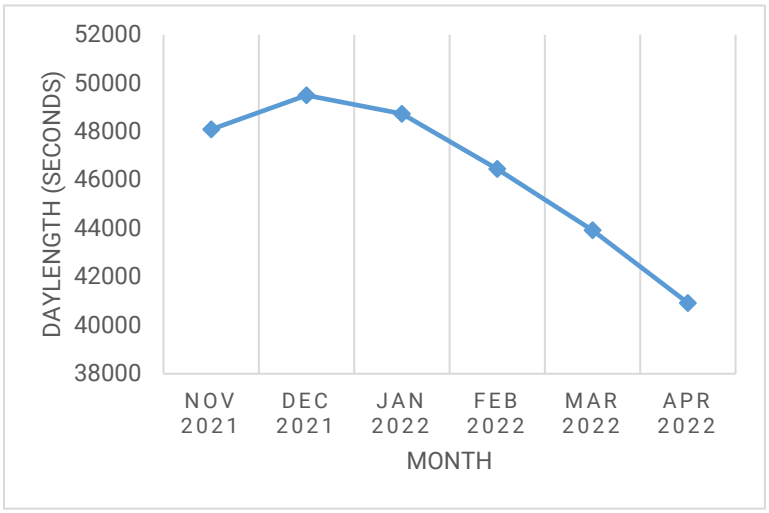


Figure 6.7: Line chart illustrating the daylength for the experimental study period between 1 November 2021 and 30 April 2022

Table 6.4: Average monthly daylength during the experimental study period

Month	Daylength (h:m:s)
November 2021	13:13:04
December 2021	13:40:47
January 2022	13:37:12
February 2022	13:14:41
March 2022	12:35:02
April 2022	11:46:26

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6.2.2 Soil conditions

i. Soil temperature

For the period of the experimental study, the natural soils reached maximum soil temperatures higher than 25℃, with the Eco Green Wall reaching a maximum of 24,1℃ and the Vicinity reaching 22,6℃ maximum (see Figure 6.8).

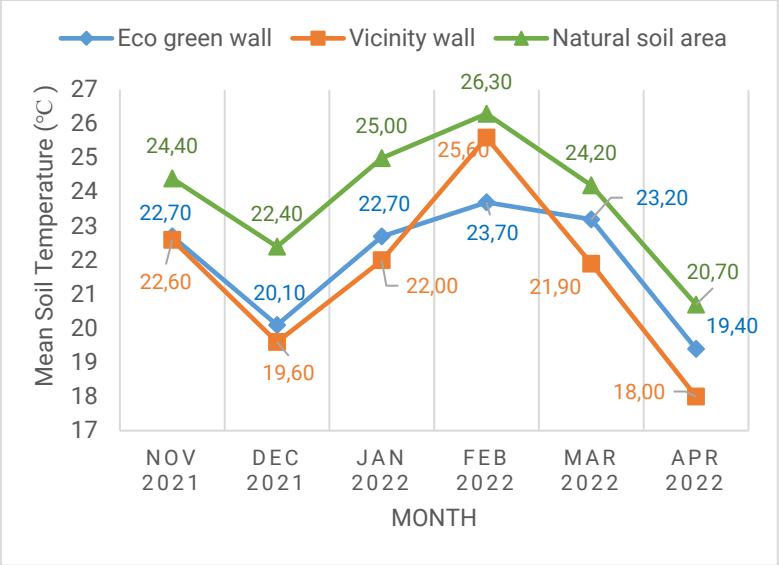


Figure 6.8: A line chart illustrating the mean soil temperature (℃) for *each typology during the experimental study period between 1 November 2021 and 30 April 2022*

In the Eco Green Wall, mean soil temperatures followed the pattern of the ambient temperatures, with the lowest value at 19.4℃ in April 2022 and the highest at 23.7℃ in February 2022. The ambient temperatures in the Vicinity Wall had the lowest value at 18℃ in April 2022 and the highest at 25.6℃ in February 2022. In the natural soil, mean soil temperatures followed the pattern of the ambient temperatures, with the lowest soil temperature at 20.7℃ in April 2022 and the highest soil temperature at 26.3℃ in February 2022.

Refer to Table 6.5 for the soil temperatures of the two LWS typologies and the natural soil.

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Table 6.5: Soil temperature for the two LWS typologies and the natural soil

Typology	Count	Mean	Median	Minimum	Maximum	Standard deviation	Variance
Eco Green Wall	180	20.200000	21.05	15.6	24.1	3.156265	9.962011
Vicinity Wall	180	19.500000	20.10	15.6	22.6	2.985440	8.912849
Natural soil	180	22.933333	23.15	17.0	26.9	3.589868	12.887151

ii. Soil volumetric water content (VWC)

The irrigation system was non-operational in January 2022, which affected the VWC, especially in the LWSs. The campus maintenance team hand-watered the natural soil area, and the LWSs received no water over this period. Figure 6.9 illustrates the soil water content of the three typologies for the experimental study period.

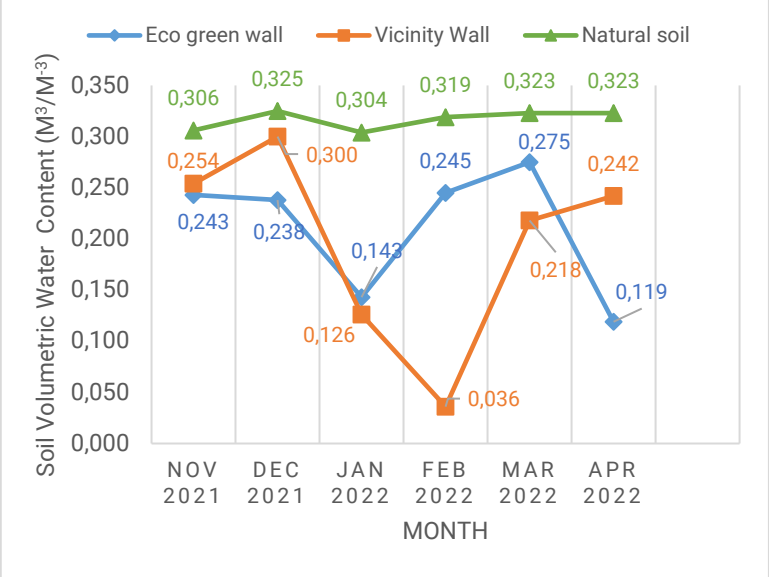


Figure 6.9: A line chart illustrating the soil water content of the three typologies for the experimental study period between 1 November 2021 and 30 April 2022. The low VWC in January 2022 resulted from an irrigation problem on the study site. The natural soil area was hand-watered during the three weeks without irrigation, and the LWSs received no water

The analysis revealed limited variations in the soil water content of the three typologies (n = 540), with the Eco Green Wall (n = 180) showing the lowest mean in VWC (0.205m^3/m^{-3}). As Table 6.6 shows, the Vicinity Wall (n = 180) had a slightly higher soil water content mean (0.228m^3/m^{-3}) than the Eco Green Wall with the natural soil area (n = 180), as control,

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displaying the highest soil water content (0.315m^3/m^{-3}). The variance (0.003682) in the Eco Green Wall remained lower than the variance in the Vicinity Wall (0.005161), although the natural soil had the lowest variance (0.000250). The VWC of all three typologies falls below the range of 19% (PWP) and 32% (FC), with the natural soil values just below the acceptable VWC content of 0.440m^3/m^{-3}.

Table 6.6: Soil volumetric water content for the two LWS typologies and the natural soil

Typology	Count	Mean	Median	Minimum	Maximum	Standard deviation	Variance
Eco Green Wall	180	0.205167	0.2365	0.101	0.262	0.060682	0.003682
Vicinity Wall	180	0.227667	0.2515	0.079	0.307	0.071837	0.005161
Natural soil	180	0.315167	0.3125	0.289	0.337	0.015796	0.000250

iii. Soil electrical conductivity (EC)

Figure 6.10 and Table 6.7 show the EC values. The natural soil had the highest mean EC values (0.681 mS/cm), followed by the Vicinity Wall (0.259 mS/cm), with the lowest mean value recorded in the Eco Green Wall (0.109 mS/cm). Except for January, when the irrigation system was not functioning, the Vicinity Wall's EC values fell within the accepted range. However, the Eco Green Wall's EC values were below the acceptable range.

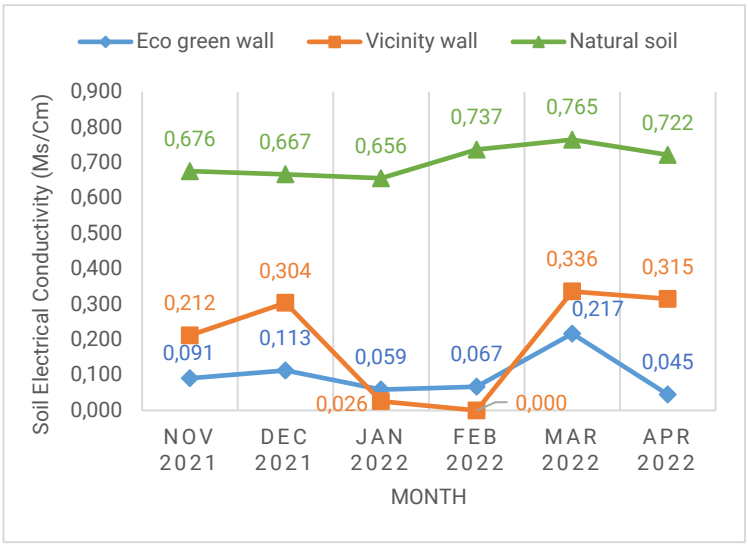


Figure 6.10: A line chart illustrating the mean electrical conductivity of the three typologies for the experimental study period between 1 November 2021 and 30 April 2022

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The Eco Green Wall's EC values ranged between 0.045 and 0.217 mS/cm during the 6-month experimental study. Salinity levels fell in the acceptable range, below 1.5-2 mS/cm. The soil electrical conductivity recovered in February to a sufficient value of over 0.200 mS/cm after the dry conditions experienced in January, with another substantial decline in April.

The Vicinity Wall's EC values ranged between 0.000 and 0.336 mS/cm during the 6-month experimental study. Salinity levels were acceptable as values were below 1.5-2 mS/cm. The soil's electrical conductivity declined during the dry spell in January, with the drop being more severe than the Eco Green Wall. The EC dropped slightly in April.

The natural soil's EC values, shown in Figure 6.10, ranged between 0.656 and 0.765 mS/cm during the 6-month experimental study. Although the natural soil area's EC values were significantly higher than the LWSs, salinity levels fall in the acceptable range below 1.5-2 mS/cm.

Table 6.7: Electrical conductivity for the two LWS typologies and the natural soil

Typology	Count	Mean	Median	Minimum	Maximum	Standard deviation	Variance
Eco Green Wall	180	0.108500	0.1190	0.000	0.173	0.059147	0.003498
Vicinity Wall	180	0.258667	0.3130	0.000	0.373	0.126972	0.016122
Natural soil	180	0.681333	0.6755	0.629	0.747	0.041656	0.001735

6.3 Which external factors affected the LWS efficiency and crop performance?

The primary data from five variables were analysed to determine correlations with the fresh and dry biomass leaf yield as determining factors of crop performance. These variables included the daily maximum (T_{max}) and minimum temperatures (T_{min}), relative humidity (RH), precipitation (P), daylength (DF), soil volumetric water content (VWC), soil temperature (ST) and soil electrical conductivity (EC). The aim was to determine if there were any external influences on the performance of the crops in addition to the 1) positioning of crops (see section 6.5, 2) the growth system typologies, comprising the LWSs and natural soil area (see section 6.6), and 3) crop species (see section 6.7). Figure 6.11 shows the monthly fresh and dry weight during the study period, with the biggest yields in March and April 2022.

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This is an important indicator of the significance of the typologies and crops on biomass and any external influences that might have impacted biomass.

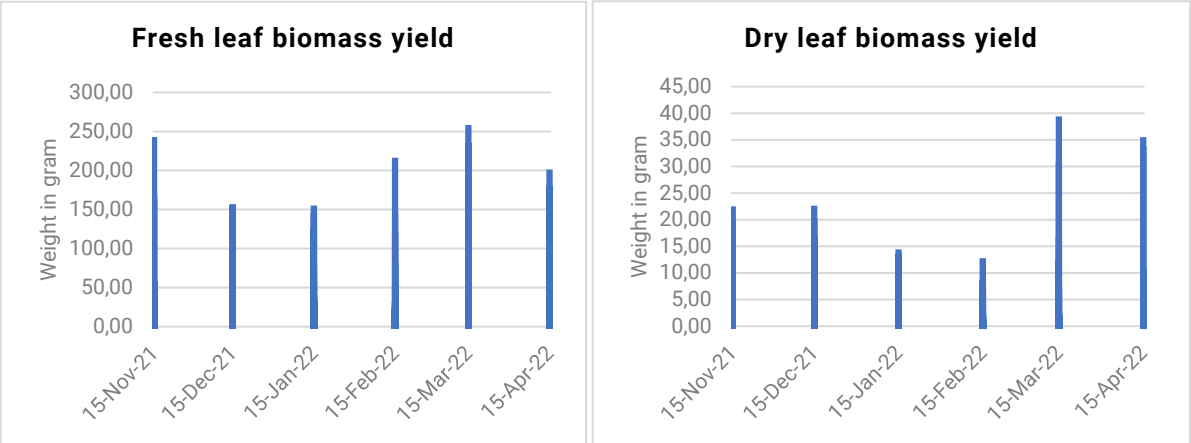


Figure 6.11: Charts illustrating the monthly fresh and dry leaf biomass yield of all three typologies for the experimental study period between 1 November 2021 and 30 April 2022

The ANOVA revealed no statistically significant differences in daily maximum (T_{max}) and minimum temperatures (T_{min}), relative humidity (RH), precipitation (P), daylength (DF) and soil temperature (ST) across different crops, typologies and positioning. To ensure that the LWS typologies and TAV species as moderating variables were not affected by external influences, the correlation coefficient (r) values were determined by performing a Pearson pairwise correlation matrix method using Python software (ver. 3.11, 2021, Santa Clara, California, US). The Pearson pairwise correlation matrix revealed statistically significant correlations ($p < 0.05$) between fresh and dry leaf yield mass and local maximum and minimum temperatures, relative humidity, total precipitation and daylength (see tables 6.8 and 6.9). However, these variables did not significantly affect the performance of the TAV and the control crop, as the electrical conductivity was the only variable showing a p-value below 0.001 following the correlation coefficient results (see Tables 6.13 and 6.14). The soil EC was the only significant variable following the univariate analysis, indicating the direct correlation between the soil EC and biomass, whereas the biophysical variables only showed a statistically significant correlation in the multivariate analysis.

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Table 6.8: Pearson pairwise correlation matrix results showing statistically significant correlations between the local minimum and maximum temperatures, local relative humidity, precipitation and daylength and crop performance based on fresh biomass yield

	Local minimum temperature	Local maximum temperature	Local Relative humidity	Total precipitation	Daylength	Fresh mass leaf yield
Local minimum temperature	1.000					
Local maximum temperature	0.359	1.000				
Local Relative humidity	-0.036	-0.789	1.000			
Total precipitation	0.365	0.384	0.717	1.000		
Daylength	0.559	-0.058	0.078	-0.322	1.000	
Fresh mass leaf yield	-0.027	0.002	-0.020	0.043	0.019	1.000

Table 6.9: Pearson pairwise correlation matrix results showing statistically significant correlations between the local minimum and maximum temperatures, local relative humidity, precipitation and daylength and crop performance based on dry biomass yield

	Local minimum temperature	Local maximum temperature	Local Relative humidity	Total precipitation	Daylength	Dry mass leaf yield
Local minimum temperature	1.000					
Local maximum temperature	-0.040	1.000				
Local Relative humidity	-0.209	-0.942	1.000			
Total precipitation	0.376	0.777	0.884	1.000		
Daylength	0.304	0.886	0.868	-0.798	1.000	
Dry mass leaf yield	-0.013	0.027	0.028	0.014	-0.036	1.000

The mediating variables of soil temperature, soil water content (VWC) and electrical conductivity (EC) with the typologies and crop performance showed statistically significant correlations. The ANOVA revealed statistically significant differences between soil temperature ($F_{(1, 57)}$ = 55.96, p = 0.00, np^2 = 0.17), VWC ($F_{(1, 63)}$ = 200.57, p = 0.00, np^2 = 0.43), and EC ($F_{(1, 3)}$ = 2230.83, p = 0.00, np^2 = 0.89) the different growth typologies.

The post-hoc results for the soil temperature can be interpreted as small between the Eco Green Wall and the Vicinity Wall (see Table 6.10). However, the effect sizes for the soil

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temperature of the Eco Green Wall and Vicinity Wall with the natural soil are interpreted as large should Cohen's d rule of thumb be applied (Cohen, 1988).

Table 6.10: Post-hoc results of soil temperature in the typologies, with the Eco Green Wall and Vicinity Wall showing statistically significant differences ($p<0.05$) in soil temperature with the natural soil (control)

Typology A	Typology B	mean(A)	mean(B)	difference	Standard error	T-statistic	P-Tukey value	Hedges g (standard deviation)
Eco Green Wall	Vicinity Wall	20.2	19.500	0.700	0.343	2.041	0.104	0.215
Eco Green Wall	Natural soil	20.2	22.933	-2.733	-0.343	7.969	0.000	-0.838
Vicinity Wall	Natural soil	19.5	22.933	-3.433	-0.343	10.010	0.000	-1.053

The VWC showed variations across the three typologies (see Table 6.6). The VWC of the Eco Green Wall (m = 0.205 m^3/m^{-3}) was slightly lower than the VWC of the Vicinity Wall (m = 0.228 m^3/m^{-3}), with the natural soil area, as control, displaying the highest VWC (m = 0.315m^3/m^{-3}).

The post-hoc results revealed the VWC means for the Eco green and Vicinity Walls could be considered small (hedges g = 0.41). However, the VWC means for both the LWSs and the natural soil could be interpreted as large (hedges g = 1.99 for the Eco Green Wall and hedges g = 1.59 for the Vicinity Wall), should Cohen's d rule of thumb be applied (Cohen, 1988) (see Table 6.11).

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Table 6.11: Post-hoc results of VWC in the typologies, with all typologies showing a statistically significant difference (p<0.05) in VWC

Typology A	Typology B	mean(A)	mean(B)	difference	Standard error	T-statistic	P-Tukey value	Hedges g (standard deviation)
Eco Green Wall	Vicinity Wall	0.205	0.228	0.022	0.006	3.877	0.0	0.408
Eco Green Wall	Natural soil	0.205	0.315	0.110	0.006	18.956	0.0	1.994
Vicinity Wall	Natural soil	0.228	0.315	0.088	0.006	15.078	0.0	1.586

The highest mean EC value (see Table 6.7) was measured in the natural soil (m = 0,681333 mS/cm), followed by the Vicinity Wall (m = 0,258667 mS/cm), with the lowest value found in the Eco Green Wall (m = 0,108500 mS/cm).

Post-hoc results revealed the EC means for all typologies included in Table 6.12 could be interpreted as large, should Cohen's d rule of thumb be applied (Cohen, 1988).

Table 6.12: Post-hoc results of EC in the typologies, with all typologies showing a statistically significant difference (p<0.05) in EC

Typology A	Typology B	mean(A)	mean(B)	difference	Standard error	T-statistic	P- value	Hedges g (standard deviation)
Eco Green Wall	Vicinity Wall	0.109	0.259	-0.150	0.009	-16.885	0.0	-1.776
Eco Green Wall	Natural soil	0.109	0.681	-0.573	0.009	-64.411	0.0	-6.775
Vicinity Wall	Natural soil	0.259	0.681	-0.423	0.009	-47.525	0.0	-4.999

The leaf biomass yield has a low probability (fresh mass = 9.4%; dry mass 10.8%) of being significantly affected by the soil VWC, EC and temperature (see tables 6.13 and 6.14). The soil VWC has a likelihood between 35.5% to 38.2% not to affect the crop performance or yield (fresh leaf biomass yield p = 0.355; dry leaf biomass yield p = 0.382), with the soil temperature (fresh leaf biomass yield p = 0.721; dry leaf biomass yield p = 0.944) even less likely to affect the fresh leaf mass yield. However, the EC is expected to impact the crop performance in terms of yield (fresh leaf biomass yield p < 0.001; dry leaf biomass yield p < 0.001). For every increase of 45.069mS/m in the soil EC, one gram of fresh leaf mass was gained, assuming that the other variables remained constant. Moreover, for every gram of dry leaf biomass, there was an increase of 5.9834 mS/m in the soil EC. The biophysical and other soil variables were not significant predictors.

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Table 6.13: Linear regression results of the soil water content, soil electrical conductivity and soil temperature in terms of fresh leaf mass

Variables	Coefficient	Standard error	T-statistic	P-value	R-squared	adj_r2	CI [2.5%]	CI [97.5%]
Intercept	-0.552	11.309	-0.049	0.961	0.094	0.089	-22.768	21.664
Soil VWC	-30.686	33.172	-0.925	0.355	0.094	0.089	-95.849	34.476
Soil EC	45.069	9.740	4.627	0.000	0.094	0.089	25.935	64.203
Soil Temp	0.300	0.416	0.721	0.471	0.094	0.089	-0.518	1.118

Table 6.14: Linear regression results of the soil water content, soil electrical conductivity and soil temperature in terms of dry leaf mass

Variables	Coefficient	Standard error	T-statistic	P-value	R-squared	adj_r2	CI [2.5%]	CI [97.5%]
Intercept	0.667	1.363	0.489	0.625	0.108	0.103	-2.010	3.344
Soil VWC	-3.498	3.998	-0.875	0.382	0.108	0.103	-11.351	4.355
Soil EC	5.983	1.174	5.097	0.000	0.108	0.103	3.678	8.289
Soil Temp	-0.004	0.050	-0.070	0.944	0.108	0.103	-0.102	0.095

6.4 Performance of LWSs compared to natural soil concerning household-scale food production

6.4.1 Biomass

Regarding fresh leaf mass results over the 6-month data collection period, the natural soil area produced a higher yield than the two LWSs (total = 5278.62g, mean = 29.33g, sd = 52.77, var = 2785.17). The Vicinity Wall (total = 1140.99g, mean = 6.34g, sd = 11.61, var 134.73) produced a higher yield than the Eco Green Wall (1042.77g, mean = 5,79g, sd = 9.19, var 84.43). The dry mass figures confirm these correlations, with the natural soil (total = 693.34g, mean = 3.85g, sd = 6.28, var = 39.34), Vicinity Wall (total = 147.73g, mean = 0.82g, sd = 1.75, var 3.07) and Eco Green Wall (total = 137.55g, mean = 0.76g, sd = 0.96, var 0.92). Refer to section 6.5.3 for details of the statistical difference between the natural soil and the two LWS typologies. Appendix D contains the descriptive statistical analysis of biomass.

Considering the vertical area occupied by the LWSs versus the horizontal area of the natural soil area, the natural soil produced the highest yield per m^2 (see Table 6.15 and Figure 6.12).

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Table 6.15: Comparison of typologies' yield per area to average conventional mixed-stand, small-scale agriculture production benchmark (Rabin, J., Zinati, G., & Nitzsche, P. (2012) in Nagle et al., 2012)

	Plants per square meter in typology	Mean monthly mass per plant (g)	Yield/square meter per month (g)	Benchmark (average conventional small-scale agriculture production rate)(Rabin et al., 2012 in Nagle et al. 2017)	Difference between typology yield and benchmark
Eco Green Wall	22	5,793	127,446	244	-116,554
Vicinity Wall	33	6,339	209,187	244	-34,813
Natural soil	9	29,326	263,934	244	19,934

The Eco Green Wall produced almost 50% lower yields per square meter than the average conventional small-scale mixed-use agricultural production benchmark (Rabin et al., 2021 in Nagle et al., 2017). The Vicinity Wall produced 14% lower yields than the benchmark. Figure 6.12 presents the fresh monthly yield per m^2 of the three typologies, with the Eco Green Wall and the Vicinity Wall, which produced smaller fresh leaf yields than the natural soil.

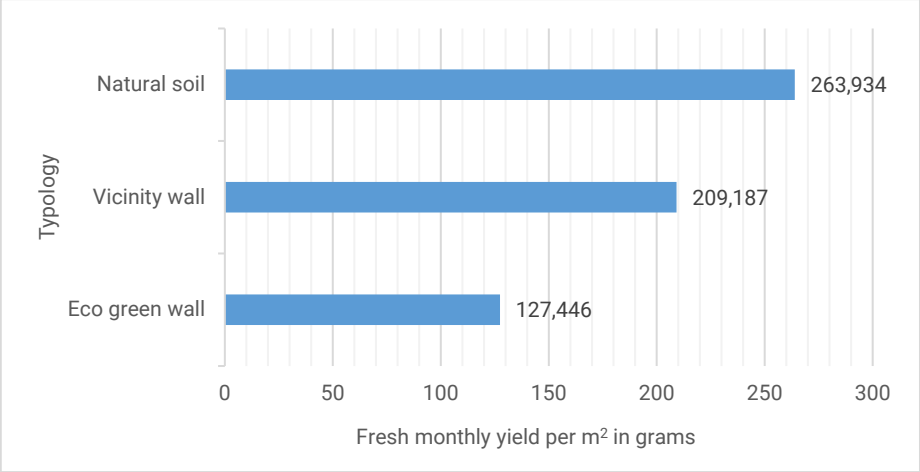


Figure 6.12: Performance comparing the fresh monthly yield per m^2 of the natural soil (control) with the Eco Green Wall and the Vicinity Wall, which produced smaller fresh leaf yields than the natural soil

Considering the benchmark average fresh produce weight of 244g/m^2 (Rabin et al., 2021 in Nagle et al., 2017), the typologies produced more than required considering footprint.

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Figure 6.13 and Table 6.16 compare typologies concerning the fresh monthly yield performance per m^2 horizontal footprint. The Vicinity Wall was the most productive by producing over five times the yield of the natural soil area. The Eco Green Wall was over two times more productive than the natural soil area, which had the lowest yield per m^2 in terms of footprint.

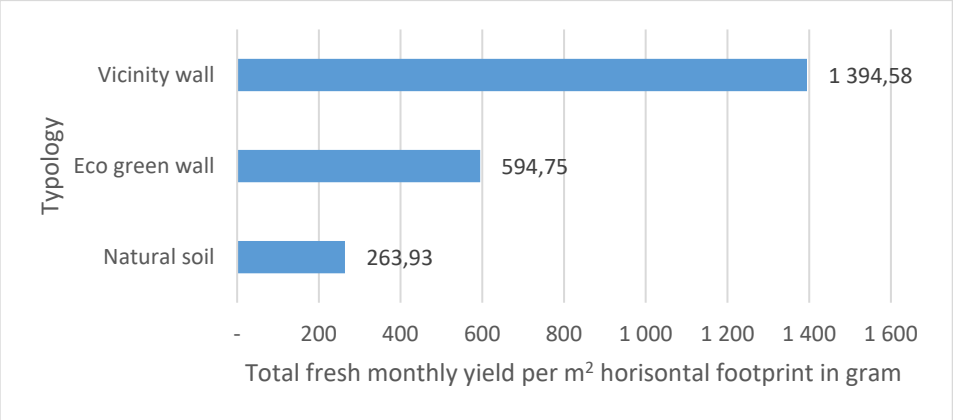


Figure 6.13: Performance relating to the horizontal footprint of the natural soil (control) versus the Vicinity Wall, which produced the highest fresh leaf yield, with over four times the yield of the natural soil over six months, and the Eco Green Wall, which had just over three times the yield of the natural soil

Table 6.16: Comparison of typologies' yield per horizontal footprint

	Area planted	**Horizontal footprint**	**Yield/m^2 per month (g)**	**Total yield per wall per month based on g/m^2 yield**	**Total monthly yield per m^2 footprint**
Natural soil	12	12	127,446	1529,352	263,93
Eco Green Wall	4,2	0,9	209,187	878,5854	594,75
Vicinity Wall	4	0,6	263,934	1055,736	1 394,58

6.4.2 Installation skills, costs and maintenance

In addition to biomass, the researcher observed the costs and maintenance during the experimental study period. Table 6.17 compares the two LWSs relating to all actions required during the study period. The natural soil area required intensive weeding during November 2021, January 2022 and March 2022.

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Table 6.17: Comparison of the Eco Green and Vicinity Walls' installation and maintenance actions. Costs are based on the construction time of the experiment, October 2020, and indicated in South African Rand (ZAR)

	Eco Green Wall (amount of times during six months indicated in brackets)	**Vicinity Wall (amount of times during six months indicated in brackets)**
Installation cost	ZAR 7931,75	ZAR 10094,00
Tools and equipment	Drill, level, measuring tape	level, measuring tape
Labour	4 hours	8 hours
Specialised skills	Basic (low technology) The installation guide provides sufficient guidance for installation.	Medium to specialised (high technology) For installation, the installation guide provides sufficient guidance to a skilled person. Installation requires a submersible pump.
Maintenance required	A slow-release fertiliser (Culterra Vitaflora 5:1:5) is applied to both LWSs. Plants are treated for mealybug with Koinor (1). Minor weeding (1).	A slow-release fertiliser (Culterra Vitaflora 5:1:5) is applied to both LWSs Plants are treated for mealybug with Koinor (1). Minor weeding (1). Clean the water reservoirs (2 times) Clean the water filter (2 times) Clean the drip emitters when malfunctioning (1) Clear rope ties at the top of planters that block drainage into pots positioned in bottom rows (2 times). Repositioning drippers in the top row to enter the drainage opening (3 times). Clipping pots back onto the aluminium rail due to bypassers removing/ repositioning them (2 times).
Irrigation	Regulated drip irrigation is provided for each row. A battery-operated irrigation controller is installed. The battery needed replacement in October 2021.	Only the top row is irrigated, with the gravitation of water to the bottom pots. A digital timer is installed. The timer needed a reset in January 2022.
Other requirements	The contractor repaired the faulty irrigation.	The contractor repaired the faulty irrigation.

The Eco Green Wall's installation was 21% more cost-effective, considering the installation cost.

6.5 Does the positioning of crops affect their performance?

This section describes the correlation between the crop positions based on the top, second and third rows in the LWSs and the natural soil and the crop performance measured by the fresh and dry leaf biomass yield.

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The data were tested for normality before being analysed. A one-way ANOVA was conducted, followed by Tukey's Multiple Comparison post-hoc tests to assess the positioning of crops in the LWS typologies or natural soil impacted on crop performance (See Appendix E for the statistical analysis results testing the correlation between positioning of crops and biomass).

6.5.1 Eco Green Wall

The boxplots (see Figures 6.14 and 6.15) revealed no outliers or heterogeneity in fresh or dry leaf mass in the Eco Green Wall, based on position.

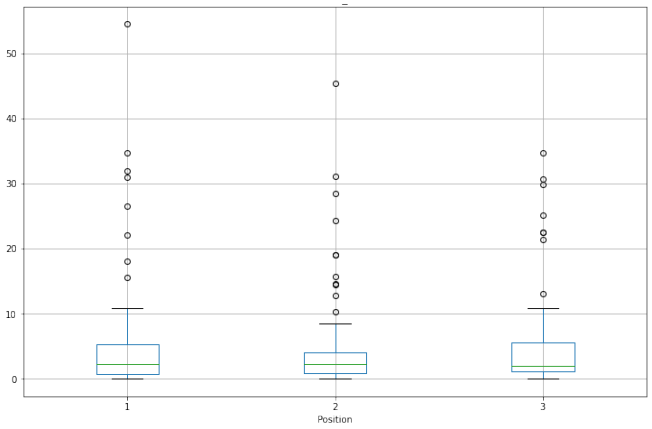


Figure 6.14: Boxplot grouped by position in the Eco Green Wall, showing fresh leaf mass with the crops represented as follows: 1) The top row in the LWS, 2) the 2nd row in the LWS and 3) the 3rd row in the LWS

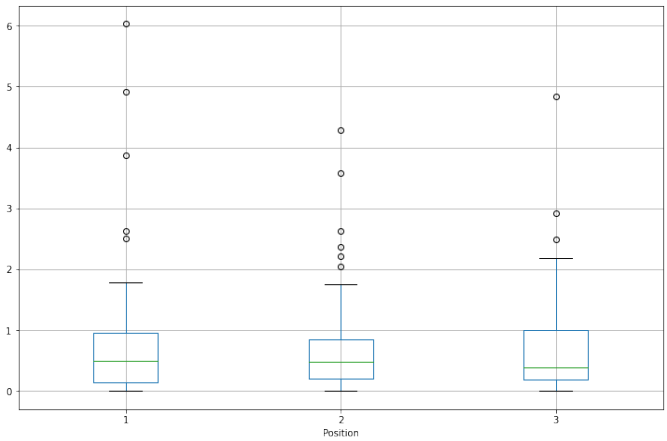


Figure 6.15: Boxplot grouped by position in the Eco Green Wall, showing dry leaf mass with the crops represented as follows: 1) The top row in the LWS, 2) the 2nd row in the LWS and 3) the 3rd row in the LWS

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The ANOVA revealed no statistically significant differences between crops in terms of fresh mass ($F_{(1, 15)}$ = 0.05, p = 0.948, np^2 = 0.00) and dry mass production ($F_{(1, 16)}$ = 0.18, p = 0.832, np^2 = 0.00) for the Eco Green Wall based on the positioning of crops (top, second or third row).

6.5.2 Vicinity Wall

Like the Eco Green Wall, the boxplots (see Figures 6.16 and 6.17) revealed no outliers or heterogeneity in fresh or dry leaf mass in the Vicinity Wall based on the positioning of crops.

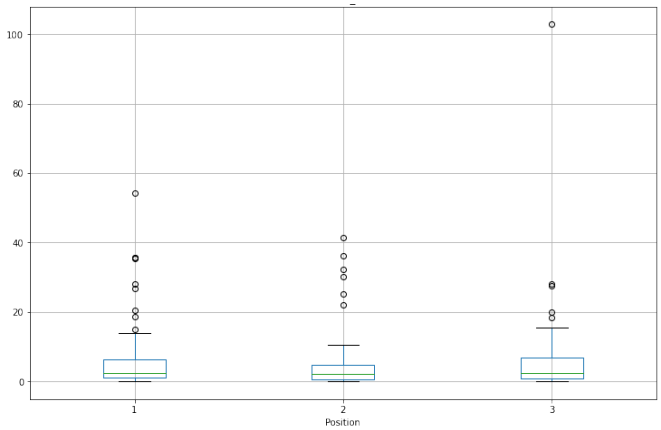


Figure 6.16: Boxplot grouped by position in the Vicinity Wall, showing no statistically significant difference in fresh leaf mass with the crops represented as follows: 1) The top row in the LWS, 2) the 2nd row in the LWS, and 3) the 3rd row in the LWS

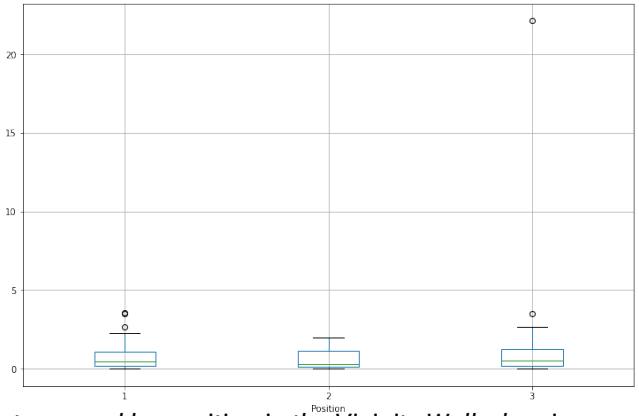


Figure 6.17: Boxplot grouped by position in the Vicinity Wall, showing no statistically significant difference in dry fresh leaf mass with the crops represented as follows: 1) The top row in the LWS, 2) the 2nd row in the LWS, and 3) the 3rd row in the LWS

The ANOVA revealed that there were no statistically significant differences between crops in terms of fresh mass ($F_{(1, 24)}$ = 0.21, p = 0.209, np^2 = 0.00) and dry mass production ($F_{(1, 54)}$ = 1.34, p = 0.264, np^2 = 0.01) for the Vicinity Wall in terms of positioning of crops.

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6.5.3 Natural soil

The boxplots (see Figures 6.18 and 6.19) revealed significant differences in the natural soil's fresh and dry yield production compared to crops in the top, second and third rows of the LWSs. The ANOVA revealed statistically significant differences between crops in terms of fresh mass ($F_{(1, 54)} = 21.59$, $p < 0.001$, $np^2 = 0.11$) and dry mass production ($F_{(1, 78)} = 25.93$, $p = 0.00$, $np^2 = 0.13$) for the natural soil compared to the positioning of crops in the Eco green and Vicinity Walls.

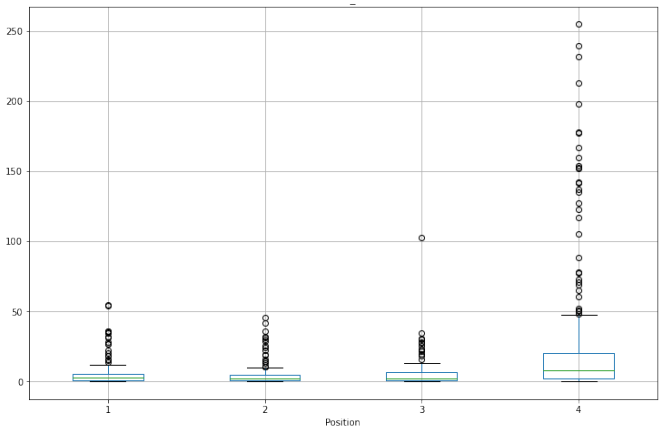


Figure 6.18: Boxplot grouped by position in the LWSs, showing a statistically significant difference between crops in the LWSs and the natural soil in fresh leaf mass with the crops represented as follows: 1 The top row in the LWS, 2) the 2nd row in the LWS, 3) the 3rd row in the LWS and 4) the natural soil.

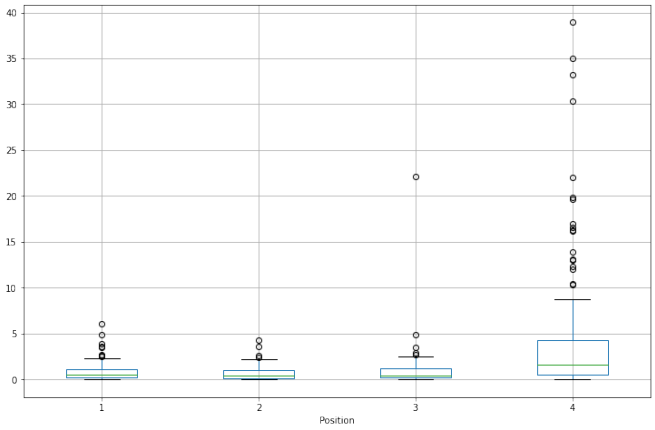


Figure 6.19: Boxplot grouped by position in the LWSs, showing a statistically significant difference between crops in the LWSs and the natural soil in dry leaf mass with the crops represented as follows: 1) The top row in the LWS, 2) the 2nd row in the LWS, 3) the 3rd row in the LWS and 4) the natural soil

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6.5.4 Top, second, and third rows and natural soil

A Tukey multi-comparison post-hoc procedure (p = 0.05) was performed to assess pairwise differences amongst the mean crop fresh leaf mass yield differences in different positions in the LWSs and the natural soil (see Table 6.18).

Table 6.18: Post-hoc results of the positioning of crops based on fresh biomass yield

Typology A	Typology B	P-Tukey value	Hedges g (standard deviation)
Top row LWS	*Second row LWS*	0.996	0.029
Top row LWS	*Third row LWS*	1.000	0.013
Top row LWS	*Natural soil*	0.000	-0.718
Second row LWS	*Third row LWS*	0.999	-0.016
Second row LWS	*Natural soil*	0.000	-0.747
Third row LWS	*Natural soil*	0.000	-0.732

The post-hoc results of the mean fresh mass yields between the top, second and third-row combinations for both LWS typologies were not statistically significant (p > 0.05). However, the mean fresh mass yield difference between all positions in the LWSs and the natural soil was statistically significant (p < 0.05). The mean fresh mass between the LWS top row is 0.718 standard deviations smaller than the natural soil, with the LWS second row 0.747 standard deviations smaller than the natural soil and the LWS third row 0.732 standard deviations smaller than the natural soil.

The post-hoc results for the mean dry mass revealed similar results to the fresh mass, namely the mean dry mass between the LWS top row being 0.801 deviations smaller than the natural soil, the LWS second row 0.836 standard deviations smaller and the LWS third row 0.768 deviations smaller than the natural soil (see Table 6.19). The mean dry mass yield in the natural soil was statistically significantly larger than all positions in the LWSs (p < 0.05). The effect sizes for these combinations are interpreted as large, applying Cohen's d rule of thumb (Cohen, 1988), explained in section 3.4.3 iii Experimental study.

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Table 6.19: Post-hoc results of the positioning of crops based on dry biomass yield

Typology A	Typology B	P-Tukey value	Hedges g (standard deviation)
Top row LWS	*Second row LWS*	0.993	0.036
Top row LWS	*Third row LWS*	0.994	0.033
Top row LWS	*Natural soil*	0.000	-0.801
Second row LWS	*Third row LWS*	0.952	-0.068
Second row LWS	*Natural soil*	0.000	-0.836
Third row LWS	*Natural soil*	0.000	-0.768

Values of fresh and dry mass yields correlated with position (see Table 6.20) are near 0, indicating no correlation between position and crop performance based on fresh and dry biomass yield.

Table 6.20: Correlation coefficient between the positioning of crops and crop performance based on fresh and dry biomass yield

	Position	Fresh biomass leaf yield	Dry biomass leaf yield
Position	1.000	0.009	0.136
Fresh biomass leaf yield	0.009	1.000	0.873
Dry biomass leaf yield	0.136	0.873	1.000

6.6 Which crops performed best in each LWS and the natural soil?

The normality of data was evaluated using boxplots before being analysed. A one-way ANOVA was conducted to assess if there were differences in the fresh biomass yields of the different crops in the typologies. Tukey's multiple comparison post-hoc tests were conducted to determine the statistical significance of crop differences (See Appendix F: Statistical analysis results comparing typologies and biomass). The findings for each typology are elaborated on below.

6.6.1 Eco Green Wall

i. Fresh leaf biomass yield

The boxplot in Figure 6.20 reveals significant differences between fresh mass yields of *Coleus amboinicus*, *Portulacaria afra* prostrata and *Vigna unguiculata* and combinations with the other crops in the Eco Green Wall.

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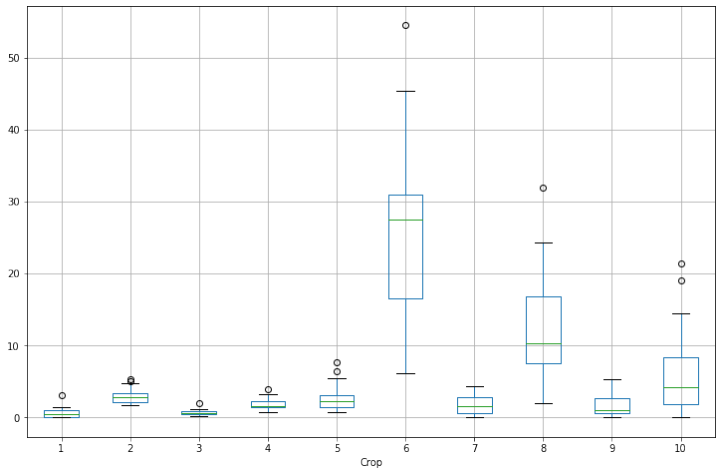


Figure 6.20: Boxplot grouped by crop indicating fresh leaf mass in the Eco Green Wall, with the crops represented as follows: 1 Amaranthus thunbergii, 2 Asystasia gangetica, 3 Corchorus confusus, 4 Dicliptera clinopodia, 5 Mentha aquatica, 6 Coleus amboinicus (= Plectranthus amboinicus), 7 Portulaca oleracea, 8 Portulacaria afra prostrata, 9 Spinacia oleracea and 10 Vigna unguiculata

Figure 6.21 shows the Eco Green Wall's mean monthly fresh leaf biomass, with *Coleus amboinicus (= Plectranthus amboinicus)* producing the highest yield. *Portulacaria afra* prostrata, *Vigna unguiculata, Asystasia gangetica,* and *Mentha aquatica* all produced higher yields than the control crop (*Spinacea oleracea*).

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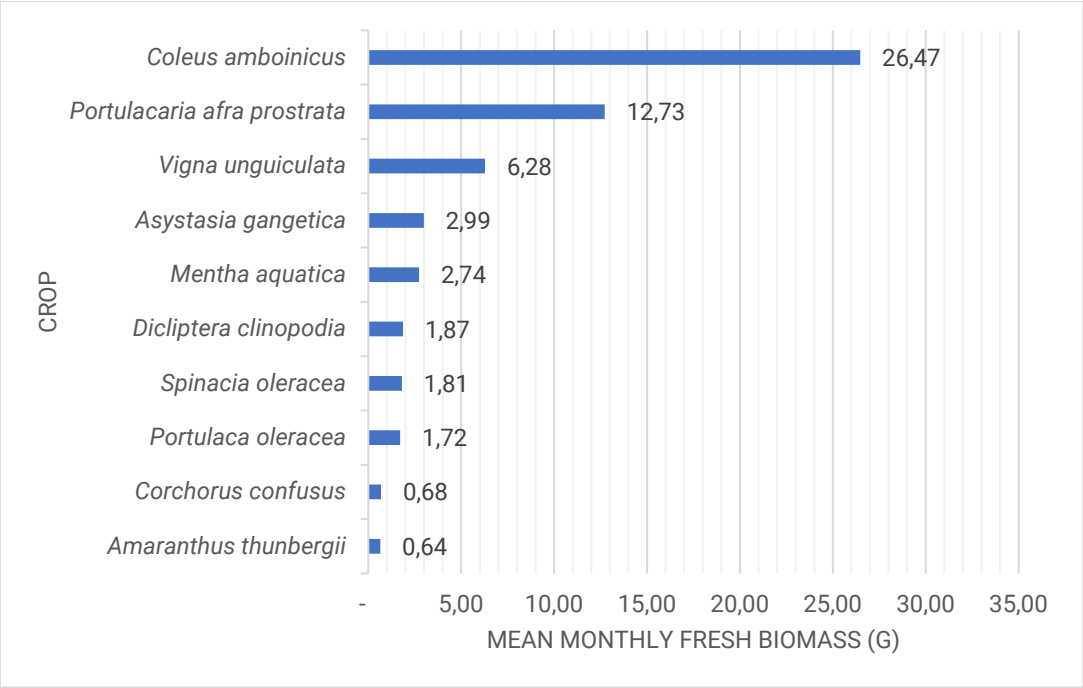


Figure 6.21: Mean monthly fresh leaf mass in the Eco Green Wall, with Coleus amboinicus, Portulacaria afra prostrata, Vigna unguiculata, Asystasia gangetica, and Mentha aquatica producing higher yields than the control crop, Spinacea oleracea

The ANOVA ($F_{(1, 44)}$ = 45.56, p < 0.001, np^2 = 0.71) revealed that there were statistically significant differences in fresh leaf mass production between crops for the Eco Green Wall. A Tukey multi-comparison post-hoc procedure (p = 0.05) was performed to assess pairwise differences amongst the fresh crop leaf mass. Appendix D contains the Tukey test results. Table 6.21 shows the post-hoc results of crop combinations with significant statistically significant differences (p < 0.05) in fresh mass yields. Combinations that did not show statistically significant different pairwise comparisons (p > 0.05) were not included in Table 6.21 but can be found in Appendix F.

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Table 6.21: Post-hoc results of crop combinations in the Eco Green Wall that showed a statistically significant difference (p<0.05) in fresh biomass yield (refer to Appendix F for results indicating all combinations, including those that did not show statistically significant differences)

Crop A	Crop B	P-Tukey values that showed statistically significant difference (p < 0.05)	Hedges g (standard deviation)
Amaranthus thunbergii	*Coleus amboinicus*	0.00000000	-4.947509
Amaranthus thunbergii	*Portulacaria afra* prostrata	0.00000000	-2.314171
Amaranthus thunbergii	*Vigna unguiculata*	0.03655759	-1.079824
Asystasia gangetica	*Coleus amboinicus*	0.00000000	-4.498284
Asystasia gangetica	*Portulacaria afra prostrata*	0.00000206	-1.864946
Corchorus confusus	*Coleus amboinicus*	0.00000000	-4.939847
Corchorus confusus	*Portulacaria afra* prostrata	0.00000000	-2.306508
Corchorus confusus	*Vigna unguiculata*	0.03920832	-1.072161
Dicliptera clinopodia	*Coleus amboinicus*	0.00000000	-4.712403
Dicliptera clinopodia	*Portulacaria afra* prostrata	0.00000007	-2.079065
Mentha aquatica	*Coleus amboinicus*	0.00000000	-4.546876
Mentha aquatica	*Portulacaria afra* prostrata	0.00000009	-1.913538
Coleus amboinicus	*Portulaca oleracea*	0.00000000	4.741690
Coleus amboinicus	*Portulacaria afra* prostrata	0.00000000	2.633338
Coleus amboinicus	*Spinacia oleracea*	0.00000000	4.724195
Coleus amboinicus	*Vigna unguiculata*	0.00000000	3.867685
Portulaca oleracea	*Portulacaria afra* prostrata	0.00000000	2.108352
Portulacaria afra prostrata	*Spinacia oleracea*	0.00000001	2.090856
Portulacaria afra prostrata	*Vigna unguiculata*	0.00078514	1.234347

The average fresh mass yields for all crops included in Table 6.21 range between 1.072161 standard deviations greater fresh biomass of *Vigna unguiculata* (black-eyed pea) than *Corchorus confusus* (jute plant) to 4.947509 greater fresh biomass of *Coleus amboinicus (= Plectranthus amboinicus)* (Indian borage) than *Amaranthus thunbergia* (pigweed). These effect sizes are interpreted as large, should Cohen's d rule of thumb be applied of small (d = 0.2), medium (d = 0.5) and large (d = 0.8) (Cohen, 1988). Therefore, the difference between all crop combinations listed in Table 6.21 is statistically significant.

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ii. Dry leaf biomass yield

Like the fresh leaf biomass findings, there are significant differences (see Figure 6.22) between dry mass yields of *Coleus amboinicus*, *Portulacaria afra* prostrata and *Vigna unguiculata* compared to the other crops.

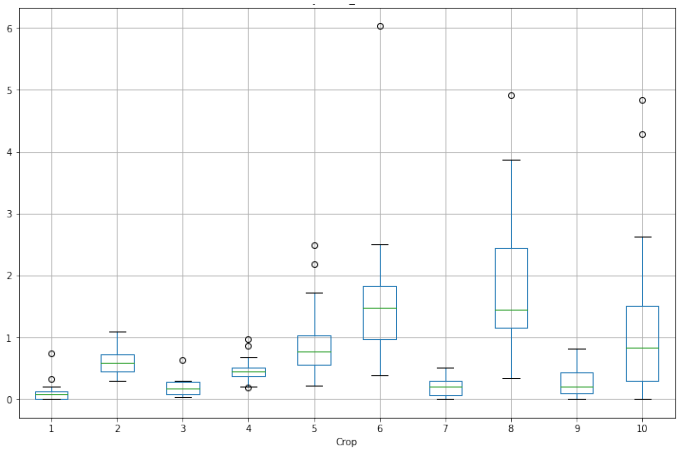


Figure 6.22: Boxplot grouped by crop indicating dry leaf mass in the Eco Green Wall, with the crops represented as follows: 1 Amaranthus thunbergii, 2 Asystasia gangetica, 3 Corchorus confusus, 4 Dicliptera clinopodia, 5 Mentha aquatica, 6 Coleus amboinicus (= Plectranthus amboinicus), 7 Portulaca oleracea, 8 Portulacaria afra prostrata, 9 Spinacia oleracea and 10 Vigna unguiculata

The *Coleus amboinicus (= Plectranthus amboinicus)*, *Portulacaria afra* prostrata, *Vigna unguiculata, Asystasia gangetica, Mentha aquatica and Diclipera clinopodia* produced a higher mean monthly dry leaf biomass than the control crop (*Spinacea oleracea*), (see Figure 6.23).

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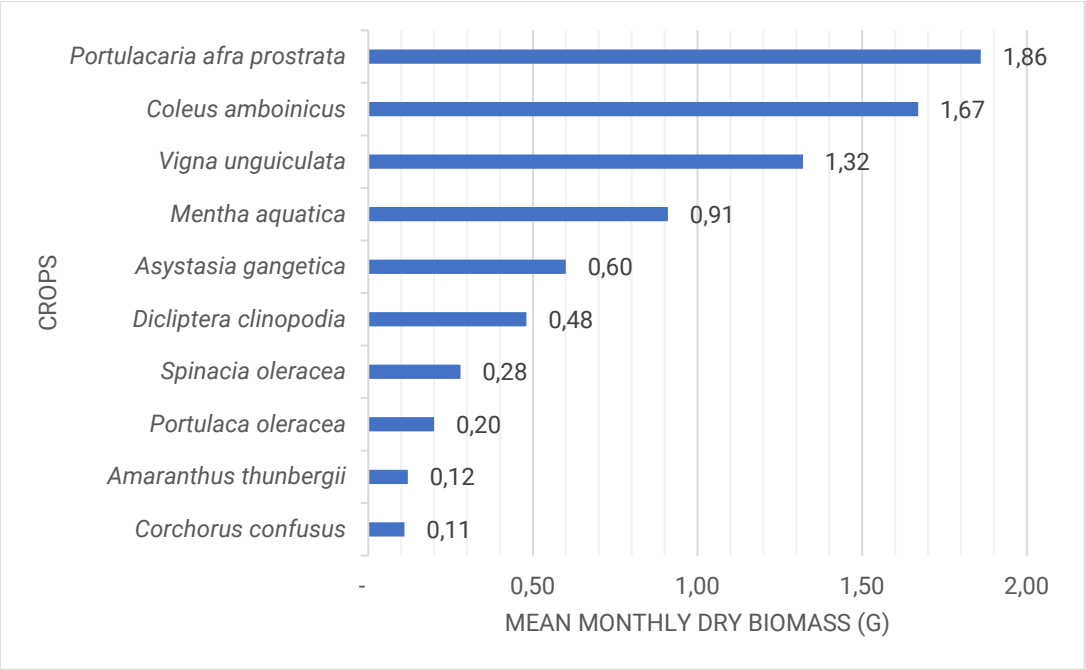


Figure 6.23: Mean monthly dry leaf mass in the Eco Green Wall, with Portulacaria afra prostrata, Coleus amboinicus Vigna unguiculata, Mentha aquatica, Asystasia gangetica and Dicliptera clinopodia producing higher yields than the control crop, Spinacea oleracea

The ANOVA ($F_{(1, 97)}$ = 13.21, p < 0.001, np^2 = 0.41) revealed that there were statistically significant differences between crops in terms of dry leaf mass production for the Eco Green Wall. A Tukey post-hoc procedure (p = 0.05) was performed to assess pairwise differences amongst the crop dry leaf mass. The results from the Tukey test are attached as Appendix D. The post-hoc results of crop combinations with statistically significant differences (p < 0.05) in dry mass yields are shown in Table 6.21. Other combinations that did not show statistically significant different pairwise comparisons (p > 0.05) were not included in Table 6.21 but are found in Appendix F.

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Table 6.22: Post-hoc results of crop combinations in the Eco Green Wall that showed a statistically significant difference (p<0.05) in dry biomass yield (refer to Appendix F for results indicating all combinations, including those that did not show statistically significant differences)

Crop A	Crop B	P-Tukey values that showed statistically significant difference (p < 0.05)	Hedges g (standard deviation)
Amaranthus thunbergii	*Coleus amboinicus*	0.00000023	-2.007422
Amaranthus thunbergii	*Portulacaria afra prostrata*	0.00000000	-2.264621
Amaranthus thunbergii	*Vigna unguiculata*	0.00016669	-1.555089
Asystasia gangetica	*Coleus amboinicus*	0.00150655	-1.380139
Asystasia gangetica	*Portulacaria afra prostrata*	0.00005500	-1.637338
Corchorus confusus	*Portulacaria afra prostrata*	0.00000002	-2.170983
Corchorus confusus	*Vigna unguiculata*	0.00055688	-1.461451
Dicliptera clinopodia	*Coleus amboinicus*	0.00018861	-1.545718
Dicliptera clinopodia	*Portulacaria afra prostrata*	0.00000519	-1.802917
Dicliptera clinopodia	*Vigna unguiculata*	0.03224855	-1.093385
Mentha aquatica	*Portulacaria afra prostrata*	0.00776409	-1.235392
Coleus amboinicus	*Portulaca oleracea*	0.00000127	1.896988
Coleus amboinicus	*Spinacia oleracea*	0.00000597	1.793474
Portulaca oleracea	*Portulacaria afra prostrata*	0.00000002	-2.154187
Portulaca oleracea	*Vigna unguiculata*	0.00068678	-1.444655
Portulacaria afra prostrata	*Spinacia oleracea*	0.00000011	2.050673
Spinacia oleracea	*Vigna unguiculata*	0.00238414	-1.341141

The effect sizes of the average dry mass yields for the crop combinations in Table 6.22 are interpreted as large should Cohen's d rule of thumb be applied (Cohen, 1988). The *Amaranthus thunbergii* (pigweed), with a -2.264621 standard deviations difference in dry biomass from *Portulaca afra* prostrata (dwarf elephant's food), showed the largest effect size. The smallest effect size is *Dicliptera clinopodia* (pink ribbons), with a -1.093385 standard deviations difference in dry biomass from *Vigna unguiculata* (black-eyed pea).

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6.6.2 Vicinity Wall

i. Fresh leaf biomass yield

Like the Eco Green Wall, the boxplot reveals significant differences between fresh mass yields of *Coleus amboinicus*, *Portulacaria afra* prostrata and *Vigna unguiculata* and combinations with the other crops and control crop in the Vicinity Wall (refer to Figure 6.24).

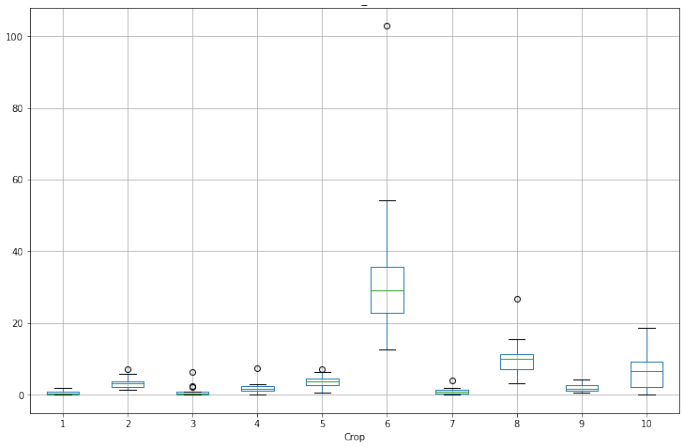


Figure 6.24: Boxplot grouped by crop indicating fresh leaf mass in the Vicinity Wall, with the crops represented as follows: 1 Amaranthus thunbergii, 2 Asystasia gangetica, 3 Corchorus confusus, 4 Dicliptera clinopodia, 5 Mentha aquatica, 6 Coleus amboinicus (= Plectranthus amboinicus), 7 Portulaca oleracea, 8 Portulacaria afra prostrata, 9 Spinacia oleracea and 10 Vigna unguiculata

Figure 6.25 shows the Vicinity Wall's mean monthly fresh leaf biomass, with *Coleus amboinicus (= Plectranthus amboinicus)* producing the highest yield, followed by *Portulacaria afra* prostrata, *Vigna unguiculata*, *Mentha aquatica*, *Asystasia gangetica* and *Dicliptera clinopodia* all producing higher yields than the control crop (*Spinacea oleracea*).

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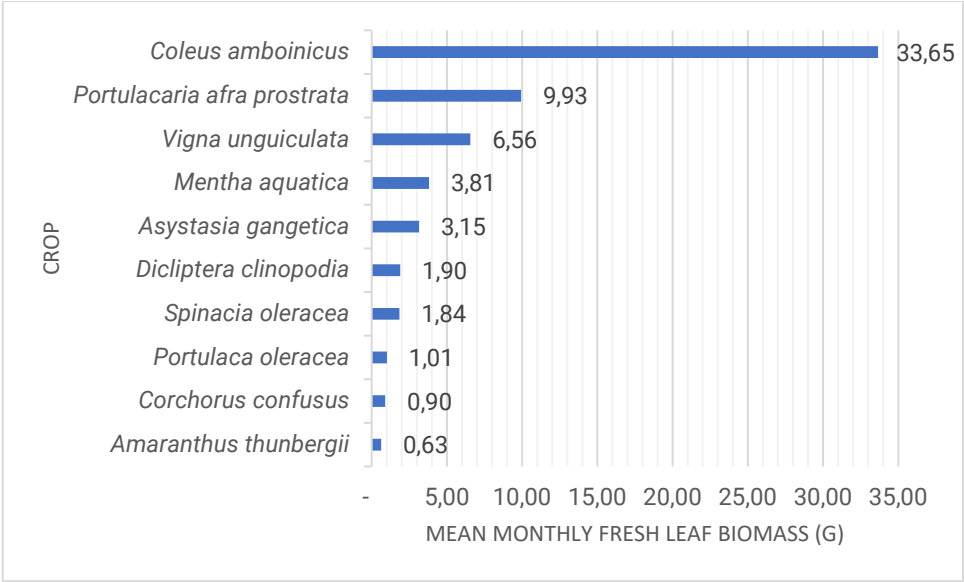


Figure 6.25: Mean monthly fresh leaf mass in the Vicinity Wall, with Coleus amboinicus, Portulacaria afra prostrata, Vigna unguiculata, Mentha aquatica, Asystasia gangetica and Dicliptera clinopodia producing higher yields than the control crop, Spinacea oleracea

The ANOVA ($F_{(1, 78)}$ = 39.44, p < 0.001, np^2 = 0.68) revealed that there were statistically significant differences between crops in fresh leaf mass production for the Vicinity Wall. The results from the Tukey post-hoc procedure (p = 0.05), which was performed to assess pairwise differences amongst the crop fresh leaf mass, are attached as Appendix F. The post-hoc results of fresh mass yield crop combinations with statistically significant differences (p < 0.05) are shown in Table 6.23. Other combinations that did not show statistically significant different pairwise comparisons (p > 0.05) were not included in Table 6.23 but are listed in Appendix F.

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Table 6.23: Post-hoc results of crop combinations in the Vicinity Wall that showed a statistically significant difference (p<0.05) in fresh biomass yield (refer to Appendix F for results indicating all combinations, including those that did not show statistically significant differences)

Crop A	Crop B	P-Tukey values that showed statistically significant difference (p < 0.05)	Hedges g (standard deviation)
Amaranthus thunbergii	*Coleus amboinicus*	0.000000	-4.763421
Amaranthus thunbergii	*Portulacaria afra prostrata*	0.002389	-1.340959
Asystasia gangetica	*Coleus amboinicus*	0.000000	-4.399560
Asystasia gangetica	*Portulacaria afra prostrata*	0.088538	-0.977098
Corchorus confusus	*Coleus amboinicus*	0.000000	-4.724640
Dicliptera clinopodia	*Coleus amboinicus*	0.000000	-4.580132
Dicliptera clinopodia	*Portulacaria afra* prostrata	0.017344	-1.157670
Mentha aquatica	*Coleus amboinicus*	0.000000	-4.305015
Coleus amboinicus	*Portulaca oleracea*	0.000000	4.708419
Coleus amboinicus	*Portulacaria afra* prostrata	0.000000	3.422463
Coleus amboinicus	*Spinacia oleracea*	0.000000	4.589621
Coleus amboinicus	*Vigna unguiculata*	0.000000	3.908399
Portulaca oleracea	*Portulacaria afra* prostrata	0.004468	-1.285956
Portulacaria afra prostrata	*Spinacia oleracea*	0.015771	1.167159

The average fresh mass yields for all crops included in Table 6.23 range between 0.977098 standard deviations in fresh biomass between *Asystasia gangetica* (creeping foxglove) and *Portulacaria afra prostrata* (dwarf elephant's food) to 4.763421 less fresh biomass of *Amaranthus thunbergia* (pigweed) than *Coleus amboinicus (= Plectranthus amboinicus)* (Indian borage). These effect sizes are interpreted as large should Cohen's d rule of thumb be applied (Cohen, 1988).

ii. Dry leaf biomass yield

Like the fresh leaf biomass findings, there are significant differences (see Figure 6.26) between dry mass yield combinations of *Mentha aquatica*, *Coleus amboinicus*, *Portulacaria afra* prostrata and *Vigna unguiculata* with the other TAV crops and the control crop in the Vicinity Wall.

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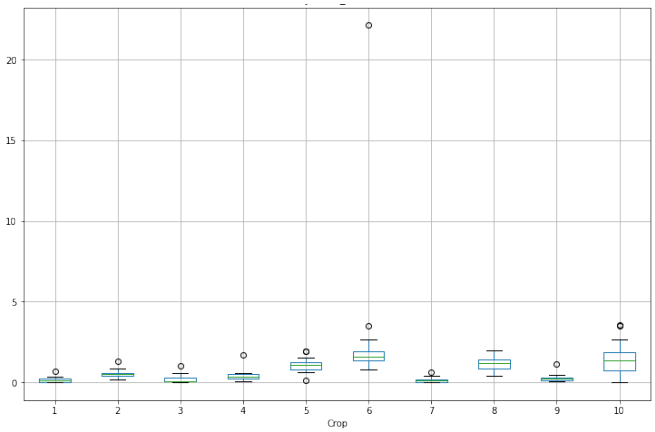


Figure 6.26: Boxplot grouped by crop indicating dry leaf mass in the Vicinity Wall, with the crops represented as follows: 1 Amaranthus thunbergii, 2 Asystasia gangetica, 3 Corchorus confusus, 4 Dicliptera clinopodia, 5 Mentha aquatica, 6 Coleus amboinicus (= Plectranthus amboinicus), 7 Portulaca oleracea, 8 Portulacaria afra prostrata, 9 Spinacia oleracea and 10 Vigna unguiculata

In the Vicinity Wall, the *Coleus amboinicus (= Plectranthus amboinicus)*, *Vigna unguiculata Portulacaria afra* prostrata*, Mentha aquatica, Asystasia gangetica and Diclipera clinopodia* produced a higher mean dry leaf biomass than the control crop (*Spinacea oleracea*) (see Figure 6.27).

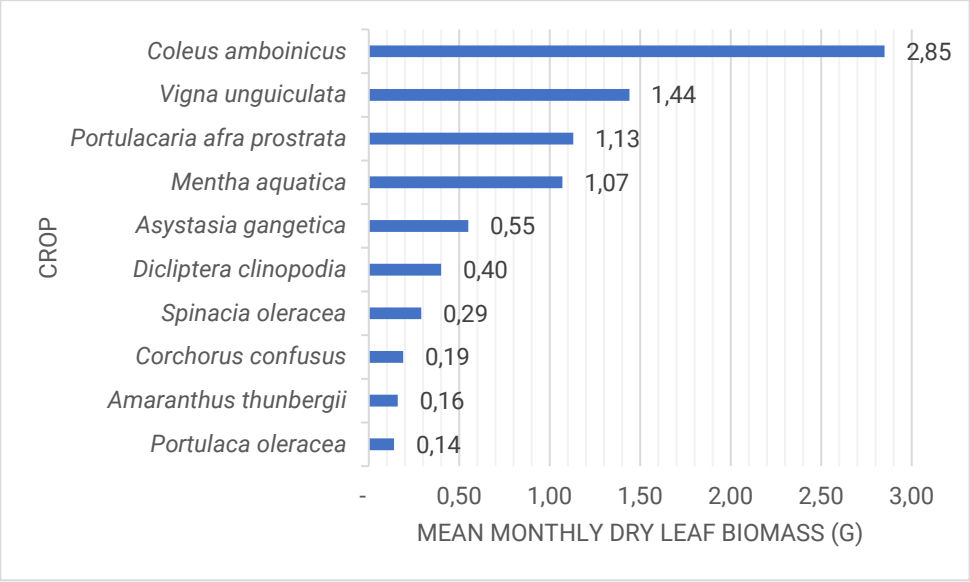


Figure 6.27: Mean monthly dry leaf mass in the Vicinity Wall, with Coleus amboinicus (= Plectranthus amboinicus), Vigna unguiculata Portulacaria afra prostrata*, Mentha aquatica, Asystasia gangetica and Diclipera clinopodia producing higher yields than the control crop, Spinacea oleracea*

The ANOVA ($F_{(1, 433)}$ = 5.09, p < 0.001, np^2 = 0.21) revealed that there were statistically significant differences in dry leaf mass production between crops in the Vicinity Wall. A

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Tukey multi-comparison post-hoc procedure (p = 0.05) was performed to assess pairwise differences amongst the crop dry leaf mass. The results from the Tukey test are attached as Appendix F. Table 6.24 shows the post-hoc results of crop combinations with statistically significant differences ($p < 0.05$) in dry mass yields. Other combinations that did not show statistically significant different pairwise comparisons ($p > 0.05$) were excluded but contained in Appendix F.

Table 6.24: Post-hoc results of crop combinations in the Vicinity Wall that showed a statistically significant difference (p<0.05) in dry biomass yield (refer to Appendix F for results indicating all combinations, including those that did not show statistically significant differences)

Crop A	**Crop B**	**P-Tukey values that showed statistically significant difference (p < 0.05)**	**Hedges g (standard deviation)**
Amaranthus thunbergii	*Coleus amboinicus*	0.00000023	-2.007422
Amaranthus thunbergii	*Portulacaria afra prostrata*	0.00000000	-2.264621
Amaranthus thunbergii	*Vigna unguiculata*	0.00016669	-1.555089
Asystasia gangetica	*Coleus amboinicus*	0.00150655	-1.380139
Asystasia gangetica	*Portulacaria afra prostrata*	0.00005500	-1.637338
Corchorus confusus	*Portulacaria afra prostrata*	0.00000002	-2.170983
Corchorus confusus	*Vigna unguiculata*	0.00055688	-1.461451
Dicliptera clinopodia	*Coleus amboinicus*	0.00018861	-1.545718
Dicliptera clinopodia	*Portulacaria afra prostrata*	0.00000519	-1.802917
Dicliptera clinopodia	*Vigna unguiculata*	0.03224855	-1.093385
Mentha aquatica	*Portulacaria afra prostrata*	0.00776409	-1.235392
Coleus amboinicus	*Portulaca oleracea*	0.00000127	1.896988
Coleus amboinicus	*Spinacia oleracea*	0.00000597	1.793474
Portulaca oleracea	*Portulacaria afra prostrata*	0.00000002	-2.154187
Portulaca oleracea	*Vigna unguiculata*	0.00068678	-1.444655
Portulacaria afra prostrata	*Spinacia oleracea*	0.00000011	2.050673
Spinacia oleracea	*Vigna unguiculata*	0.00238414	-1.341141

The effect sizes of the average dry mass yields for the crop combinations in Table 6.24 are interpreted as large should Cohen's d rule of thumb be applied (Cohen, 1988). The *Amaranthus thunbergii* (pigweed) and *Portulaca afra* prostrata (dwarf elephant's food) combination had the largest effect size, with a -2.264621 standard deviations difference in

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dry biomass. The *Dicliptera clinopodia* (pink ribbons) and *Vigna unguiculata* (black-eyed pea) had the smallest effect size, with a 1.093385 standard deviations difference in dry biomass.

6.6.3 Natural soil

i. Fresh leaf biomass yield

As the control area, the natural soil varied from the LWS typologies, as fresh mass yields of *Asystasia gangetica*, *Coleus amboinicus*, *Spinacea oleracea* and combinations with the other crops and control crop in the natural soil (refer to Figure 6.28).

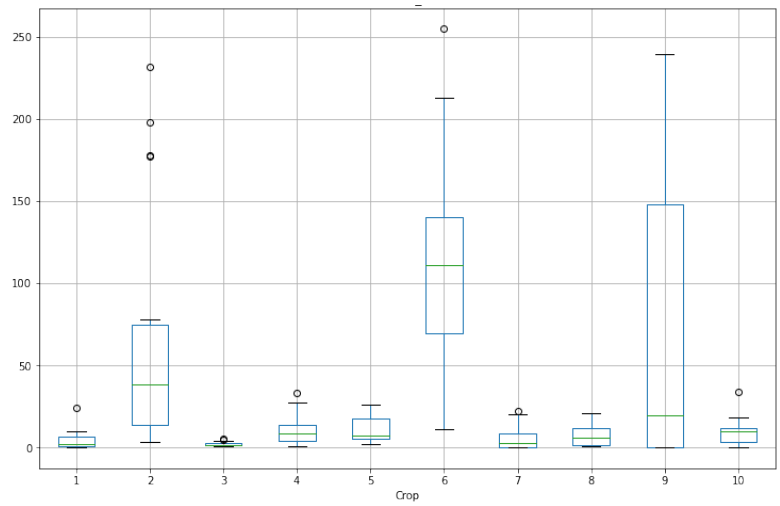


Figure 6.28: Boxplot grouped by crop indicating fresh leaf mass in the natural soil area, which is the control. The crops are represented as follows: 1 Amaranthus thunbergii, 2 Asystasia gangetica, 3 Corchorus confusus, 4 Dicliptera clinopodia, 5 Mentha aquatica, 6 Coleus amboinicus (= Plectranthus amboinicus), 7 Portulaca oleracea, 8 Portulacaria afra prostrata, 9 Spinacia oleracea and 10 Vigna unguiculata

Like the LWSs, *Coleus amboinicus (= Plectranthus amboinicus)* produced the highest mean fresh leaf mass in the natural soil (control area). *Asystasia gangetica* also had a higher yield than *Spinacea oleracea* (see Figure 6.29). Except for *Corchorus confusus, Amaranthus thunbergia* and *Portulaca oleracea*, the other TAV crops produced mean yields between 7,77 and 11 g.

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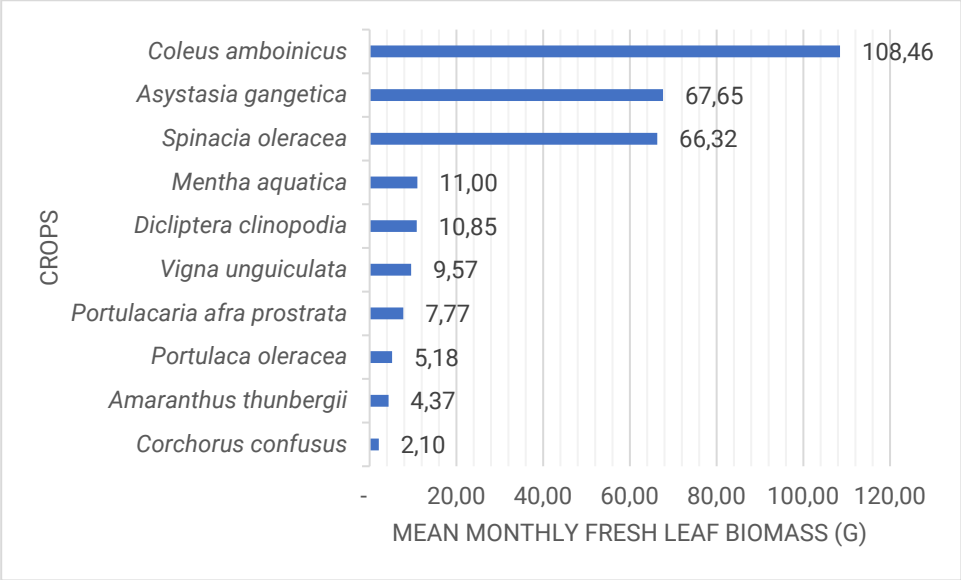


Figure 6.29: Mean monthly fresh leaf mass in the natural soil (the control). Coleus amboinicus (=Plectranthus amboinicus) and *Asystasia gangetica produced higher yields than the control crop, Spinacea oleracea*

The ANOVA ($F_{(1, 27)}$ = 15.72, p < 0.001, np^2 = 0.45) revealed that there were statistically significant differences between crops in fresh leaf mass production for the natural soil area. Appendix D contains the Tukey post-hoc procedure (p = 0.05) results, which were performed to assess pairwise differences amongst the crop fresh leaf mass. Table 6.25 shows the post-hoc results of natural soil crop combinations with statistically significant differences (p < 0.05) in fresh mass yields. Combinations that did not show statistically significant different pairwise comparisons (p > 0.05) were not included in Table 6.25 but contained in Appendix F.

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Table 6.25: Post-hoc results of crop combinations in the natural soil area that showed a statistically significant difference (p<0.05) in fresh biomass yield (refer to Appendix F for results indicating all combinations, including those that did not show statistically significant differences)

Crop A	Crop B	P-Tukey values that showed statistically significant difference (p < 0.05)	Hedges g (standard deviation)
Amaranthus thunbergii	*Asystasia gangetica*	0.00018663	-1.546518
Amaranthus thunbergii	*Coleus amboinicus*	0.00000000	-2.544011
Amaranthus thunbergii	*Spinacia oleracea*	0.00028488	-1.514076
Asystasia gangetica	*Corchorus confusus*	0.00008913	1.601933
Asystasia gangetica	*Dicliptera clinopodia*	0.00000137	1.388026
Asystasia gangetica	*Mentha aquatica*	0.00143304	1.384327
Asystasia gangetica	*Coleus amboinicus*	0.07498860	-0.997493
Asystasia gangetica	*Portulaca oleracea*	0.00024240	1.526528
Asystasia gangetica	*Portulacaria afra prostrata*	0.00054321	1.463429
Asystasia gangetica	*Vigna unguiculata*	0.00093763	1.419397
Corchorus confusus	*Spinacia oleracea*	0.00013772	-1.569492
Dicliptera clinopodia	*Coleus amboinicus*	0.00000000	-2.385519
Mentha aquatica	*Coleus amboinicus*	0.00000000	-2.381820
Mentha aquatica	*Spinacia oleracea*	0.00210347	-1.351886
Coleus amboinicus	*Portulaca oleracea*	0.00000000	2.524021
Coleus amboinicus	*Portulacaria afra prostrata*	0.00000000	2.460922
Coleus amboinicus	*Vigna unguiculata*	0.00000000	2.416890
Portulaca oleracea	*Spinacia oleracea*	0.00036834	-1.494087
Portulacaria afra prostrata	*Spinacia oleracea*	0.00081328	-1.430988
Spinacia oleracea	*Vigna unguiculata*	0.00138866	1.386956

The average fresh mass yields for all crops included in Table 6.25 range between 0.997493 standard deviations less fresh biomass of *Asystasia gangetica* (creeping foxglove) than *Coleus amboinicus (= Plectranthus amboinicus)* (Indian borage) to a -2.544011 standard deviations less fresh biomass of *Amaranthus thunbergii* (pigweed) than *Coleus amboinicus (= Plectranthus amboinicus)* (Indian borage). These effect sizes are interpreted as large should Cohen's d rule of thumb be applied (Cohen, 1988).

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ii. Dry leaf biomass yield

Significant differences exist (see Figure 6.30) between dry mass yield combinations of *Asystasia gangetica, Dicliptera clinopodia, Mentha aquatica*, *Coleus amboinicus* and *Spinacea oleracea (the control crop)* with the other TAV crops in the natural soil. These findings correlate with observations by the researcher during the experimental study period. The control crop produced high yields in the natural soil.

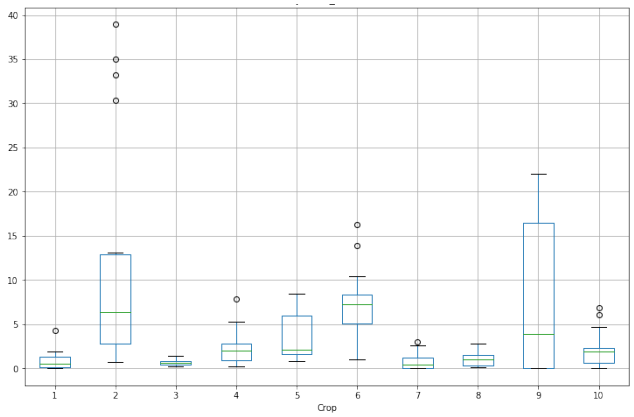


Figure 6.30: Boxplot grouped by crop indicating dry leaf mass in the Vicinity Wall, with the crops represented as follows: 1 Amaranthus thunbergii, 2 Asystasia gangetica, 3 Corchorus confusus, 4 Dicliptera clinopodia, 5 Mentha aquatica, 6 Coleus amboinicus (= Plectranthus amboinicus), 7 Portulaca oleracea, 8 Portulacaria afra prostrata, 9 Spinacia oleracea and 10 Vigna unguiculata

The *Asystasia gangetica, Spinacea oleracea and Coleus amboinicus (= Plectranthus amboinicus)* produced the highest mean dry leaf biomass in the natural soil (control area). (see Figure 6.31).

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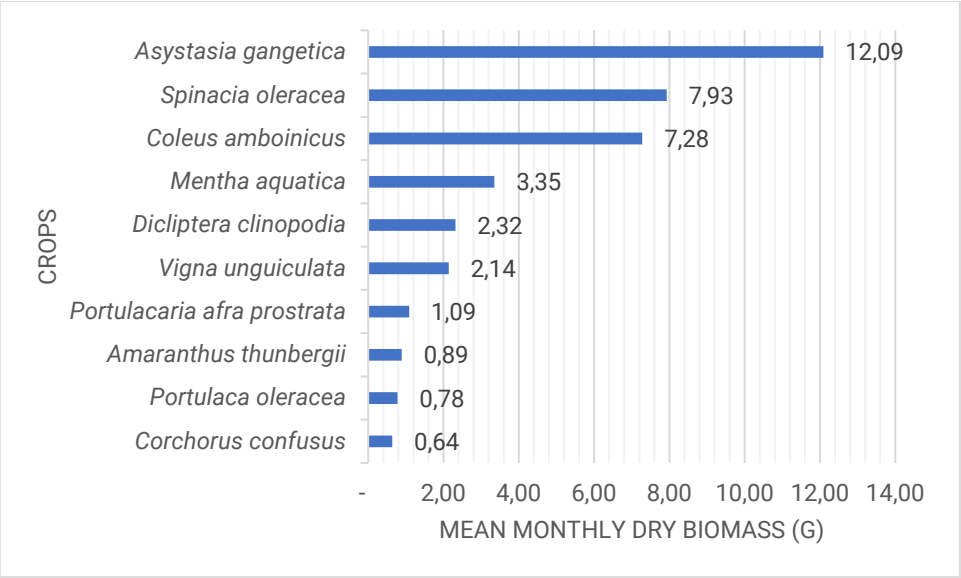


Figure 6.31: Mean monthly dry leaf mass in the natural soil (the control). Asystasia gangetica, Spinacea oleracea and Coleus amboinicus (= Plectranthus amboinicus) produced the highest mean mass in the natural soil (control area)

The ANOVA ($F_{(1, 46)}$ = 10.25, p < 0.0015, np^2 = 0.35) revealed that there were statistically significant differences between crops in dry leaf biomass production for the Eco Green Wall. A Tukey multi-comparison post-hoc procedure (p = 0.05) was performed to assess pairwise differences amongst the crop dry leaf mass. The results from the Tukey test are attached as Appendix D. Table 6.26 shows the post-hoc results of natural soil crop combinations with statistically significant differences (p < 0.05) in fresh mass yields. Other combinations that did not show statistically significant different pairwise comparisons (p > 0.05) were not included in Table 6.26 but contained in Appendix D.

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Table 6.26: Post-hoc results of crop combinations in the natural soil that showed a statistically significant difference (p<0.05) in dry biomass yield (refer to Appendix D for results indicating all combinations, including those that did not show statistically significant differences)

Crop A	Crop B	P-Tukey values that showed statistically significant difference (p < 0.05)	Hedges g (standard deviation)
Amaranthus thunbergii	*Asystasia gangetica*	0.00000004	-2.110666
Amaranthus thunbergii	*Coleus amboinicus*	0.01076190	-1.204475
Amaranthus thunbergii	*Spinacia oleracea*	0.00281831	-1.326660
Asystasia gangetica	*Corchorus confusus*	0.00000002	2.157438
Asystasia gangetica	*Dicliptera clinopodia*	0.00000296	1.840862
Asystasia gangetica	*Mentha aquatica*	0.00004757	1.647873
Asystasia gangetica	*Portulaca oleracea*	0.00000003	2.130789
Asystasia gangetica	*Portulacaria afra prostrata*	0.00000008	2.073105
Asystasia gangetica	*Vigna unguiculata*	0.00000176	1.875269
Corchorus confusus	*Coleus amboinicus*	0.00654496	-1.251247
Corchorus confusus	*Spinacia oleracea*	0.00163172	-1.373432
Dicliptera clinopodia	*Spinacia oleracea*	0.04500746	-1.056856
Coleus amboinicus	*Portulaca oleracea*	0.00871015	1.224599
Coleus amboinicus	*Portulacaria afra prostrata*	0.01580983	1.166915
Portulaca oleracea	*Spinacia oleracea*	0.00223263	-1.346784
Portulacaria afra prostrata	*Spinacia oleracea*	0.00431414	-1.289100
Spinacia oleracea	*Vigna unguiculata*	0.03289181	1.091263

The effect sizes of the average dry mass yield crop combinations in Table 6.26 are interpreted as large should Cohen's d rule of thumb be applied (Cohen, 1988). The *Asystasia gangetica* (creeping foxglove) and *Corchorus confusus* (Jute plant) combination had the largest effect size, with a 2.157438 standard deviations difference in dry biomass. *Dicliptera clinopodia* (pink ribbons) and *Spinach oleracea* (spinach) had the smallest effect size, with a -1.093385 standard deviations difference in dry biomass.

6.7 Which crop produced the biggest total leaf biomass yield in the experimental study period?

A one-way analysis of variance (ANOVA) test was performed to compare the total fresh yield (g FW plant^{-1}) per species over the 6-month experimental period, regardless of their

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position in a living wall typology or natural soil. The ANOVA analysis revealed that the *Coleus amboinicus* (Indian borage) (56,20 g FW plant^{-1}) and *Asystasia gangetica* (foxglove) (24,6 g FW plant^{-1}) produced the highest mean yields in fresh mass per specie. These yields were higher than those of the control crop *Spinacea oleracea* (spinach) (23,32 g FW plant^{-1}), with the other crops producing lower mean yields. Table 6.27 presents the fresh mass (g FW plant^{-1}) yield range of the crops measured over the 6-month data collection period, including the mean, standard deviation, and minimum and maximum weights (See Appendix G: Statistical analysis results comparing the different crops and biomass).

Table 6.27: Range of the crop fresh leaf mass (g FW plant^{-1}) over the 6-month experimental study period

Crop	Count	Mean	Standard deviation	Minimum weight (g)	Maximum weight (g)
Amaranthus thunbergii	54.0	1.88	3.85	0.00	24.30
Asystasia gangetica	54.0	24.60	52.28	1.27	231.82
Corchorus confusus	54.0	1.23	1.32	0.07	6.36
Dicliptera clinopodia	54.0	4.87	6.65	0.06	32.96
Mentha aquatica	54.0	5.85	5.82	0.59	26.01
Plectranthus amboinicus	54.0	56.20	52.97	6.14	254.76
Portulaca oleracea	54.0	2.64	4.30	0.00	22.12
Portulacaria afra prostrata	54.0	10.14	6.99	0.65	31.91
Spinacia oleracea	54.0	23.32	54.31	0.00	239.48
Vigna unguiculata	54.0	7.47	6.79	0.00	33.59

As can be seen from Table 6.28, the dry leaf mass yields show a similar trend, with the *Asystasia gangetica* (foxglove) (4.41g) producing the highest mean yield, followed by *Coleus amboinicus (previously Plectranthus amboinicus)* (Indian borage) (3.93g). These yields were higher than those of the control crop *Spinacea oleraecea* (spinach) (2.83g).

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Table 6.28 The crop dry leaf mass over the 6-month experimental study

Crop	Count	Mean	Standard deviation	Minimum weight (g)	Maximum weight (g)
Amaranthus thunbergii	54.0	0.39	0.72	0.00	4.24
Asystasia gangetica	54.0	4.41	9.15	0.18	38.92
Corchorus confusus	54.0	0.34	0.33	0.01	1.36
Dicliptera clinopodia	54.0	1.07	1.42	0.05	7.83
Mentha aquatica	54.0	1.78	1.83	0.10	8.44
Plectranthus amboinicus	54.0	3.93	4.28	0.38	22.13
Portulaca oleracea	54.0	0.38	0.63	0.00	3.03
Portulacaria afra prostrata	54.0	1.36	0.95	0.09	4.92
Spinacia oleracea	54.0	2.83	6.02	0.00	22.02
*Vigna **unguiculata***	54.0	1.63	1.54	0.00	6.83

Figure 6.32 illustrates the total fresh and dry leaf biomass for each crop, irrespective of position or typology, over the 6-month experimental period, with *Coleus amboinicus* (Indian borage), *Asystasia gangetica* (creeping foxglove), *Spinacea oleracea* (spinach), *Portulacaria afra* prostrata (pork bush) and *Vigna unguiculata* (black-eyed pea) producing the highest yields.

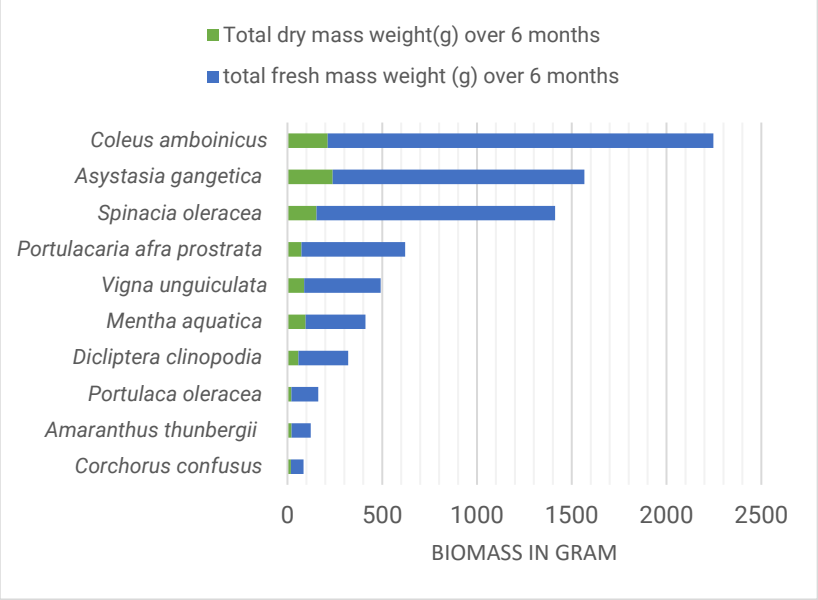


Figure 6.32: Total fresh and dry leaf mass of crops over the 6-month experimental study

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6.8 Discussion

Abiotic conditions in which the LWSs and TAV crops performed entailed the Vicinity Wall reaching the highest daily maximum temperatures and relative humidity. However, the difference between typologies was not statistically significant. The warmest daily maximum temperatures for all three typologies were similar to the November average for Gauteng (27.5℃) in November 2021, which was the hottest month. April 2022 showed the lowest recorded daily minimum temperatures for all three typologies, which were 2℃ lower than the Gauteng average (12.26℃). Months with the highest precipitation included December 2021 (275.2mm), which is 149mm compared to the monthly average for December in Gauteng (126mm). December also showed the highest relative humidity, with the RH of all three typologies more than 20% higher than the Gauteng average (59%) and daylength. Daily maximum (T_{max}) and minimum temperatures (T_{min}), relative humidity (RH), precipitation (P), daylength (DF), soil temperature (ST) and soil water content (VWC) have weak/ no significant statistical correlations with biomass yield and crop performance. However, a significant direct correlation was revealed between the soil electrical conductivity (EC) and leaf biomass yield as a crop performance indicator. Soil EC, which impacts yields due to the soil salinity, indicates the soil nutrient uptake and moisture content. The soil EC reached the lowest levels in both LWSs in January and February, which had the lowest yields, looking at the dry leaf biomass yield results in Figure 6.11(see Section 6.3). As the EC is linked to the soil moisture content, the EC levels can be explained by the irrigation malfunction in January. The EC levels recovered in March and April, which resulted in higher yields during these two months. The soil EC, the only variable found to correlate with the yield, is a significant consideration when considering systems. This implies that the LWS typologies mediated other variables to create required crop growth conditions, except for the soil EC during the irrigation malfunction.

Soil temperature impacts seed germination and yield for most warm-season vegetables, with higher temperatures leading to improved yields (Abou-Hussein, 2012). Although the response of different genera to soil temperatures varies, a study of eight warm-season crops showed that 25℃ was optimal for the root growth of seedlings (Kaspar, 1992).

Although dependent on many factors, such as soil characteristics and climate, for optimal VWC to maximize biomass yield, VWC should ideally be maintained well above the permanent wilting point (PWP) and below field capacity (FC) (Meter Group Inc., 2021). The

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FC is reached when the soil is fully saturated after watering with negligible drainage, and PWP occurs when the plant has wilted due to a loss of turgor pressure (Meter Group Inc., 2021).

No set guidelines exist for optimal VWC measures. A study that evaluated the effect of different volumetric water contents (VWC) on the growth, fruit yield, and quality of cherry tomatoes in a soil mixture of 59% sand, 9% silt, and 32% clay indicated a VWC of 0.44 $m^3\ m^{-3}$ as optimal (De Moura Campos et al., 2021). The soil for the experimental study comprises potting soil, river sand and perlite (ratio 1:4:1), which compares to a sandy clay loam on the soil texture triangle, implying an FC of 32% and a PWP of 19% (Meter Group Inc., 2021; Ács et al., 2010).

The VWC values fell below the acceptable value of $0.44m^3/m^{-3}$ in all three typologies. The irrigation system experienced problems in January 2022, decreasing VWC values. The Eco Green and Vicinity Wall's VWC values were well below the recommended value of $0.44m^3/m^{-3}$, with the natural soil's VWC values slightly affected by the dry spell in January and recovering in February.

LWSs are more effective in space-saving of a horizontal footprint than traditional soil-based food production on a household scale, as the natural soil area produced the lowest yield per m^2 considering footprint. The Vicinity Wall was the most productive, considering the horizontal footprint area occupied in terms of yield per m^2. The Vicinity Wall produced over four times the yield of the natural soil area, with the Eco Green Wall over three times more productive than the natural soil area.

The Eco Green Wall and Vicinity Wall data revealed that the positioning of crops in a LWS does not impact their yield. However, there were statistically significantly higher yields in the natural soil compared to the top, second and third rows in the LWSs. The soil volume explains the higher yields in the natural soil and the yields in the Vicinity Wall, with a soil volume double the volume of the Eco Green Wall containers.

Concerning the total fresh yield (g FW $plant^{-1}$) per species over six months, regardless of their position in a living wall typology or natural soil, the *Coleus amboinicus* (Indian borage) and *Asystasia gangetica* (foxglove) produced higher mean yields in fresh mass per specie than the control crop, with the other crops producing lower yields. The dry leaf mass yields show the *Asystasia gangetica* (foxglove) having the highest yield, followed by *Coleus*

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amboinicus (Indian borage). The dry mass yields of these crops were also higher than those of the control crop, *Spinacea oleraecea* (spinach). *Coleus amboinicus* and *Portulacaria afra* prostrata produced statistically significantly higher yields than the other TAV crops and the control crop, *Spinacea oleracea*. These crops are, therefore, considered suitable for food production in LWSs. Thus, although limited research has been conducted to improve the genetics of TAV crops, these crops already show the potential to contribute to household food security.

In the LWSs, other TAV also produced higher yields than the control crop, in addition to the *Coleus amboinicus* (Indian borage) and *Portulacaria afra* prostrata *(dwarf elephant's food)*. These include *Vigna unguiculata* (black-eyed pea), *Asystasia gangetica* (creeping foxglove), *Mentha aquatica* (water mint), and *Diclipera clinopodia* (pink ribbons) for the Eco Green Wall. The same crops produced a higher mean fresh and dry leaf biomass in the Vicinity Wall than the control crop (*Spinacea oleracea*), indicating their potential for household food security compared to commercial crops. *Coleus amboinicus* (Indian borage) and *Asystasia gangetica* (creeping foxglove) produced higher yields than the control crop, *Spinacea oleracea,* in the natural soil area (see Figure 6.33).

Amaranthus thunbergii (Thunberg's pigweed), *Corchorus confusus* (Jute plant), and *Portulaca oleracea* (purslane) had significantly lower yields than the control crop and other crops in the LWS typologies and natural soil conditions. The commercial crop, *Spinacea oleracea,* was a benchmark for an acceptable yield in the LWSs. Based on biomass yield, these crops are not considered productive for household food security in LWSs.

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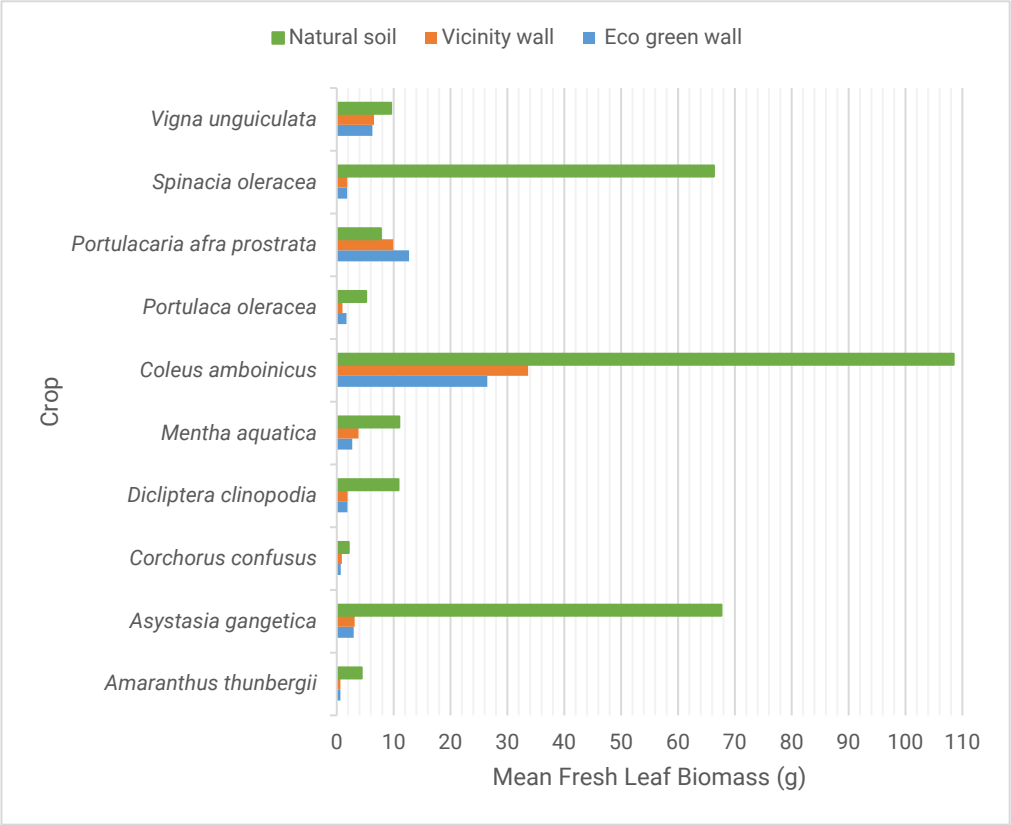


Figure 6.33: A comparison of the mean fresh leaf biomass of the ten crops in the three typologies

6.9 Conclusions

LWSs offer a potential option for urban agriculture, as they are more effective in space-saving considering the horizontal footprint. They use interstitial space, which would otherwise not have been used productively. The LWSs managed to mediate all climatic variables except for the soil EC during extended dry spells. Therefore, regular and correct volumes of water are vital for TAV crops in LWSs to keep the soil available water content and EC at acceptable levels. LWSs with bigger soil volumes produce higher yields.

Six TAV crops produced higher mean fresh and dry leaf biomass than the control crop in the LWSs, indicating their potential for vertical production for household food security.

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Chapter 7

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7. MOST SUITABLE LWSs FOR TAV PRODUCTION AND TAV's PLANT STRESS PERFORMANCE

7.1 Introduction

Chapter 7 elaborates on the statistical analysis of the second dependent variable to determine plant performance, namely the plant stress of crops in both the LWS typologies and the natural soil conditions (control). The study postulates that outdoor modular LWS with TAV could contribute to local household food security as EGI in local urban environments (Gauteng, South Africa).

Outcome 3 involves assessing the performance of the two selected LWS typologies in providing optimal growing conditions for TAV in Gauteng, South Africa and comparing them to the natural soil as control. Outcome 5 entails analysing the TAV species in terms of their potential for cultivation in outdoor living walls in Gauteng, South Africa, and comparing them to the control crop. The plant stress findings are the final step in achieving research outcomes 3 and 5.

Photosynthesis affects biomass and plant performance (Salam et al., 2022). Photosynthetic efficiency is reduced when plants experience dry, hot extremes, diseases and lack of nutrients (Salam et al., 2022). Therefore, this study aimed to determine the maximum quantum yield of photosystem II (Fv/Fm) and total performance index (PI_{total}) differences in the nine TAV crops and the control crop to evaluate the possible tolerance to the conditions of the study area. An ANOVA of the maximum quantum yield of photosystem II (Fv/Fm) and the total performance index (PI_{total}) was conducted as performance indicators of the TAV and control crops.

Chapter 7 contains two parts. The first part describes the results of the total crop performance in each typology to address research outcome 3. The second part zooms into each crop's performance to address outcome 5 (see Figure 7.1).

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Figure 7.1: Diagram of the layout for Chapter 7, illustrating Part 1, focusing on the performance of the LWSs, and Part 2, focusing on the performance of the TAV crops. Part 3 entails the concluding remarks

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7.2 How did the crops perform in each typology?

This section compares the crop performance in Eco green and Vicinity Walls and the natural soil. First, the mean maximum quantum yield (Fv/Fm) and total performance index (PI_{total}) for all crops per typology are compared during the 6-month data period to assess the typologies' performance. Subsequently, the crops' mean maximum quantum yields are analysed in each typology to compare their performance. Refer to Appendix H to M for the plant stress statistical analysis (results from the One-way ANOVA, Tukey multi-comparison post-hoc procedures, independent samples T-tests and Pearson's correlation tests).

7.2.1 Comparing the crops' mean maximum quantum yield and total performance index per typology

The researcher compared the mean Fv/Fm and PI_{total} values of the crops in each typology to assess their performance over the 6-month study period. The crops in the natural soil area (mean = 0.81448, sd = 0.027303) showed a higher mean maximum quantum yield than those in the LWSs. The crops in the Vicinity Wall (mean = 0.81329, sd = 0.029974) had a higher maximum quantum yield than those in the Eco Green Wall (mean = 0.80860, sd = 0.031573).

Considering the total performance index, the crops in the natural soil area had the highest mean in PI_{total} values (mean = 1.709974, sd = 0.9560993). Unlike the maximum quantum yield, the crops in the Eco Green Wall (mean = 1.626365, sd =1.0263101) had a higher PI_{total} mean value than the crops in the Vicinity Wall (mean = 1.395481, sd = 0.8686037). Statistically significant differences evident in crops in each typology are discussed below.

The one-way ANOVA showed statistically significant differences in the maximum quantum yield (Fv/Fm) of crops between the typologies ($F(2,1168) = 4.165$, $p = 0.016$, $np^2 = 0.007$) and the total performance index of crops ($F(2,1168) = 11.852$, $p < 0.001$, $np^2 = 0.020$). Where statistically significant differences were evident ($p < 0.05$), Tukey multi-comparison post-hoc procedures and independent samples T-tests were performed to assess pairwise differences in the maximum quantum yield and total performance index of crops amongst the typologies. Table 7.1 shows the post-hoc results of pairwise Fv/Fm comparisons between the three typologies.

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Table 7.1: Post-hoc results of typology combinations concerning the crops' maximum quantum yield

Typology A	Typology B	Mean difference (A – B)	Standard error	Significance
Natural soil	Eco Green Wall	0.005885	0.002151	0,017
Natural soil	Vicinity Wall	0.001195	0.002095	0.836
Vicinity Wall	Eco Green Wall	0.004690	0.002124	0.070

There were no statistically significant differences in the maximum quantum yield between the crops that were grown in the Vicinity Wall and the Eco Green Wall ($p > 0.05$) and those that were grown in the natural soil compared to the Vicinity Wall ($p > 0.05$). The post-hoc tests for the mean maximum quantum yield between the natural soil ($F_v/F_m = 0.81448$) and the Eco Green Wall ($F_v/F_m = 0.80860$) reveal a statistically significant ($p = 0.017$) difference between the natural soil and the Eco Green Wall.

Table 7.2 presents the crops' total performance index (PI_{total}) post-hoc results of all typology combinations.

Table 7.2: Post-hoc results of typology combinations concerning the crops' total performance index

Typology A	Typology B	Mean difference (A – B)	Standard error	Significance
Eco Green Wall	Vicinity Wall	0.2308844	0.0679350	0.002
Natural soil	Vicinity Wall	0.3142928	0.0670120	<0.001
Natural soil	Eco Green Wall	0.0834085	0.0687960	0.446

The post-hoc test for the total performance index (PI_{total}) reveals a statistically significant difference between the crops in the Eco Green Wall and the Vicinity Wall ($p = 0.002$), and the Vicinity Wall also showed statistically significant lower PI_{total} values than the natural soil ($p < 0.001$).

7.2.2 Comparing crops in the Eco Green Wall

The one-way ANOVA showed statistically significant differences with a medium effect size (Cohen, 1988) in the mean maximum quantum yield of crops in the Eco Green Wall ($F(9,360) = 47.705$, $p < 0.001$, $np^2 = 0.544$) over the 6-month study period. Where statistically significant differences were evident ($p < 0.05$), Tukey multi-comparison post-hoc procedures and independent samples T-tests were performed where required to assess

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pairwise differences in the maximum quantum yield and total performance index of crops amongst the typologies.

Table 7.3 shows the post-hoc results of statistically significant pairwise comparisons in the Eco Green Wall. The table does not include combinations that did not show statistically significant differences. Appendix H contains the statistical analysis of the comparison of crops in the typologies based on the one-way ANOVA tests, Tukey multi-comparison post-hoc procedures and independent sample T-tests.

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Table 7.3: Post-hoc results of crop combinations in the Eco Green Wall that showed a statistically significant difference (p<0.05) in the maximum quantum yield (refer to Appendix H for results indicating all combinations, including those that did not show statistically significant differences)

Crop A	Crop B	Mean Difference (A-B)	Standard Error	Significance
Amaranthus thunbergii	*Asystasia gangetica*	-.023409	0,007277	0,045
	Corchorus confusus	-.031247	0,007811	0,003
	Mentha aquatica	-.044727	0,007312	0,000
	Coleus amboinicus	-.069524	0,007090	0,000
	Portulacaria afra prostrata	-.065453	0,007063	0,000
	Spinacea oleracea	-.054781	0,007413	0,000
	Vigna unguiculata	-.042242	0,007516	0,000
Asystasia gangetica	*Mentha aquatica*	-.021318	0,004657	0,000
	Coleus amboinicus	-.046115	0,004300	0,000
	Portulaca oleracea	.023782	0,004716	0,000
	Portulacaria afra prostrata	-.042044	0,004255	0,000
	Spinacea oleracea	-.031372	0,004815	0,000
	Vigna unguiculata	-.018833	0,004971	0,007
Coleus amboinicus	*Portulaca oleracea*	.069897	0,004421	0,000
	Spinacea oleracea	.014743	0,004527	0,040
	Vigna unguiculata	.027281	0,004693	0,000
Corchorus confusus	*Coleus amboinicus*	-.038277	0,005152	0,000
	Portulaca oleracea	.031620	0,005504	0,000
	Portulacaria afra prostrata	-.034206	0,005114	0,000
	Spinacea oleracea	-.023534	0,005589	0,001
Dicliptera clinopodia	*Mentha aquatica*	-.020941	0,006205	0,028
	Coleus amboinicus	-.045738	0,005942	0,000
	Portulaca oleracea	.024159	0,006250	0,005
	Portulacaria afra prostrata	-.041667	0,005910	0,000
	Spinacea oleracea	-.030995	0,006325	0,000
Mentha aquatica	*Coleus amboinicus*	-.024797	0,004358	0,000
	Portulaca oleracea	.045100	0,004769	0,000
	Portulacaria afra prostrata	-.020726	0,004314	0,000
Portulaca oleracea	*Portulacaria afra prostrata*	-.065826	0,004378	0,000
	Spinacea oleracea	-.055154	0,004924	0,000
	Vigna unguiculata	-.042615	0,005077	0,000
Portulacaria afra prostrata	*Vigna unguiculata*	.023211	0,004652	0,000

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The PSII of *Coleus amboinicus*, *Portulacaria afra* prostrata, *Spinacea oleracea*, *Mentha aquatica and Vigna unguiculata* functioned at a higher optimum than the other crops in the Eco Green Wall (see Figures 7.2 and 7.3).

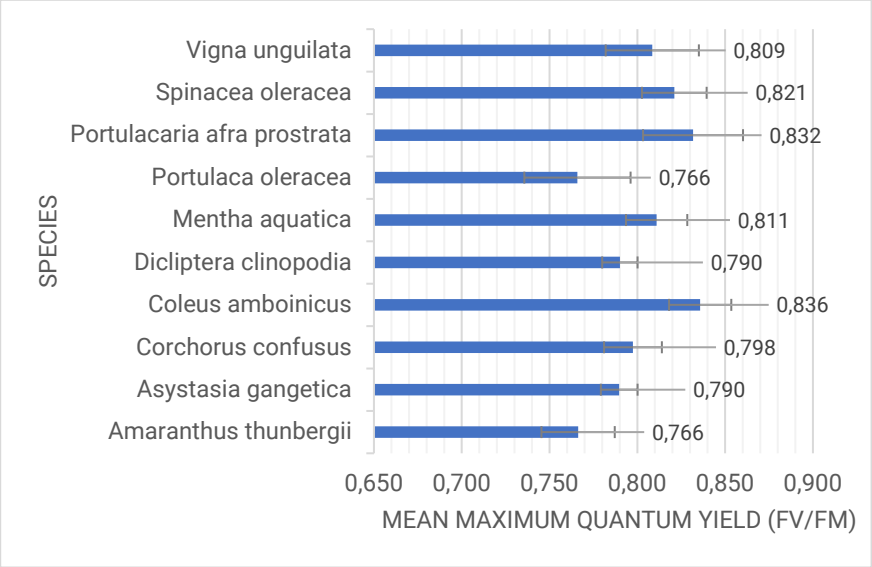


Figure 7.2: A clustered bar chart comparing the mean maximum quantum yield of photosystem II (Fv/Fm) of all crops in the Eco Green Wall

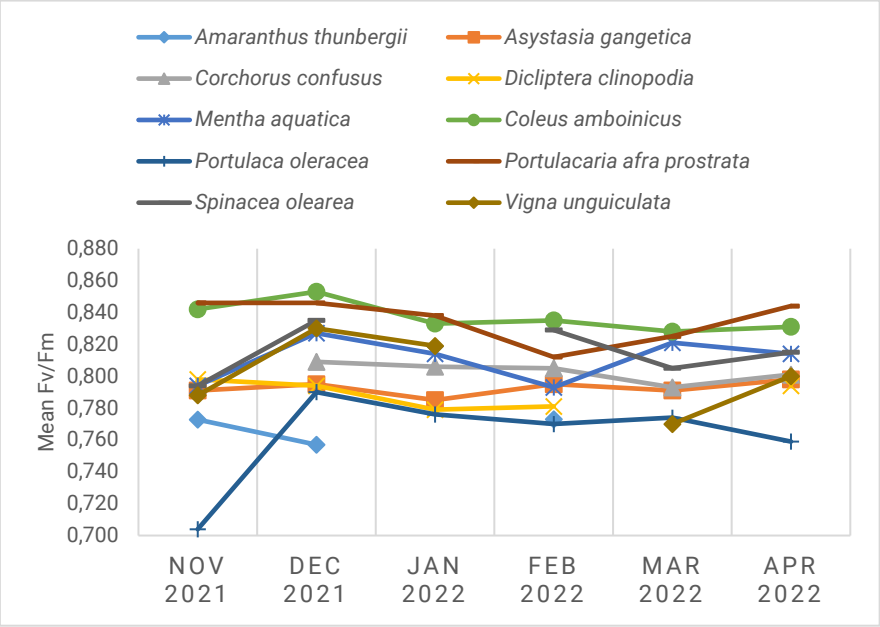


Figure 7.3: A line chart comparing the mean maximum quantum yield of photosystem II (Fv/Fm) of all crops in the Eco Green Wall

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The mean maximum quantum yield of *Portulaca oleracea* showed a value below 0.75 in November 2021, indicating a damaged PSII. However, the plant recovered in December 2021. From Table 7.3, it is clear that the effect sizes were small (Cohen, 1988) and can therefore be regarded as statistically insignificant. Except for *Amaranthus thunbergii*, which did not survive in the Eco Green Wall, the overall vitality of crops was good, with Fv/Fm values above 0.75. Eight TAV and the control crop survived in the LWS.

The daylength and maximum temperature correlations with the Fv/Fm (see Table 7.4) in the Eco Green Wall explain *Vigna unguiculata's* seasonality, leading to the crop's PSII decline.

Table 7.4: Statistically significant correlations between variables in the Eco Green Wall

Crops showing statistically significant correlations	Fv/Fm	PI_{total}	Daylength	Max. temp.	Min. temp.	Precipitation	RH	Soil temp.	Soil VWC	Soil EC
Asystasia gangetica						-0.395				
Coleus amboinicus			0.285							
Coleus amboinicus						-0.361		-0.317		
Corchorus confusus					0.471			0.458	0.534	0.453
Dicliptera clinopodia						-0.582	0.517			
Dicliptera clinopodia			-0.748			-0.738				
Mentha aquatica				-0.591			0.533	-0.368		
Mentha aquatica									-0.543	-0.376
Portulaca oleracea			-0.493		-0.499	-0.409	0.387	-0.434		
Portulacaria afra prostrata				-0.301			0.321	-0.317		
Portulacaria afra prostrata						-0.403				
Spinacea oleracea						0.372				
Vigna ***unguiculata***			0.392	-0.384						
Vigna ***unguiculata***						0.361				

7.2.3 Comparing crops in the Vicinity Wall

The one-way ANOVA showed statistically significant differences with a medium effect size (Cohen, 1988) in the mean maximum quantum yield of crops in the Vicinity Wall ($F(9,401) = 53.006$, $p < 0.001$, $np^2 = 0.543$) over the 6-month study period.

Where statistically significant differences were evident ($p < 0.05$), Tukey multi-comparison post-hoc procedures and independent sample T-tests were performed to assess pairwise

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differences in the maximum quantum yield and total performance index of crops amongst the typologies. Table 7.5 shows the post-hoc results of statistically significant pairwise comparisons in the Vicinity Wall. The table does not include combinations that did not show statistically significant differences. Appendix H contains the statistical analysis of the comparison of crops in the typologies based on the one-way ANOVA tests, Tukey multi-comparison post-hoc procedures and independent sample T-tests.

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Table 7.5: Post-hoc results of crop combinations in the Vicinity Wall that showed a statistically significant difference ($p<0.05$) in the maximum quantum yield (refer to Appendix H for results indicating all combinations, including those that did not show statistically significant differences)

Crop A	Crop B	Mean Difference (A-B)	Standard Error	Significance
Amaranthus thunbergii	*Asystasia gangetica*	-.043076	0,006154	0,000
	Corchorus confusus	-.042412	0,006081	0,000
	Dicliptera clinopodia	-.032956	0,006462	0,000
	Mentha aquatica	-.061779	0,006038	0,000
	Coleus amboinicus	-.076945	0,005734	0,000
	Portulacaria afra prostrata	-.079800	0,005784	0,000
	Spinacea oleracea	-.063938	0,006017	0,000
	Vigna unguiculata	-.053714	0,005928	0,000
Asystasia gangetica	*Mentha aquatica*	-.018703	0,004678	0,003
	Coleus amboinicus	-.033869	0,004279	0,000
	Portulaca oleracea	.024806	0,004652	0,000
	Portulacaria afra prostrata	-.036723	0,004346	0,000
	Spinacea oleracea	-.020861	0,004652	0,000
Coleus amboinicus	*Portulaca oleracea*	.058675	0,004080	0,000
	Spinacea oleracea	.013008	0,004080	0,049
	Vigna unguiculata	.023231	0,003948	0,000
Corchorus confusus	*Mentha aquatica*	-.019367	0,004581	0,001
	Coleus amboinicus	-.034534	0,004173	0,000
	Portulaca oleracea	.024141	0,004555	0,000
	Portulacaria afra prostrata	-.037388	0,004241	0,000
	Spinacea oleracea	-.021526	0,004555	0,000
Dicliptera clinopodia	*Mentha aquatica*	-.028823	0,005076	0,000
	Coleus amboinicus	-.043989	0,004711	0,000
	Portulacaria afra prostrata	-.046844	0,004772	0,000
	Spinacea oleracea	-.030981	0,005052	0,000
	Vigna unguiculata	-.020758	0,004946	0,001
Mentha aquatica	*Coleus amboinicus*	-.015166	0,004110	0,010
	Portulaca oleracea	.043508	0,004497	0,000
	Portulacaria afra prostrata	-.018021	0,004179	0,001
Portulaca oleracea	*Portulacaria afra prostrata*	-.061529	0,004150	0,000
	Spinacea oleracea	-.045667	0,004470	0,000
	Vigna unguiculata	-.035443	0,004349	0,000
Portulacaria afra prostrata	*Spinacea oleracea*	.015862	0,004150	0,006
	Vigna unguiculata	.026085	0,004020	0,000

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The PSII of *Coleus amboinicus*, *Portulacaria afra* prostrata, *Spinacea oleracea*, *Mentha aquatica, Corchorus confusus, Asystasia gangetica and Vigna unguiculata* functioned at a higher optimum than the other crops in the Vicinity Wall (see Figures 7.4 and 7.5).

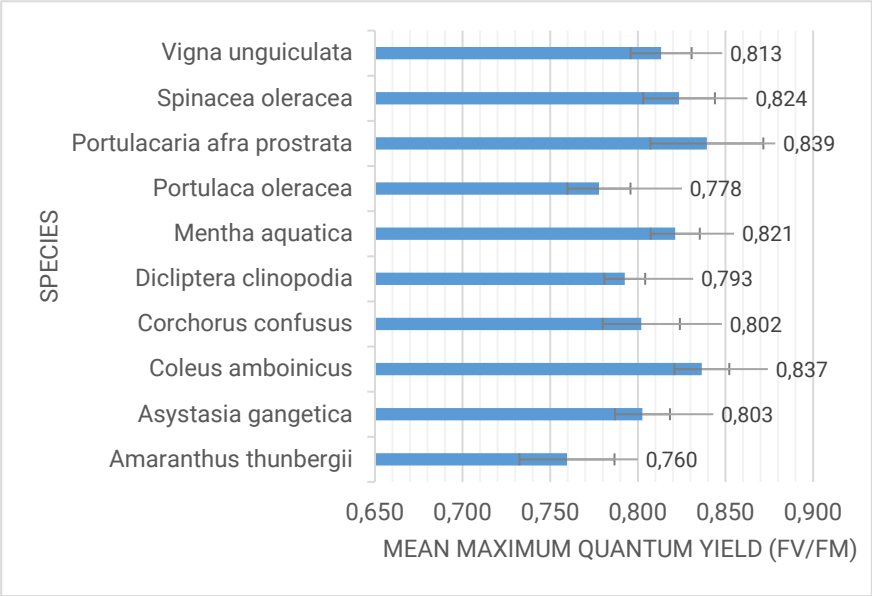


Figure 7.4: A clustered bar chart comparing the mean maximum quantum yield of photosystem II (Fv/Fm) of all crops in the Vicinity Wall

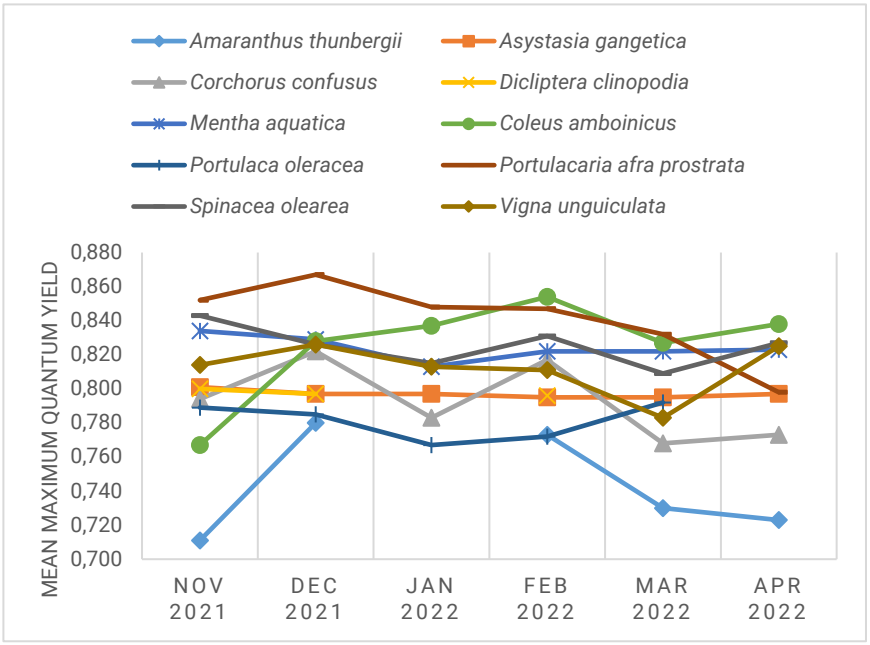


Figure 7.5: A line chart comparing the mean maximum quantum yield of photosystem II (Fv/Fm) of all crops in the Vicinity Wall

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Amaranthus thunbergii had a damaged PSII (Fv/Fm < 0.75) in November 2021 and March and did not survive in the Vicinity Wall. The maximum quantum yield of the other eight TAV crops and the control crop was above 0.75, indicating that the Vicinity Wall's crops coped well with their environmental circumstances.

In the Vicinity Wall, six crops' correlations with precipitation were prominent (see Table 7.6).

Table 7.6: Statistically significant correlations between variables in the Vicinity Wall

Crops showing statistically significant correlations	Fv/ Fm	PI_{total}	Max. Temp.	Min. Temp.	Precipitation	RH	Daylength	Soil temp.	Soil VWC	Soil EC
Amaranthus thunbergii					0.621		0.696			
Amaranthus thunbergii					-0.784					
Coleus amboinicus			0.314			-0.342		0.351	-0.456	-0.413
Coleus amboinicus							0.446			-0.468
Corchorus confusus					-0.404					
Corchorus confusus					-0.356					
Dicliptera clinopodia				0.486						
Mentha aquatica					-0.360				0.382	
Mentha aquatica					-0.551		-0.487			0.436
Portulaca oleracea			-0.369		-0.413			-0.364	0.436	0.491
Portulacaria afra prostrata				0.298			0.627			
Portulacaria afra prostrata							0.524		0.320	
Spinacea oleracea					-0.472					
Vigna ***unguiculata***				-0.469				-0.307		
Vigna ***unguiculata***			-0.520	-0.492		0.529	-0.304	-0.507	0.365	0.410

7.2.4 Comparing crops in the natural soil

The one-way ANOVA showed statistically significant differences with a medium effect size (Cohen, 1988) in the mean maximum quantum yield of crops in the natural soil ($F(9,380) = 68.525$, $p < 0.001$, $np^2 = 0.619$) over the 6-month study period.

Where statistically significant differences were evident ($p < 0.05$), Tukey multi-comparison post-hoc procedures and independent sample T-tests were performed to assess pairwise differences in the maximum quantum yield of crops amongst the typologies. Table 7.7 shows the post-hoc results of statistically significant pairwise comparisons in the natural soil. The table does not include combinations that did not show statistically significant differences. Appendix H contains the statistical analysis of the comparison of crops in the

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typologies based on the one-way ANOVA tests, Tukey multi-comparison post-hoc procedures and independent sample T-tests.

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Table 7.7: Post-hoc results of crop combinations in the natural soil that showed a statistically significant difference (p<0.05) in the maximum quantum yield (refer to Appendix H for results indicating all combinations, including those that did not show statistically significant differences)

Crop A	Crop B	Mean Difference (A-B)	Standard error	Significance
Amaranthus thunbergii	*Asystasia gangetica*	-.022647	0,005473	0,002
	Corchorus confusus	-.059124	0,005569	0,000
	Mentha aquatica	-.048795	0,005631	0,000
	Coleus amboinicus	-.066074	0,005444	0,000
	Portulacaria afra prostrata	-.059333	0,005444	0,000
	Spinacea oleracea	-.060872	0,005631	0,000
	Vigna unguiculata	-.034238	0,005583	0,000
Asystasia gangetica	*Corchorus confusus*	-.036477	0,003531	0,000
	Mentha aquatica	-.026148	0,003628	0,000
	Coleus amboinicus	-.043427	0,003331	0,000
	Portulaca oleracea	.016934	0,003967	0,001
	Portulacaria afra prostrata	-.036686	0,003331	0,000
	Spinacea oleracea	-.038225	0,003628	0,000
	Vigna unguiculata	-.011591	0,003554	0,039
Coleus amboincius	*Portulaca oleracea*	.060361	0,003927	0,000
	Vigna unguiculata	.031836	0,003509	0,000
Corchorus confusus	*Dicliptera clinopodia*	.046235	0,004188	0,000
	Portulaca oleracea	.053411	0,004099	0,000
	Vigna unguiculata	.024886	0,003700	0,000
Dicliptera clinopodia	*Mentha aquatica*	-.035906	0,004270	0,000
	Coleus amboinicus	-.053185	0,004020	0,000
	Portulacaria afra prostrata	-.046444	0,004020	0,000
	Spinacea oleracea	-.047983	0,004270	0,000
	Vigna unguiculata	-.021349	0,004207	0,000
Mentha aquatica	*Coleus amboinicus*	-.017279	0,003584	0,000
	Portulaca oleracea	.043082	0,004182	0,000
	Vigna unguiculata	.014557	0,003793	0,006
Portulaca oleracea	*Portulacaria afra prostrata*	-.053621	0,003927	0,000
	Spinacea oleracea	-.055159	0,004182	0,000
	Vigna unguiculata	-.028525	0,004118	0,000
Portulaca afra prostrata	*Vigna unguiculata*	.025095	0,003509	0,000
Spinacea oleracea	*Vigna unguiculata*	.026634	0,003793	0,000

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The PSII of *Coleus amboinicus, Portulacaria afra* prostrata, *Corchorus confusus, Spinacea oleracea*, and *Mentha aquatica* functioned at a higher optimum than the other crops in the control area, the natural soil (see Figures 7.6 and 7.7).

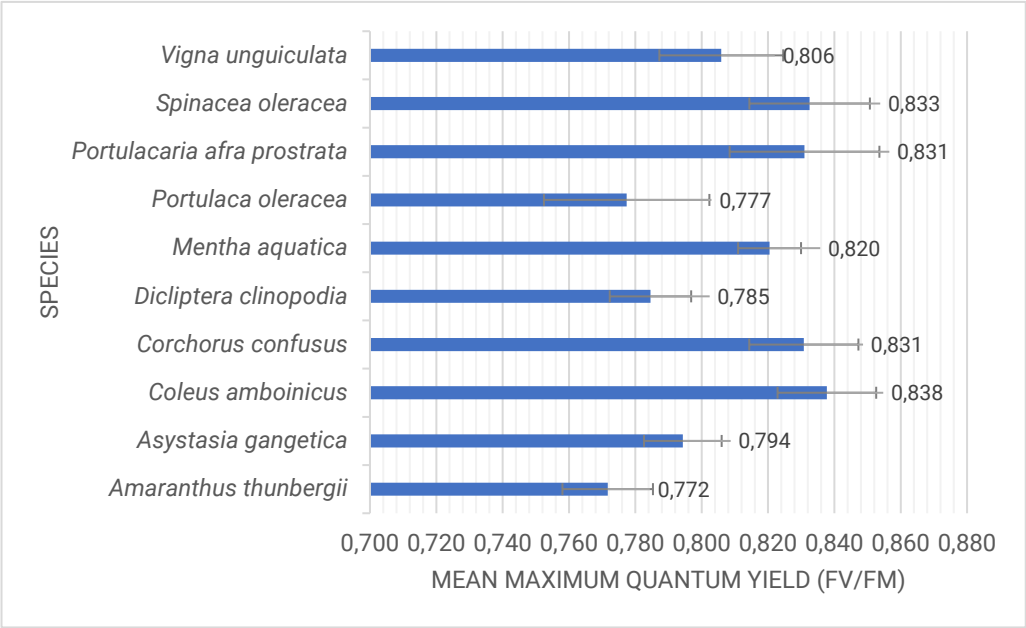


Figure 7.6: A clustered bar chart comparing the mean maximum quantum yield of photosystem II (Fv/Fm) of all crops in the Eco Green Wall

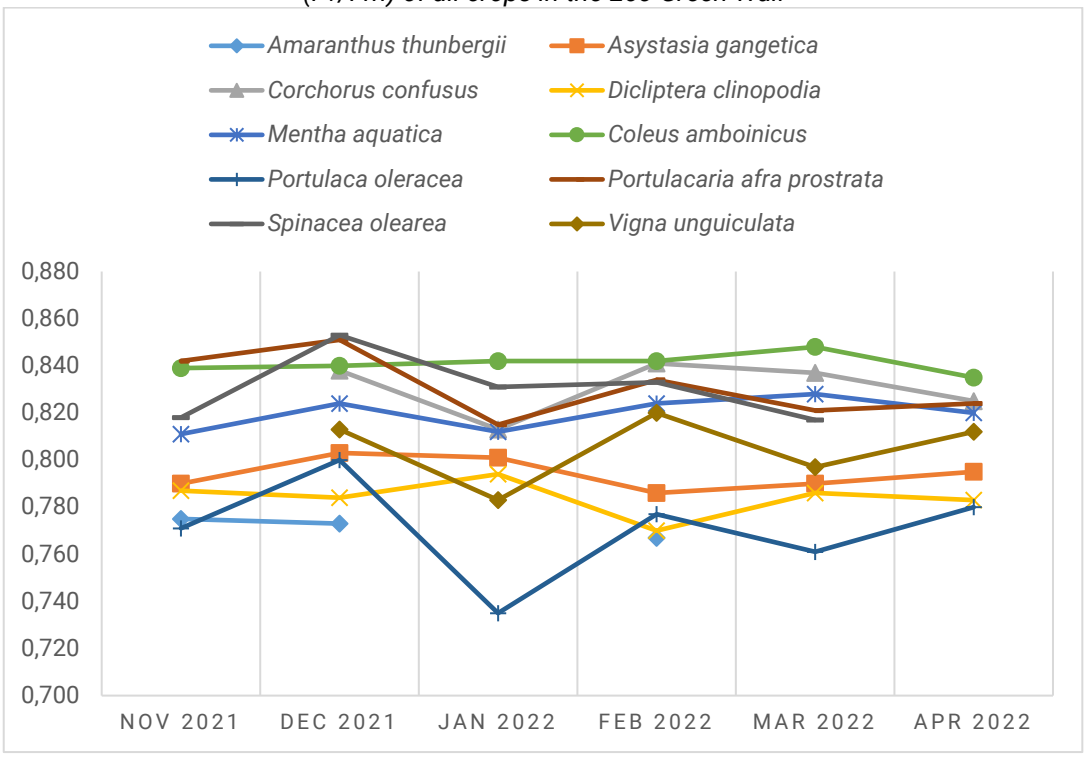


Figure 7.7: A line chart comparing the mean maximum quantum yield of photosystem II (Fv/Fm) of all crops in the natural soil (the control)

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Portulaca oleracea had an Fv/Fm value below 0.75 in January 2022, indicating a damaged PSII. Although the species recovered temporarily in February 2022, *Amaranthus thunbergii* and *Portulaca oleracea* did not survive in the natural soil. The other seven TAV crops and the control crop had Fv/Fm values above 0.75, indicating that the crops coped with the environmental circumstances in the natural soil area.

The *Portulaca oleracea* experienced severe stress in the natural soil due to Fv/Fm correlations with minimum temperature, RH, soil temperature, VWC, and EC (see Table 7.8). Also, the crop's PI_{total} correlated with daylength and EC. The correlation with daylength supports the argument that the annual has reached the end of its short lifecycle.

Table 7.8: Statistically significant correlations between variables in the natural soil area

Crops showing statistically significant correlations	Fv/Fm	PI_{total}	Daylength	Max. Temp.	Min. Temp.	Precipitation	RH	Soil temp.	Soil VWC	Soil EC
Asystasia gangetica				-0.329	-0.338	-0.322	0.345			-0.388
Amaranthus thunbergii				0.714	0.749	0.739		0.624		0.714
Coleus amboinicus			0.271							
Corchorus confusus						0.403			0.504	0.343
Corchorus confusus			0.490	0.556	0.415	0.317		0.565		
Dicliptera clinopodia						-0.431				
Dicliptera clinopodia							0.431			
Mentha aquatica									0.508	0.398
Mentha aquatica										0.545
Portulaca oleracea					-0.445		0.416	0.404	0.417	-0.370
Portulaca oleracea			0.463							-0.372
Portulacaria afra prostrata					-0.351					
Portulacaria afra prostrata				-0.322	-0.634			-0.318		-0.358
Spinacea oleracea			0.505				0.459		0.359	
Spinacea oleracea			0.615	-0.357	-0.359	-0.330		-0.451		-0.505
*Vigna **unguiculata***				0.354		0.384			0.467	
*Vigna **unguiculata***				0.461		0.498	-0.333			

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7.3 The performance of each crop [maximum quantum yield of photosystem II (Fv/Fm) and total plant performance (PI_{total})

Appendix I, Appendix J and Appendix K contain the one-way ANOVA statistical analysis for comparing all crops in all typologies for each month during the study. Each crop is elaborated below.

7.3.1 *Amaranthus thunbergii* (Thunberg's pigweed)

Amaranthus thunbergii had a zero per cent survival rate in all typologies at the end of the six months. Plants in the natural soil had the highest mean maximum quantum yield (Fv/Fm = 0.77167), followed by the plants in the Eco Green Wall (Fv/Fm = 0.76627). The *Amaranthus thunbergii* in the Vicinity Wall showed the lowest mean maximum quantum yield values (Fv/Fm = 0.75836). Concerning the total performance index, the mean value in natural soil (PI_{total} = 1.696675) was higher than the total performance index of plants grown in the Vicinity (PI_{total} = 1.575636) and those grown in the Eco Green Walls (PI_{total} =1.225291). Figure 7.8 compares the maximum quantum yield of photosystem II (Fv/Fm) and total performance index (PI_{total}) for *Amaranthus thunbergii* between the three typologies.

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Figure 7.8: A comparison of the maximum quantum yield of photosystem II and total performance index for Amaranthus thunbergii between the three typologies, with the Eco Green Wall (A), the Vicinity Wall (B)and the natural soil area (C)

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i. The maximum quantum yield of photosystem II (F_vF_m)

In the Eco Green Wall, the maximum quantum yield values of *Amaranthus thunbergii* indicated no plant stress (Fv/Fm > 0.75) between November 2021 and February 2022 (see Figure 7.8). The one-way ANOVA showed no statistically significant differences in the species' maximum quantum yield between months in the Eco Green Wall ($F(2,8) = 0.413$, $p = 0.675$). However, the species did not survive in the Eco Green Wall.

In the Vicinity Wall, the one-way ANOVA showed a statistically significant difference in the species' maximum quantum yield between months ($F(4,9) = 13.837$, $p < 0.001$, $np^2 = 0.860$). The *Amaranthus thunbergii* experienced stress (Fv/Fm < 0.75) in November, after which it recovered, followed by another stress period in March, with no recovery. Table 7.9 presents the Eco Green Wall combinations with statistically significant differences determined by the independent samples T-test results. The table does not include combinations that did not show statistically significant differences. Appendix I contains the statistical analysis for comparing crops in the Eco Green Wall, including the one-way ANOVA, Tukey multi-comparison post-hoc procedures and independent samples T-tests.

Table 7.9: Post-hoc results of the significant mean total performance index differences of Amaranthus thunbergii in the Vicinity Wall, based on the mean difference between months in the 6-month study period

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Mar 2022	Dec 2021	-0.061400	0,014221	0,013
Mar 2022	Feb 2022	-0.053750	0,006217	0,003

In the natural soil, the one-way ANOVA revealed no statistically significant differences in the species' maximum quantum yield ($F(2,9) = 0.228$, $p = 0.756$) between months.

ii. Total performance index (PI_{total})

Figure 7.8 shows the total performance index of *Amaranthus thunbergii* in the three typologies. The one-way ANOVA showed no statistically significant differences in the species' total performance index ($F(2,8) = 0.726$, $p = 0.513$) between months in the Eco Green Wall and the Vicinity Wall ($F(3,10) = 3.437$, $p = 0.060$). However, the one-way ANOVA showed statistically significant differences, with medium effect sizes in the species' total performance index in the natural soil ($F(2,9) = 10.886$, $p = 0.004$, $np^2 = 0.708$). In the natural

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soil, the Tukeys post-hoc test showed a significant mean difference (-1.4230750) at the 0.05 level between November 2021 and February 2022.

iii. Possible stress causes considering climate and soil conditions

A statistically significant ($p < 0.05$) moderate positive correlation was recorded between the *Amaranthus thunbergii*'s maximum quantum yield, precipitation ($r = 0.621$) and a strong correlation with daylength ($r = 0.696$) in the Vicinity Wall (see Appendix L for the Pearson's correlation analysis of the maximum quantum yield with soil and climate variables). However, no statistically significant correlations were evident between Fv/Fm and climate and soil variables in the Eco Green Wall and natural soil.

Regarding the total performance index of *Amaranthus thunbergii,* Pearson's correlation coefficient showed a strong statistically significant correlation with precipitation (negative $r = -0.784$) in the Vicinity wall. Pearson's correlation coefficient in the natural soil area showed a statistically significant moderate positive ($r = 0.624$) correlation between the total performance index and soil temperature (See Appendix M). Moreover, the total performance index in the crops in the natural soil showed statistically significant strong positive correlations with the soil EC ($r = 0.714$) local maximum ($r = 0.714$) and minimum temperatures ($r = 0.749$) and precipitation ($r = 0.739$) (See Appendix M).

The natural habitat of *Amaranthus thunbergii* entails warm climates and river and pan areas (Hyde, 2022). Possible causes of the plant's stress could have included the collective impact of the soil VWC and EC decline in all the typologies in January 2022 (refer to section 6.2.2). In February 2022, the VWC and EC in the Vicinity Wall and natural soil areas also fell and, therefore, may have contributed to plant stress and affected plant growth and survival of the *Amaranthus thunbergii*. Except for the natural soil area, where correlations with climate and soil were evident, the living walls did not show statistically significant correlations between the maximum quantum yield and total performance index and soil variables. The cumulative impact of the soil VWC and EC could have contributed to the plant stress and ultimate death of the *Amaranthus thunbergii* in the LWS typologies and natural soil.

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7.3.2 *Asystasia gangetica* (creeping foxglove)

Figure 7.9 shows the mean maximum quantum yield and performance index differences for *Asystasia gangetica* in the three LWS typologies. The mean values of the crop's maximum quantum yield and total performance index in the natural soil (Fv/Fm = 0.79431; PI_{total} = 1.458635) were higher than those of plants grown in the Vicinity (Fv/Fm = 0.79707; PI_{total} = 0.924248) and those grown in the Eco Green Walls (Fv/Fm = 0.79241; PI_{total} = 1.006708).

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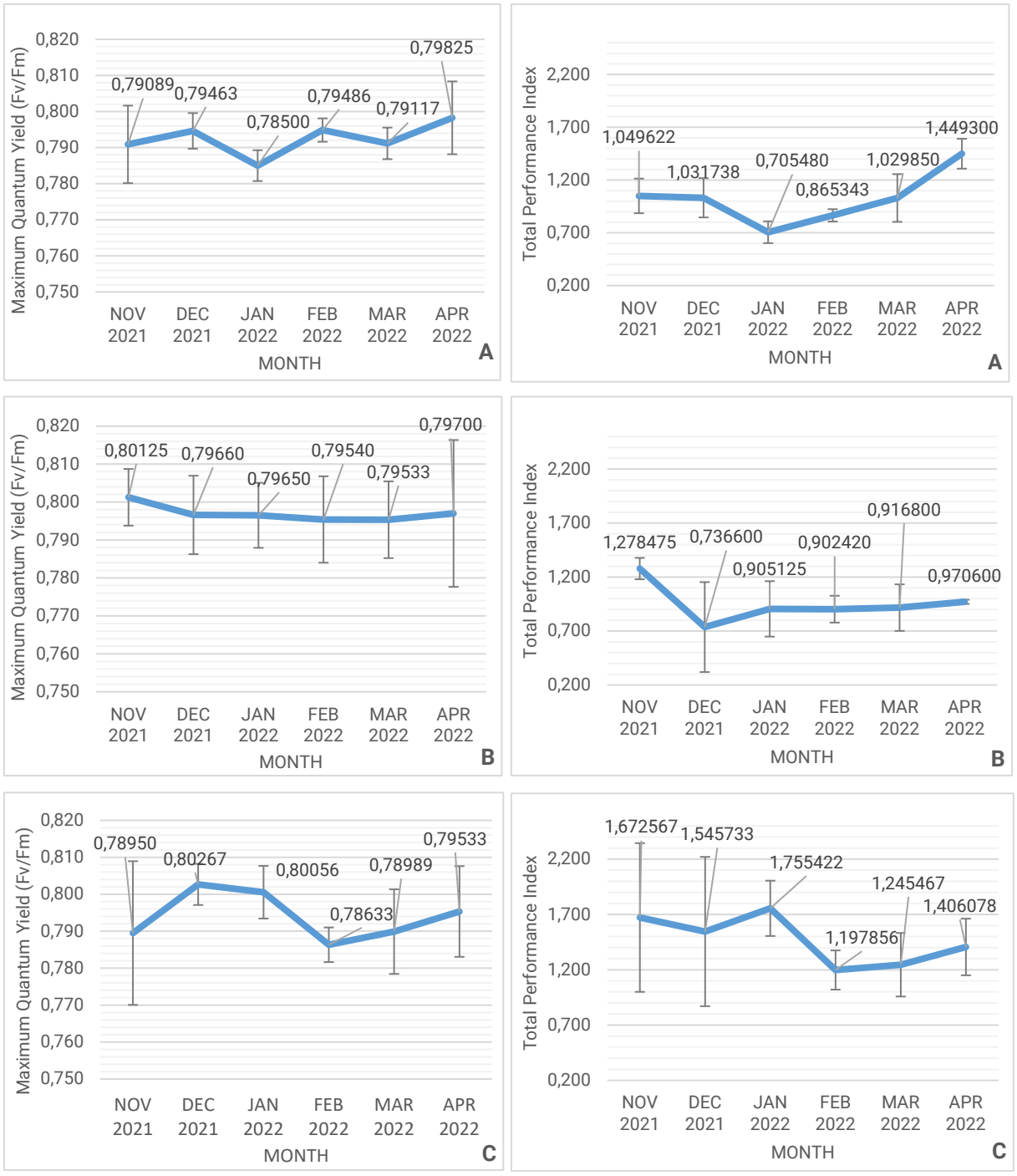


Figure 7.9 A comparison of the mean maximum quantum yield of photosystem II and total performance index for Asystasia gangetica between the three typologies with (A) the Eco Green Wall, (B) the Vicinity Wall and (C) the natural soil area

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i. The maximum quantum yield of photosystem II (F_vF_m)

The Fv/Fm values for *Asystasia gangetic*a were above 0.75 in all the typologies for the study period, with the species performing optimally in all the typologies (see Figure 7.9). The one-way ANOVA revealed statistically significant differences between January and April 2022 in *Asystasia gangetica's* maximum quantum yield for the Eco Green Wall ($F(5,33) = 2.963$, $p = 0.26$, $np^2 = 0.310$) and the natural soil ($F(5,45) = 3.396$, $p = 0.011$, $np^2 = 0.274$). No statistically significant difference was evident in the Vicinity Wall ($F(5,21) = 0.148$, $p = 0.979$). However, effect sizes for the Vicinity Wall and natural soil are considered small and statistically insignificant.

ii. Total performance index (PI_{total})

The ANOVA revealed statistically significant differences between months in the total performance index for *Asystasia gangetica* in the Eco green ($F(5,33) = 11.434$, $p < 0.0012$, $np^2 = 0.634$) and Vicinity Walls ($F(5,21) = 0.148$, $p = 0.245$). The effect size for the Vicinity Wall is small (Cohen, 1988) and thus regarded as statistically insignificant. The effect sizes for the natural soil are considered medium and statistically significant.

Table 7.10 presents the Eco Green Wall combinations with statistically significant differences determined by Tukey's multicomparison test results. The table does not include combinations that did not show statistically significant differences. Appendix I contains the statistical analysis for comparing crops in the Eco Green Wall.

Table 7.10: Post-hoc results of the significant mean total performance index differences of Asystasia gangetica in the Eco Green Wall, based on the mean difference between months in the 6-month study period

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Jan 2022	0.3441422	0,0873440	0,005
Dec 2021	Jan 2022	0.3262575	0,0892723	0,011
Feb 2022	Jan 2022	0.3243700	0,0948224	0,019
Apr 2022	Nov 2021	0.3996778	0,0941013	0,002
Apr 2022	Dec 2021	0.4175625	0,0958939	0,002
Apr 2022	Jan 2022	0.7438200	0,1050465	<0,001
Apr 2022	Feb 2022	0.5839571	0,0981505	<0,001
Apr 2022	Mar 2022	0.4194500	0,1010810	0,003

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Although a statistically significant difference was evident in the natural soil ($F(5,45) = 1.460$, $p = 0.044$, $np^2 = 0.218$), the effect size is small, should Cohen's d rule of thumb (Cohen, 1988) be applied. Therefore, the differences between months in the natural soil are not statistically significant.

iii. Possible stress causes considering climate and soil conditions

The *Asystasia gangetica* coped very well with the environmental conditions in all three typologies. Statistically significant ($p < 0.05$) weak positive correlations were recorded between *Asystasia gangetica's* maximum quantum yield and RH ($r = 0.345$) in the natural soil. Moreso, statistically significant weak negative correlations were recorded between *Asystasia gangetica's* maximum quantum yield with the minimum ($r = -0.338$) and maximum ($r = -0.329$) temperatures, precipitation ($r = -0.322$) and a medium negative correlation with the soil EC ($r = -0.388$) in the natural soil (see Appendix L for the Pearson's correlation analysis of the maximum quantum yield with soil and climate variables).

Attached as Appendix M, Pearson's correlation coefficient shows statistically significant ($p < 0.05$) correlations between the total performance index and the soil VWC (weak negative $r = -0.329$), soil EC (moderate negative $r = -0.432$) and precipitation (weak negative $r = -0.314$) in the natural soil. This shows the crop's dependence on water and irrigation.

The LWSs had no statistically significant correlations between the total performance index and climate and soil variables. However, in the Eco Green Wall, the total performance index showed statistically significant correlations with soil temperature (moderate negative $r = -0.512$), maximum (weak negative $r = -0.335$) and minimum (moderate negative $r = -0.580$) temperatures, RH (moderate positive $r = 0.504$), precipitation (moderative negative $r = -0.605$) and daylength (moderative negative $r = -0.569$), which illustrates that the crop experienced temperature-related stress in the Eco Green Wall. Although the crop's PI_{total} in the Eco Green Wall declined in January 2022, *Asystasia*'s PSII index recovered and increased monthly from February 2022. The Vicinity Wall did not display the same trend in the recovery of the species, with a slower, more gradual increase in March and April 2022. In the natural soil, the species' PI_{total} declined in February when the maximum daily temperatures were highest during the experimental study period. However, the PI_{total} gradually increased in March and April 2022, and the species' PSII recovered well.

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7.3.3 *Coleus amboinicus* (Indian borage)

The maximum quantum yield values for *Coleus amboinicus* were above 0.75, revealing the crops' exemplary performance in all three typologies, as shown in Figure 7.10. The mean maximum quantum yield values of the crop were the highest in the natural soil area (Fv/Fm = 0.83774), with the mean maximum quantum yield values of crops in the Vicinity (Fv/Fm = 0.83633) and Eco Green Walls (Fv/Fm = 0.83690) slightly lower. In the Eco Green Wall, the mean total performance values of *Coleus amboinicus* were the highest (PI_{total} = 2.170019) and alternately increased and declined during the six months. The Vicinity Wall's mean values were lower (PI_{total} = 1.695333) and gradually increased during the six months (See Figure 7.10).

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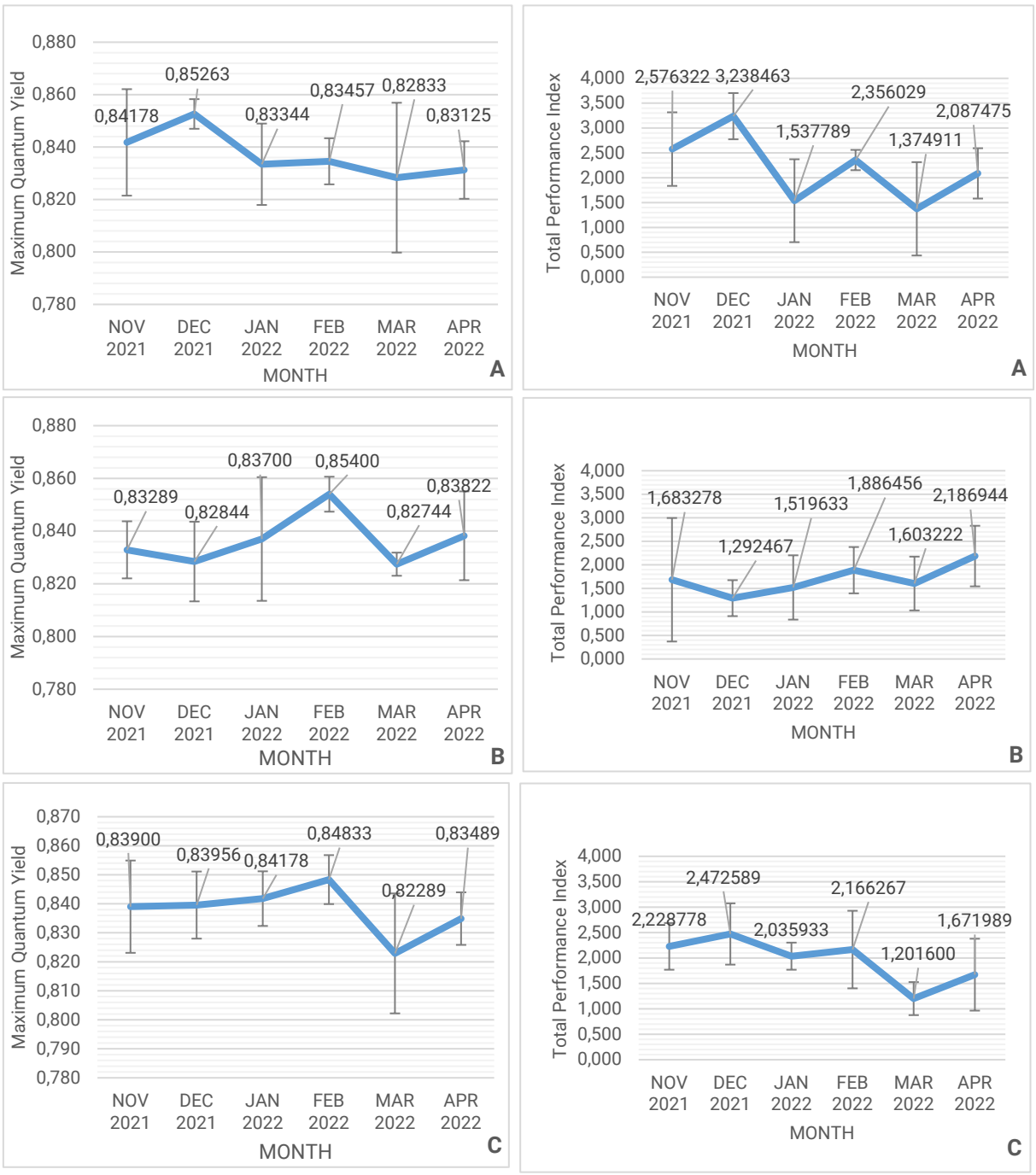


Figure 7.10: A comparison of the maximum quantum yield of photosystem II and total performance index for Coleus amboinicus between the three typologies, with (A) the Eco Green Wall, (B) the Vicinity Wall and (C) the natural soil

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i. The maximum quantum yield of photosystem II (F_vF_m)

The one-way ANOVA revealed statistically significant differences between months in the maximum quantum yield of *Coleus amboinicus* in all the typologies. However, the maximum quantum yield effect sizes between months in the Eco Green Wall ($F(5,44) = 2.543$, $p = 0.042$, $np^2 = 0.224$), Vicinity Wall ($F(5,48) = 4.037$, $p = 0.004$, $np^2 = 0.296$) and the natural soil ($F(5,48) = 3.702$, $p = 0.006$, $np^2 = 0.278$) were small (Cohen, 1988). Therefore, differences in months of the maximum quantum yield for *Coleus amboinicus* are statistically insignificant.

The crop's maximum quantum yield values in the Eco Green Wall decreased in January, after which they remained constant throughout the six months. In the Vicinity Wall and natural soil area, the functioning of photosystem II declined in March. However, the plant recovered in April.

ii. Total performance index (PI_{total})

The one-way ANOVA determined statistically significant differences between months in the total performance index of *Coleus amboinicus* for the Eco Green Wall ($F5,44) = 9.127$, $p < 0.001$, $np^2 = 0.509$) and the natural soil ($F4,48) = 6.135$, $p < 0.001$, $np^2 = 0.390$). However, no statistically significant difference was evident in the Vicinity Wall ($F(5,48) = 1.984$, $p = 0.098$). The effect size for the natural soil is small (Cohen, 1988) and thus regarded as statistically insignificant. However, the crop's total performance index effect sizes between months for the Eco Green Wall are considered medium and statistically significant.

Table 7.11 presents the crop's total performance index month combinations in the Eco Green Wall, with statistically significant differences determined by Tukey's multicomparison post-hoc test results. The table does not include combinations that did not show statistically significant differences. Appendix I, Appendix J and Appendix K contain the statistical analysis of the comparison of crops in the Eco Green Wall, Vicinity Wall and natural soil area, respectively.

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Table 7.11: Post-hoc results from significant (p<0.05) mean total performance index differences of Coleus amboinicus in the Eco Green Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Jan 2022	1.0385333	0,3136513	0,022
Nov 2021	Mar 2022	1.2014111	0,3136513	0,005
Dec 2021	Jan 2022	1.7006736	0,3233044	0,000
Dec 2021	Mar 2022	1.8635514	0,3233044	0,000
Dec 2021	Apr 2022	1.1509875	0,3326775	0,014

The total performance index in the natural soil showed a statistically significant difference between November 2021 in combination with January and March 2022. December also differed significantly from January, March and April 2022. The mean difference was significant at the 0.05 level.

The natural soil's total performance index values (mean PI_{total} = 1.962859) declined slowly, with the lowest values in March and April 2022.

iii. Possible stress causes considering climate and soil conditions

The species coped well with its environmental circumstances. The maximum quantum yield of *Coleus amboinicus* showed a statistically significant ($p < 0.05$) weak positive correlation with daylength ($r = 0.285$) in the Eco Green Wall and natural soil ($r = 0.271$). In the Vicinity Wall, the maximum quantum yield showed a statistically significant weak positive correlation with the local maximum temperature ($r = 0.314$) and a weak negative correlation with the RH (r = 0.-342). Moreover, the crops in the Vicinity wall's maximum quantum yield showed statistically significant moderate negative correlations with the soil EC ($r = -0.413$) and VWC ($r = -0.456$) and a moderate positive correlation with the soil temperature ($r = 0.351$) (See Appendix L). These correlations could have contributed to January's Eco Green and Vicinity Walls' maximum quantum yield declines in the crops. Except for March and April 2022, the photosystem II increased monthly in the Vicinity Wall and the natural soil, indicating plant vitality.

The crop's total performance index in the Eco Green Wall showed a weak negative correlation ($r = -0.317$) with soil temperature and a moderate negative correlation with precipitation ($r = -0.361$) (See Appendix M). Therefore, the high soil temperature values in

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January 2022 could have impacted the plant stress and caused the decline in January 2022 in the Eco Green Wall. The Vicinity Wall's total performance index showed a medium negative correlation (r = -0.332) with the daylength. The species in the Vicinity Wall showed a gradual increase over the study period from December 2022, except for March.

In the natural soil, the *Coleus amboinicus* total performance index values decreased in March 2022 and recovered in April. The natural soil area's total performance index showed statistically significant correlations with soil EC (moderate negative r = -0.468) and daylength (moderate positive r = 0.446).

7.3.4 *Corchorus confusus* (jute plant)

Figure 7.11 presents the maximum quantum yield of *Corchorus confusus* in the three typologies. The *Corchorus confusus* performed better in the natural soil area, considering the maximum quantum yield and total performance index (Fv/Fm = 0.83079; PI_{total} = 2.680809) than in the Vicinity (Fv/Fm = 0.80294; PI_{total} = 1.378551) and Eco Green Walls (Fv/Fm = 0.80033; PI_{total} = 2.102767).

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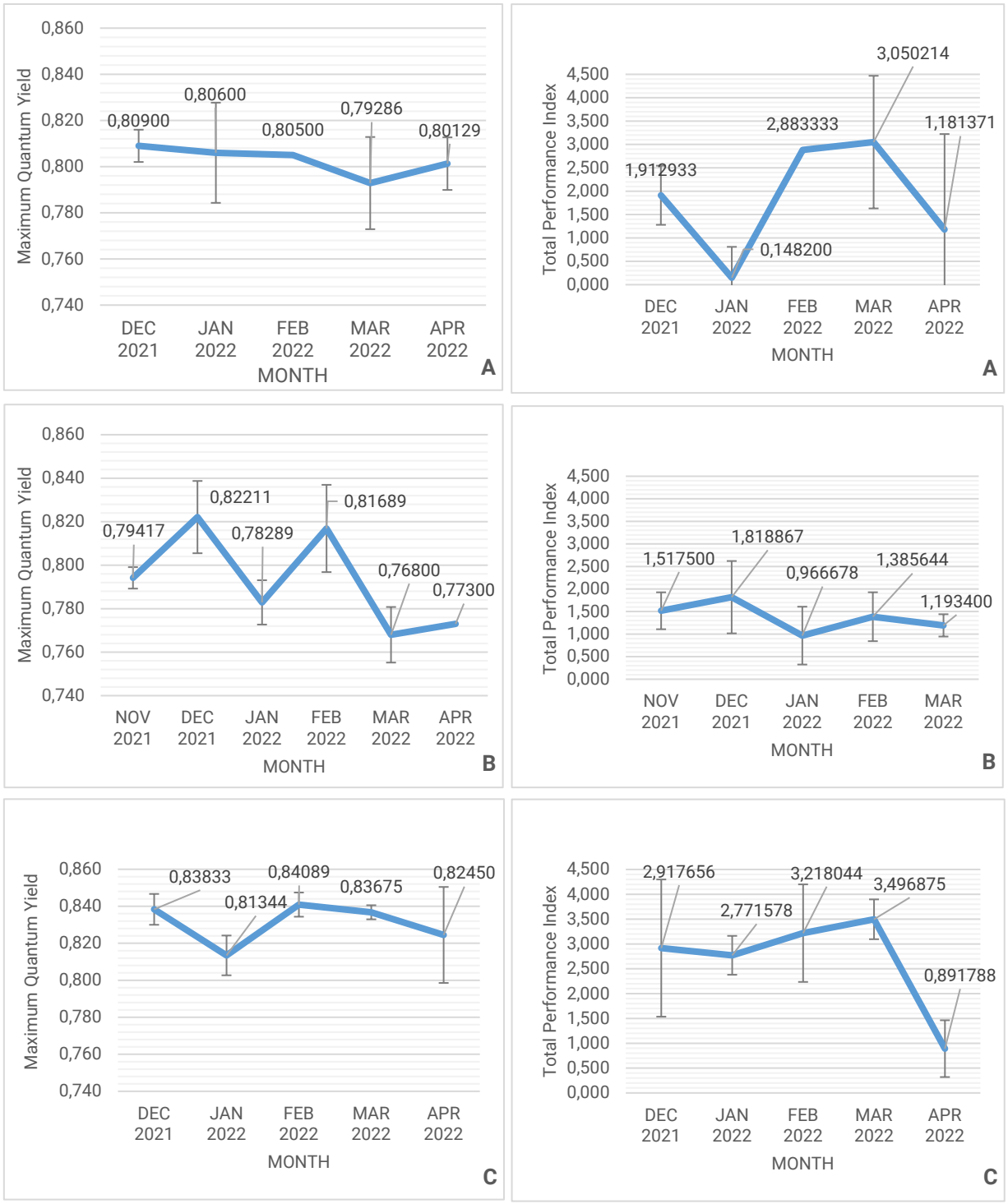


Figure 7.11: A comparison of the maximum quantum yield of photosystem II and total performance index for Corchorus confusus between the three typologies, with (A) the Eco Green Wall, (B) the Vicinity Wall, and (C) the natural soil

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i. The maximum quantum yield of photosystem II (F_vF_m)

The one-way ANOVA revealed no statistically significant difference between months during the 6-month study period in the maximum quantum yield of *Corchorus confusus* in the Eco Green Wall ($F(4,16) = 0.627$, $p = 0.650$). However, the one-way ANOVA showed statistically significant differences between months in the crop's maximum quantum yield in the Vicinity Wall ($F(5,29) = 9.687$, $p < 0.001$, $np^2 = 0.625$) and the natural soil ($F(4,38) = 6.787$, $p < 0.001$, $np^2 = 0.417$). The crop's maximum quantum yield effect sizes between months in the natural soil area are small and statistically insignificant. The crop's maximum quantum yield effect sizes between months in the Vicinity Wall are medium (Cohen, 1988) and statistically significant.

Table 7.12 presents the *Corchorus confusus* maximum quantum yield monthly combinations in the Vicinity Wall with statistically significant differences determined by the independent samples' T-test results. The table does not include combinations that did not show statistically significant differences. Appendix J contains the statistical analysis for comparing crops in the Vicinity Wall.

Table 7.12: Post-hoc results of the significant mean maximum quantum yield differences of Corchorus confusus in the Vicinity Wall, based on the mean difference between months in the 6-month study period

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Dec 2021	-0.027944	0,006874	0,001
Nov 2021	Feb 2022	-0.022722	0,007578	0,010
Dec 2021	Jan 2022	0.039222	0,007502	<0,001
Dec 2021	Mar 2022	0.054111	0,010742	0,001
Dec 2021	Apr 2022	0.049111	0,010742	0,002
Jan 2022	Feb 2022	-0.034000	0,007930	<0,001
Feb 2022	Mar 2022	0.048889	0,013473	0,007
Feb 2022	Apr 2022	0.043889	0,013473	0,012

The maximum quantum yield of *Corchorus confusus* in the Vicinity Wall showed statistically significant differences ($p < 0.05$) between November, December and February, and December and January, March and April. Furthermore, the crop's maximum quantum yield showed statistically significant differences between January and February, February and March and February and April.

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ii. Total performance index (PI_{total})

The one-way ANOVA showed no statistically significant difference between months in the total performance index of *Corchorus confusus* in the Eco Green Wall ($F4,16) = 2.065$, $p = 0.133$). Statistically significant differences in the total performance index of *Corchorus confusus* between months for the Vicinity Wall ($F(5,29) = 2.706$, $p < 0.040$, $np^2 = 0.318$) and the natural soil ($F4,38) = 11.728$, $p < 0.001$, $np^2 = 0.552$) were evident. However, the effect sizes between months in the total performance index in the Vicinity Wall are small (Cohen, 1988) and thus regarded as statistically insignificant. The effect sizes between months in the total performance index in the natural soil are considered medium and statistically significant. Table 7.13 presents the natural soil month combinations with statistically significant differences determined by Tukey's multicomparison test results. The table does not include combinations that did not show statistically significant differences. Appendix G contains the statistical analysis of the comparison of crops between months in the typologies.

Table 7.13: Post-hoc results of the significant mean total performance index differences of Corchorus confusus in the natural soil area (the control), based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Dec 2022	Apr 2022	2.0258681	0,4143328	0,000
Jan 2022	Apr 2022	1.8797903	0,4143328	0,001
Feb 2022	Apr 2022	2.3262569	0,4143328	0,000
Mar 2022	Apr 2022	2.6050875	0,4263449	0,000

The total performance index of *Corchorus confusus* in the natural soil showed statistically significant differences ($p < 0.05$) between April and December, January, February and March.

iii. Possible stress causes considering climate and soil conditions

Pearson's correlation coefficient analysis revealed statistically significant ($p < 0.05$) associations between the maximum quantum yield and precipitation in the Vicinity Wall and EC, soil water content and precipitation in the natural soil area (See Appendix L). The correlation between the maximum quantum yield and precipitation in the Vicinity Wall is

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negative moderatev(r = -0.404). The correlations between the maximum quantum yield and soil water content (r = 0.504) and precipitation (r = 0.403) are considered direct moderate in the natural soil. However, the Fv/Fm EC correlation (r = 0.343) in the natural soil area is considered weak and, therefore, not statistically significant. No statistically significant maximum quantum yield-related correlations were apparent in the Eco Green Wall.

The total performance index of *Corchorus confusus* in the Eco Green Wall showed moderate positive/ direct correlations with the soil VWC (r = 0.534), soil temperature (r = 0.458), soil EC (r = 0.453), and local minimum temperature (r = 0.471). The Vicinity Wall revealed a moderate negative PI_{total} and precipitation correlation (r = -0.356). In contrast, the PI_{total} and precipitation correlation in the natural soil area (r = 0.317) is weak and direct (See Appendix M). In the natural soil area, the crop's total performance index showed moderate positive statistically significant ($p < 0.05$) correlations with soil temperature (r = 0.565), soil VWC (r = 0.504), and a weak positive correlation with soil EC (r = 0.343). Moreover, the species' total performance index showed a moderate positive correlation with maximum (r = 0.556) and minimum (r = 0.415) temperatures and daylength (r = 0.490).

The decline in Fv/Fm values from March 2022 in all three typologies confirms the seasonal-related cause, as the leaves go dormant after the growing season. The statistically significant PI_{total} differences between April 2022 and other months in the natural soil confirm this (see Figure 7.11). Moreover, the direct correlation between the PI_{total} and the ambient and soil temperatures in the Eco Green Wall and natural soil typologies confirms the seasonal-related lifespan of the species. The PI_{total} also fell in the Eco green and Vicinity Walls over April, although the difference was not statistically significant as in the case of the natural soil.

7.3.5 *Dicliptera clinopodia* (pink ribbons)

Figure 7.12 compares the maximum quantum yield and total performance index of *Dicliptera clinopodia* in the three typologies during the study period. The crop performed optimally in all typologies, with the crops in the Vicinity Wall (Fv/Fm = 0.79650) having the highest values, followed by those in the Eco Green Wall (Fv/Fm = 0.79006) and the natural soil (Fv/Fm = 0.78456). Concerning the total performance index, the *Dicliptera clinopodia* crops in the natural soil area (PI_{total} = 1.109763) had the highest mean values, followed by the Eco Green Wall (PI_{total} = 1.1090982) and the Vicinity Wall (PI_{total} = 0.855611).

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Figure 7.12: A comparison of the maximum quantum yield of photosystem II and total performance index for Dicliptera clinopodia between the three typologies, with (A) the Eco Green Wall, (B) the Vicinity Wall and (C) the natural soil

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i. The maximum quantum yield of photosystem II (F_vF_m)

The one-way ANOVA determined no statistically significant differences between months in the maximum quantum yield of *Dicliptera clinopodia* in the natural soil ($F(5,21)$, $p = 0.273$). However, the one-way ANOVA determined statistically significant differences with a medium effect size in the maximum quantum yield of the species in the Eco Green Wall ($F(4,12) = 3.961$, $p = 0.028$, $np^2 = 0.569$) and Vicinity Wall ($F(3,14) = 7.612$, $p = 0.003$, $np^2 = 0.620$). Plants in the Eco Green Wall dropped to the lowest Fv/Fm value in January, after which the plant's photosystem II gradually recovered. The maximum quantum yield values in the Vicinity Wall declined drastically in March to the lowest Fv/Fm value. The crop's maximum quantum yield dropped to the lowest value in February in the natural soil area, after which values slightly decreased further in March.

Tables 7.14 and 7.15 present the crop's mean maximum quantum yield Eco Green Wall and Vicinity Wall month combinations with statistically significant differences determined by the independent sample's T-test results. The tables do not include combinations that did not show statistically significant differences. Appendix I contains the statistical analysis of the comparison of crops between months in the Eco Green Wall and Appendix J in the Vicinity Wall.

Table 7.14: Post-hoc results of the significant mean total performance index differences of Dicliptera clinopodia in the Eco Green Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Jan 2022	0.019833	0,002053	0,002
Nov 2021	Feb 2022	0.017083	0,004119	0,009
Dec 2021	Feb 2022	-0.015750	0,004689	0,028
Feb 2022	Apr 2022	-0.013000	0,004541	0,029

The maximum quantum yield of *Dicliptera clinopodia* in the Eco Green Wall showed statistically significant differences ($p < 0.05$) between November, January and February, December and February, and February and April.

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Table 7.15: Post-hoc results of the significant mean maximum quantum yield differences of Dicliptera clinopodia in the Vicinity Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Mar 2022	0.030000	0,004844	<0,001
Dec 2021	Mar 2022	0.026667	0,008523	0,026
Feb 2022	Mar 2022	0.025667	0,004807	0,033

The maximum quantum yield of *Dicliptera clinopodia* in the Vicinity Wall showed statistically significant differences ($p < 0.05$) between March and November, December and February.

ii. Total performance index (PI_{total})

The one-way ANOVA determined no statistically significant differences between months in the total performance index of *Dicliptera clinopodia* for the Vicinity Wall ($F(3,14) = 2.078$, $p = 0.149$) and the natural soil ($F(5,21) = 2.183$, $p = 0.95$). However, a statistically significant difference was evident in the crop's total performance index in the Eco Green Wall ($F4,12) = 23.137$, $p < 0.001$, $np^2 = 885$). The effect sizes between months in the crop's total performance index in the Eco Green Wall were large (Cohen, 1988) and thus regarded as statistically significant.

The crop's total performance index in the natural soil showed a statistically significant difference ($p < 0.05$) between November and December, November and April, and January combined with November 2021, February 2022 and April 2022. The mean difference was significant at the 0.05 level. Table 7.16 depicts the statistically significant differences in monthly combinations of the crops in the Eco Green Wall. The table does not include combinations that did not show statistically significant differences. Appendix I contains the statistical analysis of the comparison of crops in the Eco Green Wall.

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Table 7.16: Post-hoc results of the significant mean total performance index differences of Dicliptera clinopodia in the Eco Green Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Jan 2022	0.7811500	0,1278324	0,000
Nov 2021	Dec 2021	0.5617000	0,1069523	0,002
Feb 2022	Dec 2021	0.4234500	0,0990185	0,008
Feb 2022	Jan 2022	0.6429000	0,1212725	0,001
Apr 2022	Dec 2021	0.7112000	0,0990185	0,000
Apr 2022	Jan 2022	0.9306500	0,1212725	0,000

The mean total performance index of *Dicliptera clinopodia* in the Eco Green Wall showed statistically significant differences ($p < 0.05$) between November and December, and January, and also February and December and January. April also showed statistically significant differences in the mean total performance index of *Dicliptera clinopodia* with December and January.

iii. Possible stress causes considering climate and soil conditions

Pearson's correlation coefficient, attached as Appendix L, showed a statistically significant ($p < 0.05$) moderate negative correlation between the *Dicliptera clinopodia's* maximum quantum yield with precipitation ($r = -0.582$) and a moderate positive correlation ($r = 0.517$) with the local RH in the Eco Green Wall. The low RH (66%) in February may have triggered plant stress and affected plant growth and survival in the Eco Green Wall. However, the PSII of the plant recovered well.

In the Vicinity Wall, the decline in the crop's maximum quantum yield and total performance index values in February and March were not statistically significant and cannot be attributed to any specific factor. The maximum quantum yield in the natural soil showed a moderate negative correlation ($r = -0.431$) with precipitation. In December 2021 and February 2022, which experienced the highest rainfall, the species displayed the lowest maximum quantum yield values in the natural soil (See Appendix L).

The crop's total performance index showed strong statistically significant ($p < 0.05$) correlations with precipitation (negative $r = -0.738$) and daylength (negative $r = -0.748$) in the Eco Green Wall. The Vicinity Wall's total performance index showed a medium positive correlation ($r = 0.486$) with the daily minimum temperature. In December, the total

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performance index value of the species in the Vicinity Wall dropped to its lowest level, corresponding to the lowest minimum temperature. In contrast, the total performance index in the natural soil showed a medium positive correlation (r = 0.431) with the RH, with the highest values in January and April 2022 (See Appendix M).

7.3.6 *Mentha aquatica* (water mint)

Figure 7.13 compares the maximum quantum yield and the total performance index for *Mentha aquatica* between the typologies. *Mentha aquatica* performed optimally in all the typologies, with the crops in the Vicinity Wall (Fv/Fm = 0.82411) having the highest mean value, followed by those in the natural soil (Fv/Fm = 0.82046) and the Eco Green Wall (Fv/Fm = 0.81582). The species in the Eco Green Wall (PI_{total} = 0.772994) had the highest mean total performance index values, followed by those in the natural soil area (PI_{total} = 0.770436) and the Vicinity Wall (PI_{total} = 0.630540).

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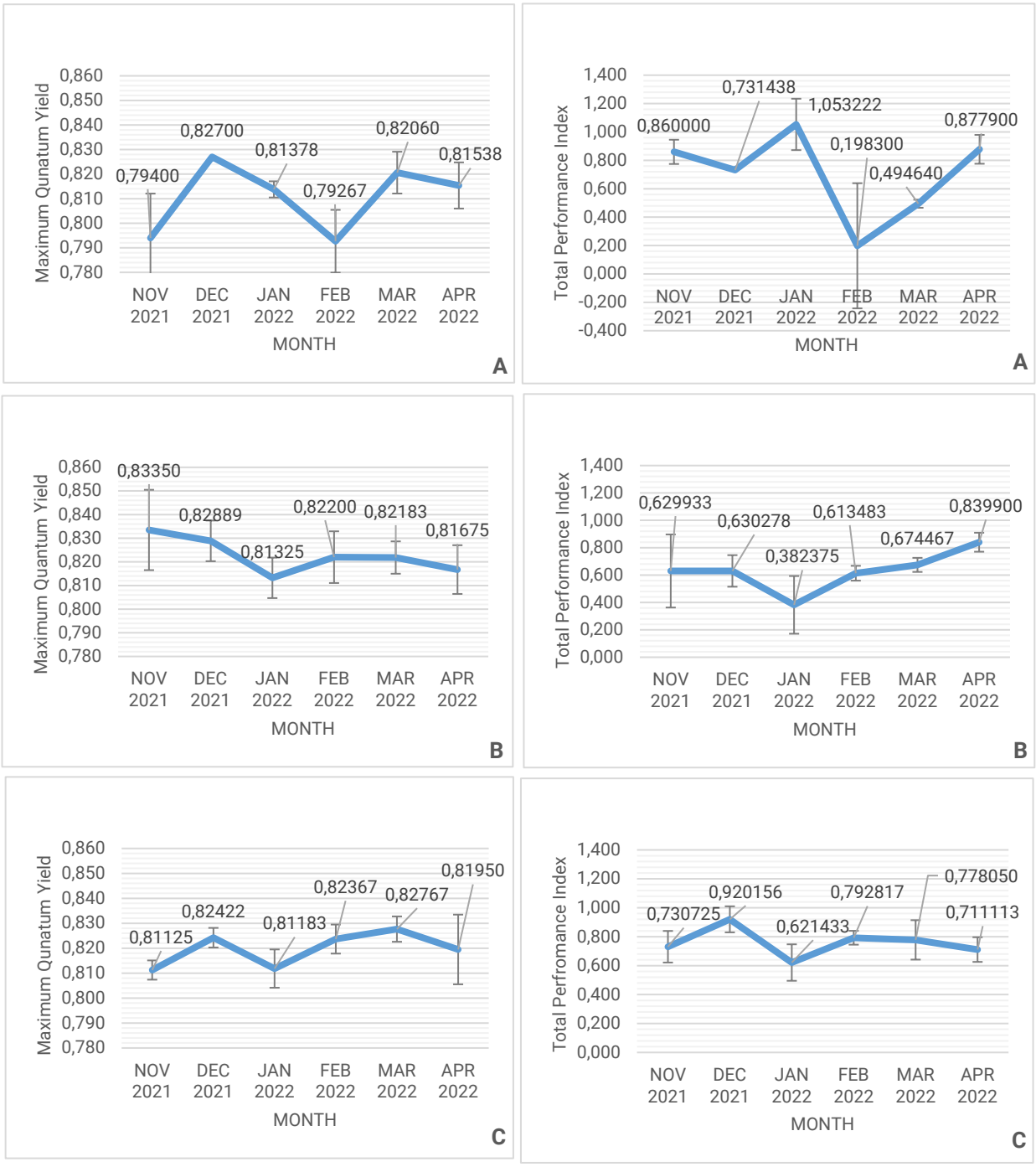


Figure 7.13: A comparison of the maximum quantum yield of photosystem II and total performance index for Mentha aquatica between the three typologies, with (A) the Eco Green Wall, (B) the Vicinity Wall and (C) the natural soil

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i. The maximum quantum yield of photosystem II (F_vF_m)

The one-way ANOVA showed statistically significant differences between months in the maximum quantum yield of *Mentha aquatica* for the Eco Green Wall ($F(5,28) = 6.449$, $p < 0.001$, $np^2 = 0.535$), the Vicinity Wall ($F(5,29) = 2.790$, $p = 0.036$, $np^2 = 0.325$) and the natural soil ($F(5,33) = 4.013$, $p = 0.006$, $np^2 = 0.378$). The maximum quantum yield effect sizes between months for the Eco Green Wall are medium (Cohen, 1988) and regarded as statistically significant. Table 7.17 depicts the crops' mean maximum quantum yield, showing statistically significant differences in monthly combinations in the Eco Green Wall. The table does not include combinations that did not show statistically significant differences. Appendix I contains the statistical analysis of the comparison of crops in the Eco Green Wall.

Table 7.17: Post-hoc results of the significant mean maximum quantum yield differences of Dicliptera clinopodia in the Eco Green Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Dec 2021	-0.03300	0,003495	<0,001
Feb 2022	Dec 2021	-0.034333	0,006784	0,000
Feb 2022	Jan 2022	-0.021111	0,006680	0,028
Feb 2022	Mar 2022	-0.027933	0,007318	0,006
Feb 2022	Apr 2022	-0.022708	0,006784	0,018

The mean total performance index of *Mentha aquatica* in the Eco Green Wall showed statistically significant differences ($p < 0.05$) between November and December, and February, with December, January, March and April.

Effect sizes for the Vicinity Wall and natural soil area are small and statistically insignificant (Cohen, 1988).

The maximum quantum yield values of the crops in the Eco Green Wall declined in January and February 2022 but recovered well in March 2022 (See Figure 7.13). The values in the Vicinity Wall also fell in January 2022, after which it recovered in February 2022.

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ii. Total performance index (PI_{total})

The one-way ANOVA revealed statistically significant differences between months in the total performance index of *Mentha aquatica* for the Eco Green Wall ($F(5,28) = 5.725$, $p < 0.001$, $np^2 = 0.506$), Vicinity Wall ($F(5,29) = 4.233$, $p = 0.005$, $np^2 = 0.422$) and the natural soil area ($F(5,33) = 7.340$, $p < 0.001$, $np^2 = 0.527$). The Vicinity Wall effect size is small and statistically insignificant (Cohen, 1988). However, the effect sizes for the Eco Green Wall and natural soil are medium (Cohen, 1988) and regarded as statistically significant.

Table 7.18 includes the Eco Green Wall month combinations with statistically significant differences determined by Tukey's multicomparison test results. The table does not include combinations that did not show statistically significant differences. Appendix I contains the statistical analysis of the comparison of crops in the Eco Green Wall.

Table 7.18: Post-hoc results of the significant mean total performance index differences of Mentha aquatica in the Eco Green Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Dec 2021	Nov 2021	0.1894306	0,0605616	0,039
Dec 2021	Jan 2022	0.2987222	0,0531160	0,000
Dec 2021	Apr 2022	0.2090431	0,0489705	0,002

The total performance index of the *Mentha aquatica* in the natural soil showed statistically significant ($p < 0.05$) differences between November and December, and December in combination with January 2022 and April 2022.

iii. Possible stress causes considering climate and soil conditions.

The crop's maximum quantum yield showed a statistically significant ($p < 0.05$) negative moderate correlation ($r = -0.368$) with the soil temperature and a statistically significant ($p < 0.05$) moderate negative correlation ($r = -0.591$) with the ambient maximum temperature in the Eco Green Wall. Moreover, the crop's maximum quantum yield showed a statistically significant ($p < 0.05$) moderate positive correlation ($r = 0.533$) with the local relative humidity in the Eco Green Wall.

Also, the total performance index showed statistically significant ($p < 0.05$) moderate negative correlations with the soil EC ($r = -0.376$) and the soil VWC ($r = -0.543$) in the Eco Green Wall. The maximum quantum yield values were low in February 2022 and high in April

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2022, as opposed to the soil temperatures, with the highest value in February 2022 and the lowest in April 2022. The species's total performance index values were the lowest in April 2022, in contrast to the highest EC value in April 2022 in the Eco Green Wall.

The crop's maximum quantum yield in the Vicinity Wall showed a statistically significant positive moderate correlation (r = 0.382) with the VWC and a statistically significant medium negative correlation (r = -0.360) with precipitation. January and February 2022 had the lowest VWC values, similar to the Fv/Fm values, with the highest precipitation in December 2021 and February 2022. Also, the total performance index showed statistically significant negative moderate correlations with precipitation (r = -0.551) and daylength (r = -0.487) and a positive moderate correlation with the soil EC (r = 0.436).

In contrast, the crop's maximum quantum yield in the natural soil showed statistically significant positive moderate correlations with the soil EC (r = 0.398) and VWC (r = 0.508). The total performance index of the crops in the natural soil area showed a moderate positive statistically significant correlation with the soil VWC (r = 0.545). The low EC values in November 2021 and January 2022 explain the plant stress, considering the differences between November and December 2021, December 2021 and April 2022, and December 2021 and January 2022 in the natural soil.

7.3.7 *Portulaca oleracea* (purslane)

Figure 7.14 shows the maximum quantum yield and total performance index values of *Portulaca oleracea* in the three typologies. The Eco Green Wall's mean maximum quantum yield was 0.76597, while the values of the crops in the Vicinity Wall (Fv/Fm = 0.78100) and natural soil (Fv/Fm = 0.77738) were slightly higher. The mean total performance index values were the highest in the crops in the Eco Green Wall (PI_{total} = 2.577811), with the mean values of those in the Vicinity Wall (PI_{total} = 1.870126) and the natural soil (PI_{total} = 1.694945) significantly lower.

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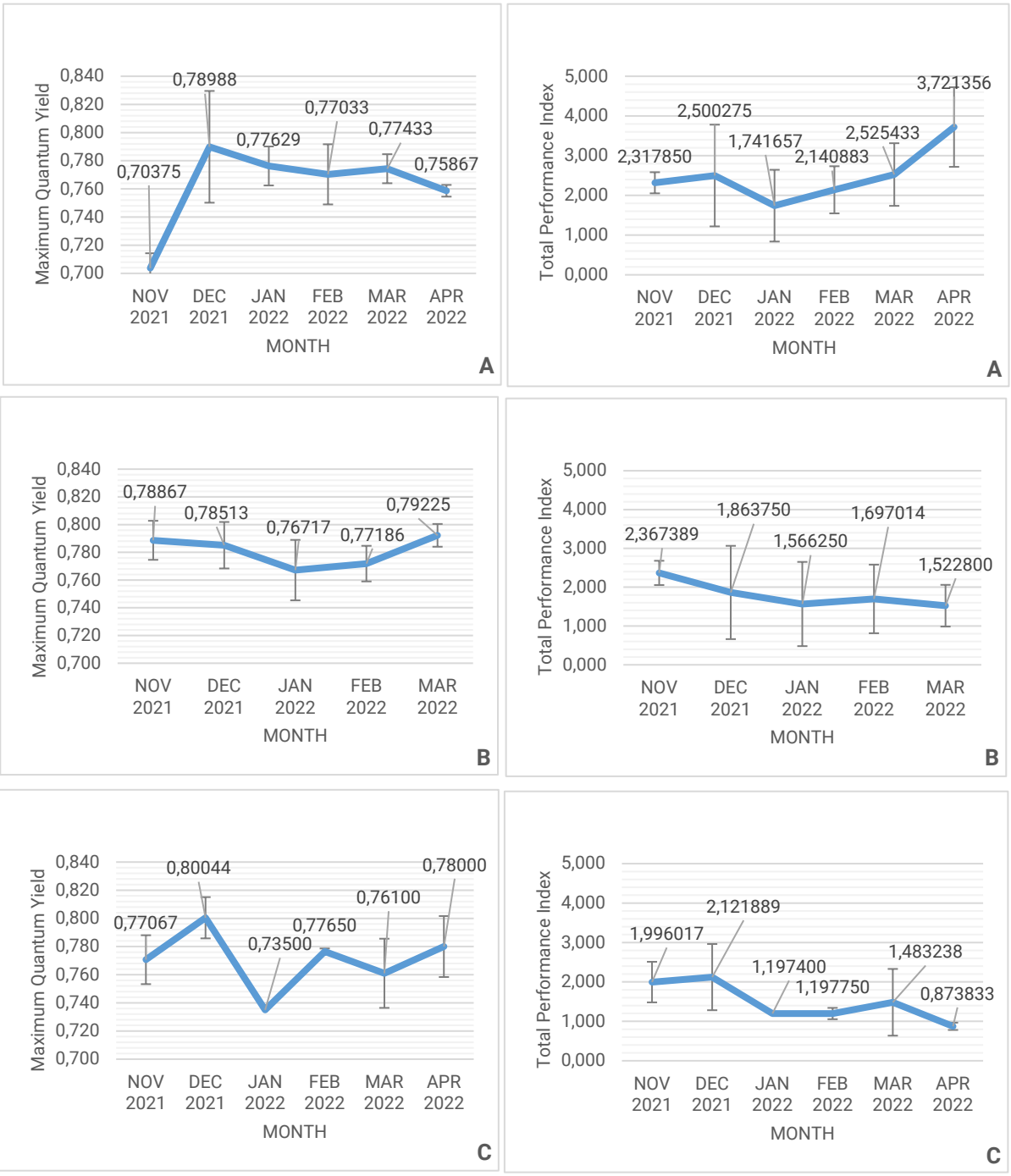


Figure 7.14: A comparison of the maximum quantum yield of photosystem II and total performance index for Portulaca oleracea between the three typologies, with (A) the Eco Green Wall, (B) the Vicinity Wall and (C) the natural soil.

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i. The maximum quantum yield of photosystem II (F_vF_m)

The one-way ANOVA showed statistically significant differences between months in the maximum quantum yield of *Portulaca oleracea* in the Eco Green Wall ($F(5,31) = 9.659$, $p < 0.001$, $np^2 = 0.609$), Vicinity Wall ($F(4,29) = 2.940$, $p = 0.037$, $np^2 = 0.289$) and the natural soil ($F(5,23) = 4.947$, $p = 0.003$, $np^2 = 0.518$). The effect size for the Vicinity Wall is small and statistically insignificant (Cohen, 1988). However, the maximum quantum yield monthly difference effect sizes for the crops in the Eco Green Wall and natural soil were medium (Cohen, 1988) and regarded as statistically significant.

Tables 7.19 and 7.20 present the Eco Green Wall and natural soil month combinations with statistically significant differences determined by Tukey's multicomparison post-hoc test results. The table does not include combinations that did not show statistically significant differences. Appendix I contains the statistical analysis of the comparison of crops in the Eco Green Wall.

Table 7.19: Post-hoc results from significant (p<0.05) mean maximum quantum yield differences of Portulaca oleracea in the Eco Green Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Dec 2021	.086125	0,012953	0,000
Jan 2022	Nov 2021	.072536	0,013257	0,000
Feb 2022	Nov 2021	.066583	0,013653	0,000
Mar 2022	Nov 2021	.070583	0,016155	0,002
Apr 2022	Nov 2021	.054917	0,012711	0,002

The *Portulaca oleracea's* total performance index values in November differed significantly from all months in the experimental study period in the Eco Green Wall. The mean difference was significant at the 0.05 level.

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Table 7.20: Post-hoc results from significant (p<0.05) mean maximum quantum yield differences of Portulaca oleracea in the natural soil, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Jan 2022	Mar 2022	0.018889	0,006255	0,044
Feb 2022	Mar 2022	0.025444	0,006255	0,002

The *Portulaca oleracea*'s November 2021 value in the Eco Green Wall indicates that the plant experienced initial stress (Fv/Fm < 0.75), which recovered in December 2021, with a slight monthly decline. The crops in the natural soil also had a low initial total performance index value, although higher (Fv/Fm > 0.75) than those in the Eco Green Wall. The species recovered in December 2021 but declined sharply in January 2022 (Fv/Fm < 0.75) due to environmental stress, with another recovery in February 2022 in the natural soil area.

ii. Total performance index (PI_{total})

The one-way ANOVA determined statistically significant differences between months in the maximum quantum yield of *Portulaca oleracea* in the Eco Green Wall ($F(5,31) = 2.692$, $p = 0.039$, $np^2 = 0.303$), Vicinity Wall ($F(4,29) = 0.981$, $p = 0.433$, $np^2 = 0.119$) and the natural soil ($F(5,23) = 2.033$, $p = 0.112$, $np^2 = 0.306$). However, the effect sizes in the total performance index between months for all the typologies were small and statistically insignificant (Cohen, 1988).

The total performance index values of *Portulaca oleracea* increased monthly from January 2022 in the Eco Green Wall. However, the Vicinity Wall and natural soil's crop total performance index values decreased monthly, indicating plant stress. In the Eco Green Wall, the total performance index values of *Portulaca oleracea* were higher (mean PI_{total} = 2.577811) than in the other typologies. After a decline in January, the total performance index gradually increased monthly to the highest value in April. The Vicinity Wall's values were lower (mean PI_{total} = 1.870126), with a gradual decrease to the lowest value in March (see Figure 7.14), with the species not surviving after the six months at the end of the experiment. The crops in the natural soil's total performance index values (mean PI_{total} = 1.694945) were the lowest. They declined in January and February, with a gradual recovery in March and dropping to the lowest in April 2022 (see Figure 7.25) and not surviving at the end of the experiment.

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iii. Possible stress causes considering climate and soil conditions

The *Portulaca oleracea*'s maximum quantum yield in the Eco Green Wall showed no statistically significant correlations with the climate and soil variables. In contrast, the Vicinity Wall's maximum quantum yield showed statistically significant ($p < 0.05$) moderate negative correlations with the soil temperature ($r = -0.364$), local maximum temperature ($r = -0.369$), and precipitation ($r = -0.413$), and moderate positive correlations with the soil VWC ($r = 0.436$) and soil EC ($r = 0.491$) (See Appendix L). The species in the natural soil area's maximum quantum yield showed statistically significant correlations with the soil water content (moderate positive $r = 0.417$), soil temperature (moderate positive $r = 0.404$), soil electrical conductivity (moderate negative $r = -0.370$), local minimum temperature (moderate negative $r = -0.445$), and local relative humidity (moderate positive $r = 0.416$).

The total performance index of the crops in the Eco Green Wall showed a moderate positive statistically significant correlation ($p < 0.05$) with the RH ($r = 0.387$) and a moderate negative correlation with precipitation ($r = -0.409$), local minimum temperature ($r = -0.499$), soil temperature ($r = -0.434$) and daylength ($r = -0.493$) (See Appendix M). The Portulaca oleracea in the Vicinity Wall's total performance index showed no statistically significant correlations with soil or climate variables. However, the natural soil showed a medium negative correlation with the EC ($r = -0.372$) and a medium positive correlation with daylength ($r = 0.463$).

Considering possible stress causes (refer to section 6.2.1), the low RH and high precipitation in February could have affected the Eco Green Wall's maximum quantum yield and total performance index. The impact of the soil and ambient temperatures and precipitation was visible in the *Portulaca oleracea* crops in the Vicinity Wall during January and February 2022. A possible explanation could be the natural habitat of *Portulaca oleracea,* which grows naturally in dry environments. The natural soil's EC, VWC, soil temperature, EC, local minimum temperature and RH could impact the crop's maximum quantum yield, with the EC affecting the crop's total performance index. In the natural soil, the Fv/Fm fell drastically below 0.75, indicating plant stress. Due to environmental stress, the species did not cope well. They experienced damage to their photosystem II and, therefore, did not survive in the Vicinity Wall and the natural soil area.

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7.3.8 Portulacaria afra prostrata (dwarf elephant's food)

Considering the maximum quantum yield, the *Portulacaria afra* prostrata performed exceptionally well in the Vicinity Wall (Fv/Fm = 0.84414) and the Eco Green Wall (Fv/Fm = 0.83511). The *Portulaca afra* prostrata crops in the natural soil (Fv/Fm = 0.83100) had the lowest maximum quantum yield value of all typologies.

Figure 7.15 compares the maximum quantum yield and total performance index for *Portulacaria afra* prostrata between the typologies. The total performance index in the Eco Green Wall was the highest (mean PI_{total} = 1.763447) in the LWSs, with a decline from November 2021 to February 2022 and a recovery in March and April 2022. The Vicinity Wall's values were lower (mean PI_{total} = 1.731368) and declined from November 2021 to April 2022. The natural soil's total performance index values (mean PI_{total} = 1.950009) were the highest. However, values sharply decreased in January, gradually recovering in February and March 2022 and dropping again in April 2022.

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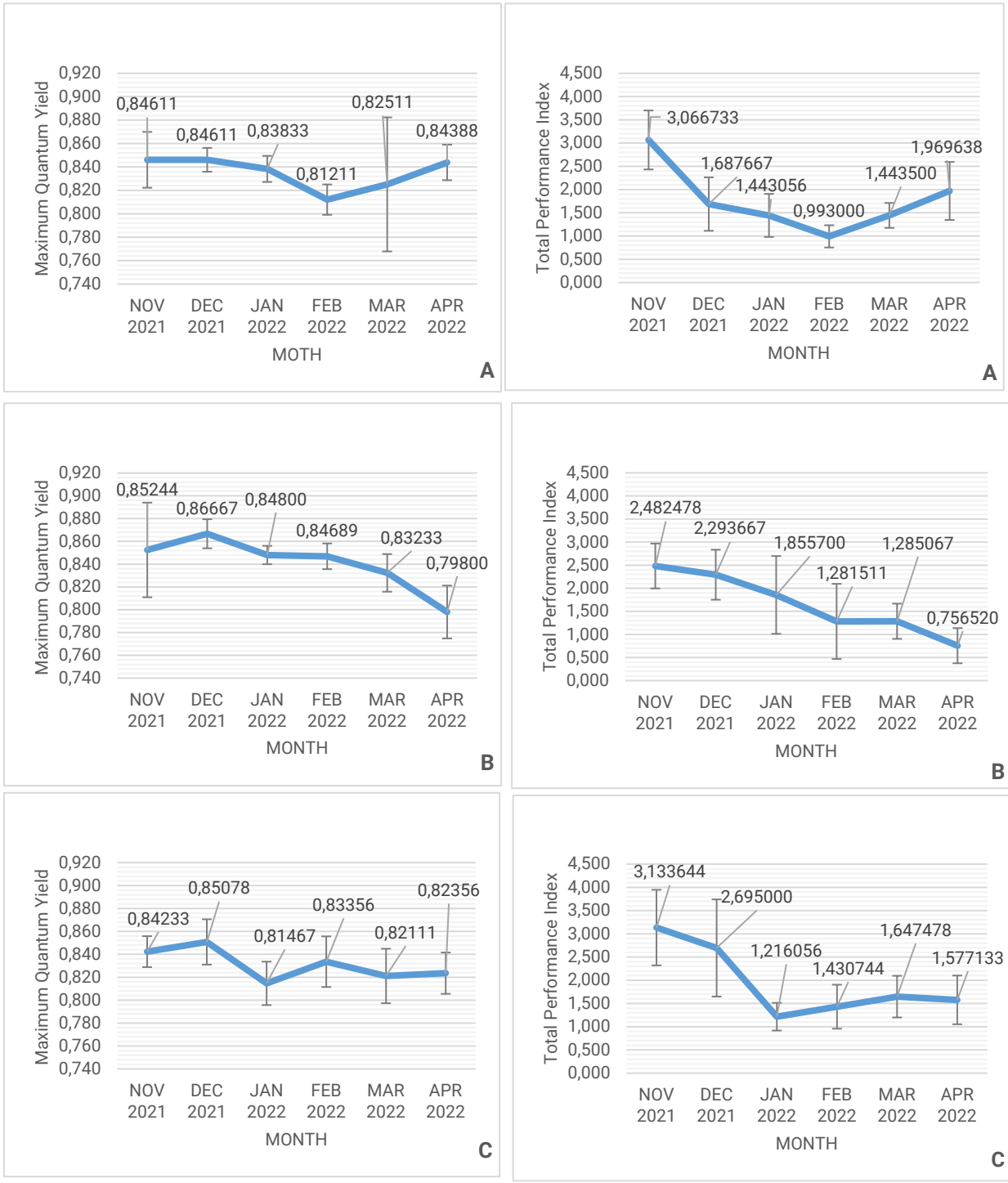


Figure 7.15: A comparison of the maximum quantum yield of photosystem II and total performance index for Portulacaria afra prostrata between the three typologies, with (A) the Eco Green Wall, (B) the Vicinity Wall and (C) the natural soil

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i. The maximum quantum yield of photosystem II (F_vF_m)

The one-way ANOVA determined statistically significant differences between months in the maximum quantum yield of *Portulacaria afra* prostrata for the Eco Green Wall ($F(5,47) = 2.499$, $p = 0.044$, $np^2 = 0.210$), Vicinity Wall ($F(5,44) = 7.039$, $p < 0.001$, $np^2 = 0.444$) and the natural soil ($F(5,48) = 4.420$, $p = 0.002$, $np^2 = 0.315$). However, the effect sizes for all typologies are small (Cohen, 1988) and statistically insignificant.

A gradual decline in the Fv/Fm values in the Vicinity Wall indicates that the species experienced stress during the experimental study.

ii. Total performance index (PI_{total})

The one-way ANOVA determined statistically significant differences between months in the maximum quantum yield of *Portulacaria afra* prostrata for the Eco Green Wall ($F(5,47) = 2.499$, $p < 0.001$, $np^2 = 0.669$), Vicinity Wall ($F(5,44) = 7.039$, $p < 0.001$, $np^2 = 0.508$) and the natural soil ($F(5,48) = 12.713$, $p < 0.001$, $np^2 = 0.570$). The effect sizes for all the typologies are medium and statistically significant (Cohen, 1988).

Appendix I, Appendix J and Appendix K contain the statistical analysis of the comparison of crops in the typologies. The mean difference was significant at the 0.05 level. Tables 7.21, 7.22 and 7.23 present the Eco Green Wall, Vicinity Wall and natural soil month combinations with statistically significant differences in total performance index determined by Tukey's multicomparison post-hoc test results. The tables do not include combinations that did not show statistically significant differences.

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Table 7.21: Post-hoc results from significant (p<0.05) mean total performance index differences of Portulacaria afra prostrata in the Eco Green Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Dec 2021	1.3790667	0,2315291	0,000
Nov 2021	Jan 2022	1.6236778	0,2315291	0,000
Nov 2021	Feb 2022	2.0737333	0,2315291	0,000
Nov 2021	Mar 2022	1.6232333	0,2315291	0,000
Nov 2021	Apr 2022	1.0970958	0,2386548	0,000
Dec 2021	Feb 2022	0.6946667	0,2315291	0,046
Apr 2022	Feb 2022	0.9766375	0,2386548	0,002

The *Portulacaria afra* prostrata PI_{total} values of November differed significantly from all months in the experimental study period in the Eco Green Wall. The PI_{total} in the Eco Green Wall also showed statistically significant differences between December 2021, February 2022 and February and April 2022.

Table 7.22: Post-hoc results from significant (p<0.05) mean total performance index differences of Portulacaria afra prostrata in the Vicinity Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Feb 2022	1.2009667	0,2833026	0,001
Nov 2021	Mar 2022	1.1974111	0,2833026	0,002
Nov 2021	Apr 2022	1.7259578	0,3352081	0,000
Dec 2021	Feb 2022	1.0121556	0,2833026	0,011
Dec 2021	Mar 2022	1.0086000	0,2833026	0,011
Dec 2021	Apr 2022	1.5371467	0,3352081	0,001
Jan 2022	Apr 2022	1.0991800	0,3352081	0,023

The *Portulacaria afra* prostrata PI_{total} values of November and December differed significantly from February, March and April 2022 in the Vicinity Wall. The PI_{total} in the Vicinity Wall also showed statistically significant differences between January and April 2022.

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Table 7.23: Post-hoc results from significant (p<0.05) mean total performance index differences of Portulacaria afra prostrata in the natural soil, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Jan 2022	1.9175889	0,3069668	0,000
Nov 2021	Feb 2022	1.7029000	0,3069668	0,000
Nov 2021	Mar 2022	1.4861667	0,3069668	0,000
Nov 2021	Apr 2022	1.5565111	0,3069668	0,000
Dec 2021	Jan 2022	1.4789444	0,3069668	0,000
Dec 2021	Feb 2022	1.2642556	0,3069668	0,002
Dec 2021	Mar 2022	1.0475222	0,3069668	0,016
Dec 2021	Apr 2022	1.1178667	0,3069668	0,008

The *Portulacaria afra prostrata* PI_{total} values of November and December 2021 differed significantly from January, February, March and April 2022 in the natural soil.

iii. Possible stress causes considering climate and soil conditions

The maximum quantum yield of *Portulacaria afra* prostrata in the Eco Green Wall showed statistically significant correlations ($p < 0.05$) with the soil temperature (medium negative $r = -0.317$), local maximum temperature (medium negative $r = -0.301$), and local relative humidity (moderate positive $r = 0.321$) (See Appendix L). The maximum quantum yield showed statistically significant correlations ($p < 0.05$) with the local minimum temperature (weak positive $r = 0.298$) and daylength (moderate positive $r = 0.627$) in the Vicinity Wall. The maximum quantum yield and the local minimum temperature ($r = -0.351$) showed a statistically significant moderate negative correlation in the natural soil.

The total performance index showed a moderate negative statistically significant correlation with precipitation ($r = -403$) in the Eco Green Wall. However, the Vicinity Wall's total performance index showed a weak positive statistically significant correlation with the soil VWC ($r = 0.320$) and a moderate positive statistically significant correlation with daylength ($r = 0.524$)(See Appendix M). Weak negative significant correlations between the total performance index and the local maximum temperature ($r = -0.322$) and soil temperature ($r = -0.318$) are evident in the natural soil. The crop's total performance index showed a moderate negative correlation with soil EC ($r = -0.358$) and local minimum temperature ($r = -0.634$).

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Portulacaria afra prostrata performed optimally in the Eco Green Wall. The dry spell in January did not affect the photosystem II, despite the Fv/Fm correlations with maximum and soil temperatures and RH. The plants in the Vicinity Wall also did not experience stress, and the photosystem II still functioned well despite a gradual decline of the Fv/Fm and PI_{total} values. The local minimum temperature caused stress in the Vicinity Wall. The maximum, minimum and soil temperatures in the natural soil induced plant stress, and plants survived but were stunted.

7.3.9 Spinacea oleracea (Control crop) (spinach)

Figure 7.16 compares the maximum quantum yield of photosystem II and total performance index values for *Spinacea oleracea* between the typologies. *Spinacea oleracea* performed exceptionally well in the natural soil (Fv/Fm = 0.832540). However, the species showed visual stress signs in the Eco green (Fv/Fm = 0.81932) and Vicinity Walls (Fv/Fm = 0.82350). In the two LWSs, the plants stayed stunted compared to the natural soil plant sizes. A gradual decline in the Fv/Fm values in the Eco Green Wall from December 2021 to March 2022 indicates that the *Spinacea oleracea* experienced stress during the experimental study. The Fv/Fm values in the Vicinity Wall declined from November, with slight recoveries in February and April 2022.

The natural soil had the highest total performance index values (mean PI_{total} = 1.480177). The PI_{total} values in the Vicinity Wall were higher (mean PI_{total} = 0.980029) than those in the Eco Green Wall (mean PI_{total} = 0.891323).

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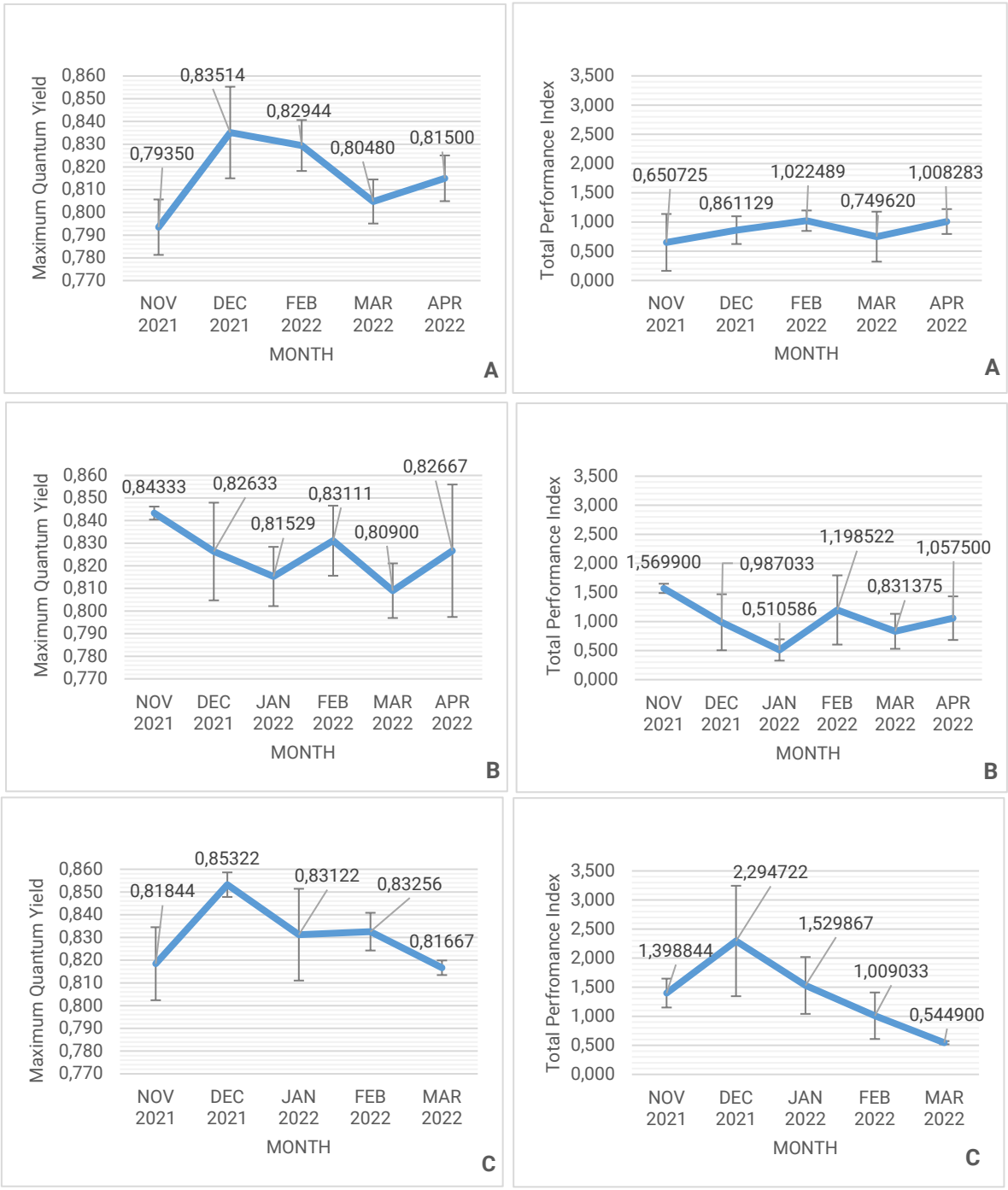


Figure 7.16: A comparison of the maximum quantum yield of photosystem II and total performance index for Spinacea oleracea between the three typologies, with (A) the Eco Green Wall, (B) the Vicinity Wall and (C) the natural soil

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i. The maximum quantum yield of photosystem II (F_vF_m)

The one-way ANOVA determined statistically significant differences between months in the maximum quantum yield of *Spinacea oleracea* for the Eco Green Wall ($F(4,26) = 9.647$, $p < 0.001$, $np^2 = 0.597$), Vicinity Wall ($F(5,36) = 2.179$, $p = 0.037$, $np^2 = 0.232$) and the natural soil ($F(4,34) = 8.890$, $p < 0.001$, $np^2 = 0.511$). The effect size for the Vicinity Wall is small and statistically insignificant (Cohen, 1988). However, the effect sizes for the Eco Green Wall and natural soil are medium (Cohen, 1988) and statistically significant.

Tables 7.24 and 7.25 present the Eco Green Wall and natural soil month combinations with statistically significant differences in the mean maximum quantum yield revealed by Tukey's multicomparison post-hoc tests. The tables do not include combinations that did not show statistically significant differences.

Table 7.24: Post-hoc results from significant (p<0.05) mean maximum quantum yield differences of Spinacea oleracea in the Eco Green Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Dec 2021	Nov 2021	0.041643	0,008140	0,000
Dec 2021	Mar 2022	0.030343	0,007604	0,004
Feb 2022	Nov 2021	0.035944	0,007804	0,001
Feb 2022	Mar 2022	0.024644	0,007244	0,017

Table 7.25: Post-hoc results from significant (p<0.05) mean maximum quantum yield differences of Spinacea oleracea in the natural soil, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Dec 2021	Nov 2021	0.034778	0,006329	0,000
Dec 2021	Jan 2022	0.022000	0,006329	0,012
Dec 2021	Feb 2022	0.020667	0,006329	0,020
Dec 2021	Mar 2022	0.036556	0,008950	0,002

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ii. Total performance index (PI_{total})

The one-way ANOVA determined statistically significant differences between months in the maximum quantum yield of *Spinacea oleracea* for the Eco Green Wall ($F(4,26) = 1.644$, $p < 0.193$, $np^2 = 0.202$), Vicinity Wall ($F(5,36) = 3.915$, $p = 0.006$, $np^2 = 0.352$) and the natural soil ($F(4,34) = 8.318$, $p < 0.001$, $np^2 = 0.495$). The effect sizes for the LWS typologies are small (Cohen, 1988) and not statistically significant. However, the effect size for the natural soil is medium (Cohen, 1988) and thus statistically significant.

Appendix G contains the statistical analysis of the comparison of crops in the typologies. The mean difference was significant at the 0.05 level. Table 7.26 presents the natural soil month combinations with statistically significant differences in total performance index determined by Tukey's multicomparison post-hoc test results. The table does not include combinations that did not show statistically significant differences.

Table 7.26: Post-hoc results from significant ($p<0.05$) mean total performance index differences of Spinacea oleracea in the natural soil, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Dec 2021	Nov 2021	0.8958778	0,2670196	0,016
Dec 2021	Feb 2022	1.2856889	0,2670196	0,000
Dec 2021	Mar 2022	1.7498222	0,3776228	0,000

The *Spinacea oleracea December* PI_{total} values differed significantly in the natural soil from November 2021, February and March 2022.

iii. Possible stress causes considering climate and soil conditions

The maximum quantum yield showed a medium positive ($r = 0.372$) statistically significant correlation with precipitation in the Eco Green Wall (See Appendix L). In the Vicinity Wall, the maximum quantum yield showed no statistically significant correlations with climate and soil variables. In the natural soil, the soil water content (moderate positive $r = 0.359$), local RH (moderative positive $r = 0.459$) and daylength (moderate positive $r = 0.505$) showed statistically significant correlations with the maximum quantum yield.

The natural soil's total performance index showed medium negative statistically significant correlations with the maximum ($r = -0.357$) and minimum ($r = -0.359$) temperatures, soil temperature ($r = -0.451$), soil EC ($r = -0.505$) and precipitation ($r = -0.330$). A moderate

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positive statistically significant correlation was shown between the total performance index and daylength (r = 0.615) (See Appendix M). However, the total performance index in the Eco Green Wall showed no statistically significant correlations with the climate and soil variables. The Vicinity Wall's total performance index showed a moderate negative statistically significant correlation ($p < 0.05$) with precipitation (r = -0.472).

The decline in Fv/Fm and PI_{total} in the natural soil confirms the reason for the crop's stress as seasonal related and the species's leaves going dormant after the growing season. The VWC, EC, soil temperature, maximum and minimum temperatures and precipitation caused the *Spinacea oleracea's* plant stress in the natural soil area. The daylength correlation in the natural soil highlights the crop's growing period.

7.3.10 Vigna unguiculata (black eyed pea)

Figure 7.17 compares the maximum quantum yield of photosystem II for Vigna unguiculata between the typologies. *Vigna unguiculata* performed optimally in all the typologies, with the Vicinity Wall (Fv/Fm = 0.81340) having the highest mean value, followed by the Eco Green Wall (Fv/Fm = 0.80853). The natural soil (Fv/Fm = 0.80590) had the lowest value.

The Eco Green Wall (PI_{total} = 2.0262467) had the highest mean total performance index values, followed by the natural soil (PI_{total} = 1.871443) and the Vicinity Wall (PI_{total} = 1.820793).

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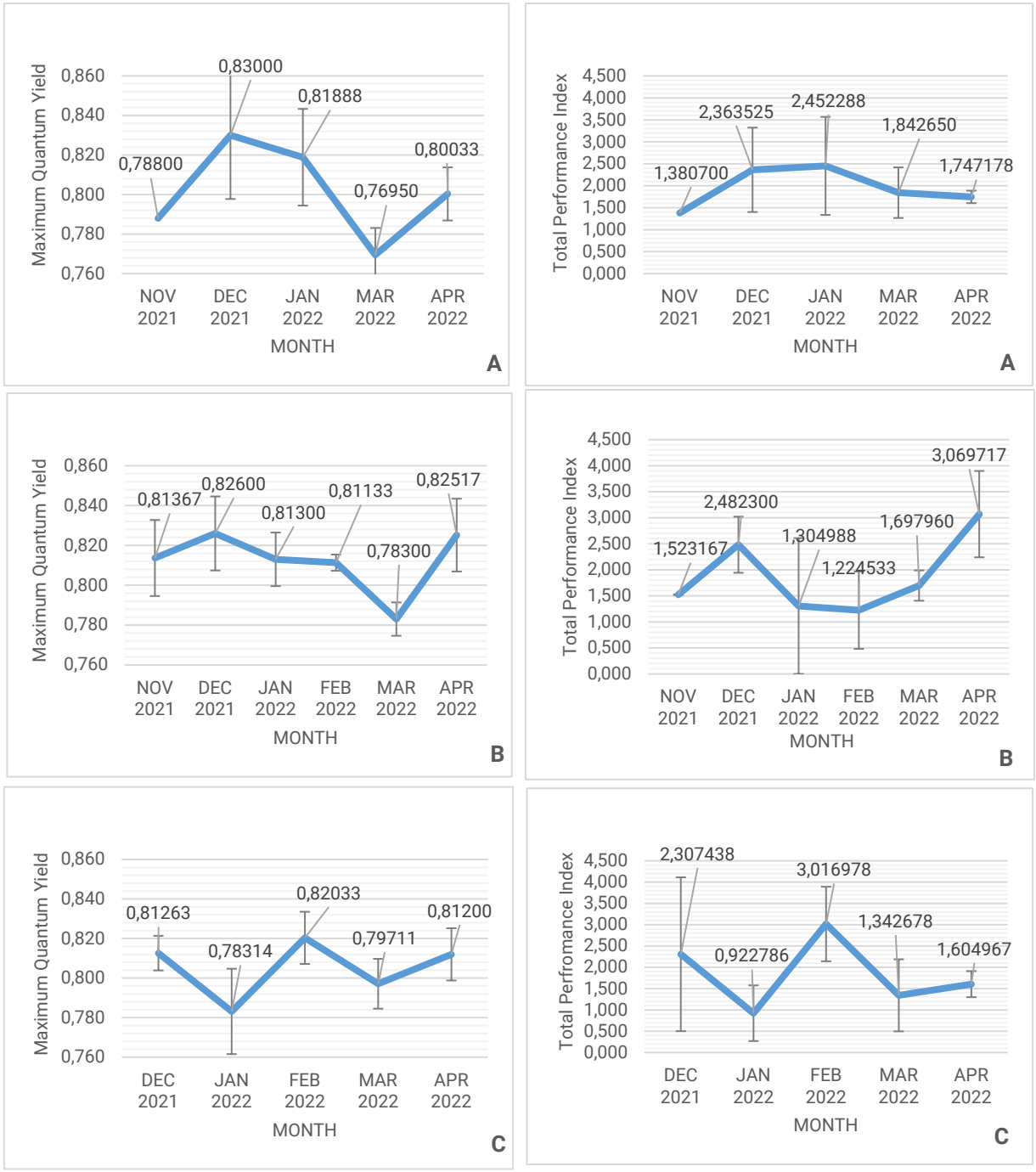


Figure 7.17 A comparison of the maximum quantum yield of photosystem II and total performance index for Vigna unguiculata between the three typologies, with (A) the Eco Green Wall, (B) the Vicinity Wall and (C) the natural soil

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i. The maximum quantum yield of photosystem II (F_vF_m)

The one-way ANOVA determined statistically significant differences between months in the maximum quantum yield of *Vigna unguiculata* for the Eco Green Wall ($F(4,27) = 5.686$, $p = 0.002$, $np^2 = 0.457$), Vicinity Wall ($F(5,39) = 7.783$, $p < 0.001$, $np^2 = 0.499$) and the natural soil ($F(4,37) = 8.625$, $p < 0.001$, $np^2 = 0.483$). The effect sizes for all typologies are medium (Cohen, 1988) and statistically significant.

Tables 7.27, 7.28 and 7.29 present the Eco Green Wall, Vicinity Wall and natural soil month combinations, showing statistically significant differences in the mean maximum quantum yield revealed by Tukey's multicomparison post-hoc tests. The tables do not include combinations that did not show statistically significant differences.

Table 7.27: Post-hoc results from significant (p<0.05) mean maximum quantum yield differences of Vigna unguiculata in the Eco Green Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Dec 2021	Nov 2021	0.042000	0,012134	0,014
Dec 2021	Mar 2022	0.060500	0,016827	0,010
Jan 2021	Mar 2022	0.049375	0,016827	0,049

Table 7.28: Post-hoc results from significant (p<0.05) mean maximum quantum yield differences of Vigna unguiculata in the Vicinity Wall, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Nov 2021	Mar 2022	0.030667	0,007353	0,002
Dec 2021	Mar 2022	0.043000	0,007515	0,000
Jan 2022	Mar 2022	0.030000	0,007515	0,004
Feb 2022	Mar 2022	0.028333	0,007353	0,005
Apr 2022	Mar 2022	0.042167	0,007982	0,000

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Table 7.29: Post-hoc results from significant (p<0.05) mean maximum quantum yield differences of Vigna unguiculata in the natural soil, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Dec 2021	Jan 2022	0.029482	0,007315	0,002
Feb 2022	Jan 2022	0.037190	0,007123	0,000
Feb 2022	Mar 2022	0.023222	0,006663	0,011
Apr 2022	Jan 2022	0.028857	0,007123	0,002

ii. Total performance index (PI_{total})

The one-way ANOVA determined statistically significant differences between months in the maximum quantum yield of *Vigna unguiculata* for the Eco Green Wall ($F(4,26) = 1.644$, $p < 0.193$, $np^2 = 0.202$), Vicinity Wall ($F(5,36) = 3.915$, $p = 0.006$, $np^2 = 0.352$) and the natural soil ($F(4,34) = 8.318$, $p < 0.001$, $np^2 = 0.495$). The effect sizes for the LWS typologies are small (Cohen, 1988) and not statistically significant. However, the effect size for the natural soil is medium (Cohen, 1988) and thus statistically significant.

Table 7.30 presents the natural soil month combinations with statistically significant differences in the mean total performance index revealed by Tukey's multicomparison post-hoc tests (See Appendix K). The table does not include combinations that did not show statistically significant differences.

Table 7.30: Post-hoc results from significant (p<0.05) mean total performance index differences of Vigna unguiculata in the natural soil, based on the mean difference between months

Month A	Month B	Mean Difference (A - B)	Standard Error	Significance
Feb 2022	Jan 2022	2.0941921	0,5104305	0,002
Feb 2022	Mar 2022	1.6743000	0,4774640	0,010
Feb 2022	Apr 2022	1.4120111	0,4774640	0,040

The *Vigna unguiculata* February PI_{total} values differed significantly from January, March and April 2022 in the natural soil.

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iii. Possible stress causes considering climate and soil conditions

The *Vigna unguiculata*'s maximum quantum yield showed a statistically significant medium negative (r = -0.384) correlation with the local maximum temperature and a positive medium correlation (r = 0.392) with daylength in the Eco Green Wall (See Appendix L). In the Vicinity Wall, the soil temperature (weak negative; r = -0.307) and local minimum temperature (moderate negative; r = -0.469) showed statistically significant correlations with the maximum quantum yield. In the natural soil area, the maximum quantum yield showed a statistically significant ($p < 0.05$) moderate positive correlation with the local maximum temperature (r = 0.354) and, precipitation (r = 0.384) and VWC (r = 0.467).

The total performance index showed a moderate positive correlation (r = 0.361) with precipitation in the Eco Green Wall. In the Vicinity Wall, the total performance index showed statistically significant correlations with soil VWC (moderate positive r = 0.365), soil temperature (moderate negative r = -0.507), soil EC (moderate positive r = 0.410), RH (moderate positive r = 0.529), minimum temperature (moderate negative r = -0.492), maximum temperature (moderate negative r = -0.520) and daylength (weak negative r = -0.304). Significant correlations of the total performance index in the natural soil area were also evident with local relative humidity (weak negative r = -0.333), precipitation (moderate positive r = 0.498), and maximum temperature (moderate positive r = 0.461) (See Appendix M).

The February difference from other months could be attributed to the short growing period of the plant and its leaves going into a dormant phase. The maximum soil temperatures were highest in February during the experimental study period.

7.4 Discussion

The maximum quantum yield of photosystem II (Fv/Fm) and total performance index (PI_{total}) measure the crops' photosynthetic efficiency. The maximum quantum yield of photosystem II (Fv/Fm) declines under the most stressful conditions. These conditions can include extended drought stress periods (Kalaji et al., 2017) and high-temperature stress or leaf senescence (Kalaji et al., 2017; Lu et al., 2002; Kotakis et al., 2014). Therefore, the maximum quantum yield of photosystem II (Fv/Fm) is regarded as a critical plant stress indicator before the appearance of any visual traces of plant stress (Kim et al., 2019). The total performance index (PI_{total}), which can only be measured within the same species, is a

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photosynthetic performance indicator that combines biophysical parameters and strongly correlates with plant growth, health, and survival rate (Yusuf et al., 2010; Berner et al., 2021; Maliba et al., 2019). The three typologies are first compared based on the plant stress findings, after which the crops are discussed regarding their suitability for LWSs.

7.4.1 The three typologies

Considering the mean crop maximum quantum yield of photosystem II and total performance index of the three typologies over the entire study period, the maximum quantum yield of photosystem II between the crops grown in the Eco Green Wall (See Table 7.1) shows a statistically significant difference with the crops grown in the natural soil. This implies that the crops in the Eco Green Wall experienced stress compared to the crops in the natural soil. Plant stress can be linked to temperature extremes or dry spells. However, the literature argues that the maximum quantum yield of photosystem II is associated with high-temperature stress, leaf senescence, and only extended drought stress periods (Kalaji et al., 2017; Lu et al., 2002; Kotakis et al., 2014). Five crops showed the lowest maximum quantum yield of photosystem II values in March 2022, with four crops in January 2022 and three in February 2022 having the lowest maximum quantum yield of photosystem II values.

Table 7.31 summarises the abiotic conditions for the Eco Green Wall, with the most adverse conditions highlighted in orange.

Table 7.31: Summary of abiotic factors that could have contributed to the plant stress in the Eco Green Wall based on the Fv/Fm values

	Jan	Feb	March
Max temp	33.7℃	37℃	34.1℃
Precipitation	156mm	139mm	80mm
RH	72.61%	66.07%	77.08%
Soil temp	22.7℃	23.7℃	23.2℃
Soil VWC	0.143m^3/m^{-3}	0.245m^3/m^{-3}	0.275m^3/m^{-3}
Soil EC	0.059Ms/cm	0.067 Ms/cm	0.217 Ms/cm

The soil EC, which impacts yields due to the soil salinity, indicates the soil nutrient uptake and moisture content. In January, the soil EC and VWC reached the lowest levels in the Eco Green Wall. These levels can be explained by the irrigation malfunction in January. January had high rainfall and lower maximum temperatures, which might have assisted in the crops' survival. The EC of the Eco Green living wall was significantly lower than the natural soil's

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EC levels. Therefore, it can be assumed that the plant stress of crops in the Eco Green Wall, depicted by the low maximum quantum yield of photosystem II mean values, results from the irrigation malfunction in January 2022, leading to available water content stress. *Portulaca oleracea* (purslane) was the only crop with an Fv/Fm level below the threshold level of 0.75, which was accepted as an indication of photosystem damage for this study (Kim et al., 2019). Photosystem damage occurs when the conversion of light energy to chemical energy is inhibited, and the cellular energy source, Adenosine triphosphate (ATP), cannot be produced, affecting growth and yield (Cooper and Hausman, 2007). Therefore, although the Eco Green Wall's crops experienced stress, the plants still coped with their environmental conditions and stresses, and their photosynthetic apparatuses were not damaged, except for the *Portulaca oleracea*.

In contrast, the total performance index (PI_{total}) reveals a statistically significant difference between the crops in the Eco Green Wall and the Vicinity Wall ($p = 0.002$), and the Vicinity Wall also showed statistically significant lower PI_{total} values than the natural soil (See Table 7.2). The PI_{total} is a photosynthetic performance indicator that combines biophysical parameters and strongly correlates with plant growth, health, and survival rate (Yusuf et al., 2010; Berner et al., 2021; Maliba et al., 2019). The PI_{total} can, therefore, only be measured across species, and the trend in PI_{total} values over a period is a good indicator of plant vitality. Five crops showed the lowest PI_{total} values in January 2022, with three crops in November 2021 and February 2022, respectively, having the lowest Fv/Fm values.

Table 7.32 summarises the abiotic factors that could have contributed to the plant stress in the Vicinity Wall based on the PI_{total} values during these months, with the most adverse conditions highlighted in orange.

Table 7.32: Summary of abiotic factors that could have contributed to the plant stress in the Vicinity Wall based on the Fv/Fm values

	November	January	March
Max temp	36.6°C	34.4°C	37.5°C
Precipitation	127mm	156mm	80mm
RH	72.79%	71.8%	66.6%
Soil temp	22.7°C	22.7°C	23.7°C
Soil VWC	0.243 m^3/m^{-3}	0.143m^3/m^{-3}	0.245m^3/m^{-3}
Soil EC	0.212 Ms/cm	0.226 Ms/cm	0.000 Ms/cm

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The soil EC, which impacts yields due to the soil salinity, indicates the soil nutrient uptake and moisture content. The soil EC and VWC reached the lowest levels in the Vicinity Wall in January and March, respectively. These levels can be explained by the irrigation malfunction in January. Therefore, it can be assumed that the plant stress of the Vicinity Wall's crops, depicted by the low PI_{total} mean values, results from the irrigation malfunction in January 2022, leading to available water content stress. All the crops, except for the *Amaranthus thunbergia* (pigweed), survived in the Vicinity Wall. Therefore, although the Vicinity Wall's crops experienced more stress than crops in the Eco Green Wall and natural soil, the plants still coped with their environmental conditions and stresses, and their photosynthetic apparatuses were not damaged.

7.4.2 The crops

Considering the mean crop maximum quantum yield (Fv/Fm) values compared across the three typologies, the PSII of *Coleus amboinicus*, *Portulacaria afra* prostrata, *Spinacea oleracea*, *Mentha aquatica and Vigna unguiculata* functioned at a higher optimum than the other crops in the Eco green and Vicinity Walls. *Corchorus confusus* and *Asystasia gangetica* performed at a higher optimum in the Vicinity Wall than the other crops. In the natural soil, the PSII of *Coleus amboinicus, Portulacaria afra* prostrata, *Corchorus confusus, Spinacea oleracea*, and *Mentha aquatica* functioned at a higher optimum than the other crops. Although statistical differences existed between the maximum quantum yield of different crops, the effect sizes were small (Cohen, 1988) and can be considered statistically insignificant. The crops' overall vitality (Fv/Fm > 0.75) indicated that they coped with the environmental circumstances in all typologies. However, *Amaranthus thunbergii* did not survive in the Eco Green Wall and Vicinity Walls and the natural soil, and *Portulaca oleracea* did not survive in the natural soil. As seven species functioned at a higher optimum in the Vicinity Wall compared to the Eco Green Wall and natural soil with five species functioning optimally, the Vicinity Wall can be considered more suitable for plant vitality concerning the mean crop maximum quantum yield.

Regarding the total performance index, the *Asystasia gangetica, Dicliptera clinopodia, Mentha aquatica, Coleus amboinicus, Portulacaria afra* prostrata, and *Vigna unguiculata* coped exceptionally well with their environmental conditions in all three typologies.

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However, the crops' photosystems were inhibited due to seasonal-related causes, with the *Vigna unguiculata*'s leaves going dormant after seeding.

The control crop, *Spinacea oleracea*, coped with the environmental conditions in all three typologies. Still, the crop's stress was seasonally related, and the species's leaves went dormant after the growing season. The *Spinacea oleracea* also experienced stress directly associated with rain, which explains the plant's stress during dry spells.

Statistically significant positive correlations with the maximum quantum yield in the Eco Green Wall included RH for *Dicliptera clinopodia* and *Portulaca oleracea*, precipitation for *Spinacea oleracea,* and daylength for *Vigna unguiculata*. In contrast, statistically significant negative correlations with the maximum quantum yield included soil temperature and EC for *Mentha aquatica* and maximum temperature for *Vigna unguiculata*. The total performance index correlations with all soil variables point to the soil conditions contributing to stress in the PSII of *Corchorus confusus.* Also, the negative correlations of the maximum quantum yield with the soil temperature and EC confirm the soil conditions as the stress caused affecting *Mentha aquatica's* performance. The materiality and design of the Eco Green Wall seem to be beneficial concerning minimum ambient temperature, as the findings showed no minimum temperature correlations.

Amaranthus thunbergii had a zero per cent survival rate in all typologies at the end of the experimental study, with significant climate and soil stress causes, except for precipitation in the Vicinity LWS and soil temperature in the natural soil. Another crop that did not cope with the environmental conditions was *Portulaca oleracea*. This crop only survived in the Eco Green Wall, and the total performance index correlations of *Portulaca oleracea* with RH and precipitation indicate stress caused by the environment's rainfall and RH. However, the succulent has a short lifecycle of 60 to 75 days (Ajay et al., 2021), which could be why it did not survive.

Except for the *Vigna unguiculata* Fv/Fm and maximum temperature correlation, which confirms the crop's decline in PSII related to seasonal growth, *Portulaca oleracea* and *Dicliptera clinopodia* showed correlations with maximum and minimum temperature, respectively. Statistically significant positive maximum quantum yield and VWC correlations in the *Mentha aquatica* point to the VWC balance as essential for the crop.

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Statistically significant positive maximum quantum yield and VWC correlations in the *Spinacea oleracea* point to the VWC as an essential factor, including the maximum and minimum temperatures and precipitation affecting the crop's PI_{total}.

In conclusion, all three typologies created favourable environmental conditions for producing TAV crops. Considering the crops' PSII, the *Coleus amboinicus*, *Portulacaria afra* prostrata, *Spinacea oleracea*, *Mentha aquatica, and Vigna unguiculata* performed the best in the Eco green and Vicinity Walls. Additionally to these *species, the Corchorus confusus and Asystasia gangetica* also performed well in the Vicinity Wall. In the natural soil, *Coleus amboinicus, Portulacaria afra* prostrata, *Corchorus confusus, Spinacea oleracea*, and *Mentha aquatica* functioned at a higher optimum than the other crops. With more statistically significant correlations in the soil relating to temperature, VWC and EC than the two LWSs, it can be assumed that the natural soil is more exposed to external factors, with the Eco Green Wall affected more by soil factors and the Vicinity Wall influenced more by ambient climate factors.

7.5 Conclusions

The Vicinity and Eco Green Walls supported plant vitality regarding the most suitable typologies for producing TAV crops. However, vitality was not as high as the crops in the natural soil. The Eco Green Wall experienced plant stress during dry spells, especially concerning EC sensitivity and VWC. This could relate to the Eco Green Wall's soil volume, which is half of the volume of the pots in the Vicinity Wall. The Vicinity Wall also showed plant stress during dry spells. However, the EC and VWC levels fell more gradually based on external interferences, such as the dry spell in January.

Based on statistically significant correlations, the Eco Green Wall retains ambient and soil temperatures better than the Vicinity Wall. This could relate to the design of the Eco Green Wall, where the seed trays (pots) are less exposed than the Vicinity design, where the pots are fully exposed, resulting in higher maximum and lower minimum temperatures.

Concerning crops, *Amaranthus thunbergii* and *Portulaca oleracea* have different water requirements and shorter lifespans than the other crops. These crops are, therefore, not recommended in combination with TAV for vertical production.

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Chapter 8

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8. DISCUSSION OF RESULTS: THE PERFORMANCE OF OUTDOOR MODULAR LIVING WALL SYSTEMS WITH TRADITIONAL AFRICAN VEGETABLES FOR FOOD SECURITY

"…agriculture in cities is often the result of spontaneous, bottom-up actions by urban dwellers. Moreover, the right to land cultivation and self-production of food is increasingly being discussed, as well as food security based on local agriculture." (Nordhal, 2009; 2014 in (Aleksandra and Elżbieta, 2021)

8.1 Introduction

Chapter 8 draws on the preceding findings in Chapters 6 and 7 by discussing and summarising the main findings of the experimental study, guided by the applicable research focus areas (See Section 1.2.1 Figure 1.1) and comparing them to the literature review findings. The previous chapters focused on each research objective in isolation, whereas this chapter discusses the combined findings in response to the research question. The chapter ends with the main conclusions on the findings.

Section one of the chapter elaborates on urban small-scale food production's contribution to household food security and interrelated SDGs in SSA. The second section of the chapter reports on how the performance of outdoor modular LWSs as EGI can be improved based on the comparison findings of the three growing typologies and the literature review results. The third section of the chapter discusses the performance of the selected TAV crops in modular LWSs in local urban environments (Gauteng, South Africa). Figure 8.1 presents the chapter layout.

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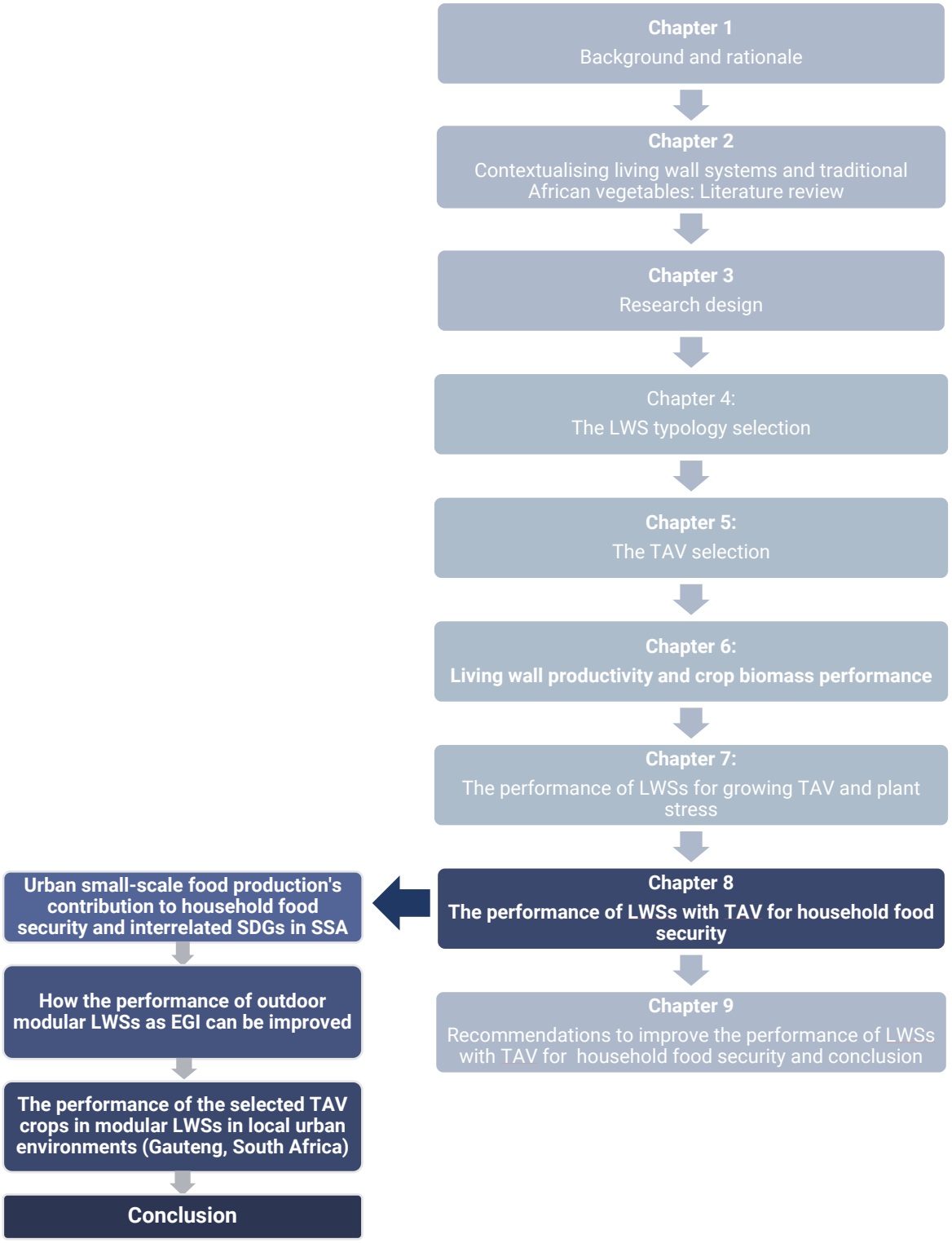


Figure 8.1: Diagram of the layout for Chapter 8, illustrating part 1, urban small-scale food production's contribution to household food security and interrelated SDGs in SSA, part 2, criteria for optimal efficiency of outdoor modular LWSs for growing TAV and part 3, suitable TAV species for small-scale vertical food production in Gauteng (South Africa) outdoor urban environments. Part 4 entails the concluding discussion and synthesis of the findings

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8.2 Urban small-scale food production to address household food security and interrelated United Nations Sustainable Development Goals (SDGs) in Sub-Saharan Africa (Research focus area 1)

Six TAV crops were more productive, giving higher yields than the commercial crop in the LWSs (See Section 6.6). Moreover, six TAV species functioned at a higher optimum in the Vicinity Wall compared to the Eco Green Wall, with four TAV species functioning optimally, considering the Fv/Fm. Six TAV crops coped exceptionally well with their environmental conditions in the LWSs considering their total performance index (See Sections 7.2 and 7.3). These findings support Mabhaudhi et al.'s (2016) argument that using non-major crops more widely could contribute to food security, food and nutrition security, human health and well-being, climate change adaptation, the environment, and employment creation in poor rural communities. South African rural and urban communities share commonalities, and food security, malnutrition and poverty are more prominent in urban than rural communities (Corinna and Francois, 2015).

Considering the horizontal footprint, the Eco Green Wall produced three times more yield than conventional soil-based production during the six months of the experiment, and the Vicinity Wall produced over four times the yield of conventional soil-based production (See section 6.4), therefore contributing to food security. The utilisation of LWSs as EGI responds to the need for sustainable food systems (FAO, 2023) and the viewpoint that food security interacts with and depends on other SDGs and vice versa and that SDG targets can only sustainably be addressed by looking at interrelated targets together (Manandhar et al., 2018; Siddiqui et al., 2020). Sustainable food systems are defined as:

> *"economically sustainable, in that they are profitable; socially sustainable, meaning that they deliver broad-based benefits for society; and environmentally sustainable, such that they have a positive or neutral impact on the environment"* (FAO, 2023).

8.3 How the performance of outdoor modular LWSs as EGI can be improved (Research Focus area 2)

Although several factors for improvement have been identified in the Eco Green and Vicinity Walls, due to crops experiencing stress compared to crops in the natural soil, the TAV plants

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still coped with their environmental conditions and stresses, and their photosynthetic apparatuses were not damaged (See Section 7.2).

This section discusses the findings from this study to show how to improve performance in six ways. This can be achieved through reduced installation costs, carbon footprint and maintenance requirements, increased resilience, crop performance and social benefits, and reduced irrigation and technological functioning, all equally essential to the system's efficiency.

8.3.1 Reduced overall (installation and operational) cost

The Eco Green Wall's installation cost was 21% lower than the Vicinity Wall's (See section 6.4.2). The time required to install the Eco Green Wall (4 hours) was 50% quicker than the Vicinity Wall's (8 hours) installation. Time-consuming actions for the Vicinity Wall included fixing the aluminium rails onto the building façade, installing the water reservoirs and pump, hooking the hexagonal planters onto the aluminium rail and filling the geotextile bags with the growth medium. Considering the maintenance, the Eco Green Wall was less labour-intensive, requiring only 4 activities compared to 15 activities for the Vicinity Wall during the 6-month study period. These activities included weeding, checking the irrigation system, and repairing the faulty irrigation system. See section 6.4.2 for the complete list of activities. These findings extend the conclusion that economic feasibility could be improved through cost-effective installation and maintenance and ensuring a broader use to increase social benefits through improving city environmental conditions (Perini and Rosasco, 2013; Bustami et al., 2018). The findings of this study expand on the research by Huang et al. (2019), which identified maintenance in the operational phase contributed to the highest expenditure. The Eco Green Wall's installation and maintenance benefits support the research by Riley et al. (2019). The study incorporated a reduced-cost lightweight system integrated into the building's structure. However, more research is needed on material with a lower carbon footprint, the limited planting palette for this system and insect control due to the standing water (Riley et al., 2019), which are essential considerations for food security and in the context of SA and SSA.

Challenges related to maintaining the systems identified in this study's findings could further reduce operational costs. These include simplifying the irrigation system to eliminate the need for cleaning filters and open reservoirs, such as those in the Vicinity Wall

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system (See section 6.4.2). Also, pot drainage holes should be designed to address possible obstructions and shifting of irrigation pipes to ensure that all plants receive water. This study confirms Passioura's (2006) findings that the size and number of drainage holes in the pots do not affect available water. However, the study found that the rope ties of the Vicinity system's geotextile planting bags caused obstructions to the drainage of the pots below (See section 6.4.2). However, no impact on the plant performance was detected in the findings looking at the positioning of crops (See section 6.5.2), as pots were checked regularly for possible blockages. The Vicinity Wall required increased maintenance to solve this problem.

Suggested trade-offs include the low-technology, simplistic components of the Eco Green Wall, which are easily assembled with minimal required skills and tools. However, the size of the pots of the Eco Green Wall would need to be doubled to 3-litre volumes, with a 200mm depth, as the Vicinity Wall's pots produced higher yields and added resilience.

8.3.2 Reduction of the carbon footprint, including reduced electricity and water requirements

Based on the yield (See section 6.8) and plant stress results (See Section 7.4), this study's findings include that locally manufactured modular LWSs with drought-tolerant TAV species adapted to the environmental context and irrigated by a drip system using harvested water can contribute to household food security. Although the study did not test the LWSs' carbon footprint, it applied measures to reduce the carbon footprint in line with the literature (Natarajan et al., 2015; Russo et al., 2017; Russo and Cirella, 2019). These measures included using harvested water (See Section 3.4.1), recycled/ recyclable components, reduced water usage through a drip irrigation system (See Section 4.3) and selecting waterwise plant species. Limiting the carbon footprint is vital for sustainable food systems and for contributing to SDGs related to food security.

This study's findings support the edible urbanism approach suggested by Russo and Cirella (2019), which integrates agriculture, nature, and ecology into the city through design. Local food production through LWSs with TAV also encourages localised production of crops in urban areas due to minimised energy resources and transport requirements (Beacham et al., 2019). The low reliance on electricity of a system such as the Eco Green wall makes this system more favourable.

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8.3.3 Enhanced resilience

Considering the mean crop maximum quantum yield and total performance index of the typologies over the entire study period, the Eco Green Wall and the Vicinity Wall crops experienced stress compared to the crops in the natural soil (See Section 7.2). Plant stress can be linked to temperature extremes or dry spells (See Section 7.4.1). However, the crops' overall vitality indicated that they coped with the environmental circumstances in both LWSs. Six TAV species produced higher yields in the LWSs than the commercial crop, with fresh mass weights over the study period ranging between 263 and 2035g (See Section 6.7). These yield and plant stress findings build on previous research (Mabhaudhi et al., 2019; FAO et al., 2018), which highlights the need for producing AOC and TAV as a response strategy to the global food system's vulnerability to climate variability, especially in marginalised countries such as SA (Gordon et al., 2017; MacFall et al., 2015; Mabhaudhi et al., 2018; Chang et al., 2018).

The dry spell in January, resulting from the irrigation malfunction for two weeks, impacted the soil EC values of the Eco Green living wall more than those of the Vicinity Wall See Section 6.2.2iii). This led to plant stress of crops concerning Fv/Fm mean values in the Eco Green Wall and also affected the EC and VWC levels in the Vicinity Wall (See Section 6.2.2ii and iii). However, the values in the Vicinity Wall fell more gradually. This finding confirms the importance of larger soil volumes and a minimum depth of 200mm in pots to increase resilience by reducing the hypoxia or oxygen deficiency risks (Passioura, 2006; Poorter et al., 2012).

Concerning the systems' design, no statistically significant correlations pointed to the exposed black parts of the pots and soil temperatures in both LWSs. Approximately a third of the Eco Green Wall pots were exposed to the sun, contrasting with the Vicinity Wall's fully exposed pots. The Eco Green Wall retains ambient and soil temperatures slightly better than the Vicinity Wall. This could relate to the design of the Eco Green Wall, where the seed trays (pots) are less exposed than the Vicinity design. The Vicinity Wall's pots are fully exposed, resulting in higher maximum and lower minimum ambient and soil temperatures (Sections 6.2.1i and 6.2.2i). Although literature warns against root damage from heated black pots exposed to solar radiation (Poorter et al., 2012), this was not experienced in

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either of the two walls, possibly due to the plants' leaf areas covering and reducing the exposed surface pot area protecting pots against overheating.

The VWC and EC findings are essential indicators of the system's resilience. Optimal VWC, which should ideally be maintained well above the permanent wilting point (PWP) and below field capacity (FC), was below accepted norms in the Vicinity and Eco Green Walls. Moreso, as an indicator of the moisture content and nutrient uptake, the EC was below the accepted standards in the Eco Green Wall. An explanation for the results is that the Vicinity Wall's pot depth of 200mm holds more benefits for moisture retention based on the VWC and EC values than the Eco Green Wall's pot depth of 5mm. The above VWC and EC results agree with the literature about pot sizes and depth affecting porosity and water content (Passioura, 2006).

Based on the plant stress findings, all typologies showed plant stress values within the acceptable norms (See Section 7.2), indicating optimal crop growth conditions and sufficient habitats for selected TAV. In addition, growing conditions in all the typologies were such that plant species coped well with their environmental conditions despite periods of heat stress, reduced precipitation, and irrigation system faults in the 6-month study period. In the study period (1 November 2021 to 30 April 2022), maintenance was limited to fault repair and weeding, emphasising the systems' resilience. This provides evidence that opposes the current criticism in the literature on LWSs regarding their economic feasibility and limited social benefits (Perini and Rosasco, 2013; Riley, 2017) and the perception of LWSs being unsustainable and only serving a decorative function (Riley, 2017).

Including additional stress variables and growth performance, such as the available water content would benefit future performance studies to improve the resilience of EGI.

8.3.4 Enhanced crop performance and social benefits

The Vicinity Wall crops produced statistically significantly higher yields than the Eco Green Wall (See Section 6.4.1). Five TAV crops in the Eco Green Wall and six in the Vicinity Wall produced higher yields than the control crop (*Spinacea oleracea*) (See Section 6.6). These findings support literature that proposes TAV for household food security (Mabhaudhi et al., 2019; FAO et al., 2018).

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Considering the plants per m^2, however, the natural soil produced the highest yield, with the Vicinity Wall producing more than the Eco Green Wall. However, the yield measured per m^2 footprint is the best performance indicator and an essential consideration for urban areas where space is limited. Considering the footprint, the findings show that the Vicinity Wall was the most productive by producing over five times the yield of the natural soil area. The Eco Green Wall was over two times more productive than the natural soil area, which produced the lowest yield per m^2 in terms of footprint. Considering the benchmark average fresh produce weight of 244g/m^2 (Rabin et al., 2021 in Nagle et al., 2017), the typologies' yield per m^2 did not meet the average requirements. However, considering the footprint of the LWSs, both the LWSs exceeded the benchmark yields (See section 6.4.1). These yield findings confirm that edible LWSs in urban environments offer social benefits and sufficient yield for household food production (Nagle et al., 2017). The benefits of LWSs relating to their limited footprint also make LWSs a favourable option concerning the cost of land, compared to conventional soil-based food production. However, the aspect needs to address the crop requirements in terms of light availability. Moreover, the biophilic benefits of LWSs are also expected to increase perceived property values.

The study findings reveal no link between yield production and the positioning of crops in the top three rows of the LWSs. Therefore, all levels or rows in the systems provided the same habitat for plants. However, yield is linked to the soil volume, as the natural soil area's yield was 20% higher than the Vicinity Wall's yield and roughly doubled the Eco Green Wall's yield (See Section 6.4.1). The Vicinity Wall has double the volume growth medium of the Eco Green Wall (See Section 4.3). These findings confirm literature linking a strong correlation between pot/ soil volume and plant growth (Poorter et al., 2012).

8.3.5 Reduced reliance on technology

The Eco Green Wall was installed in half the time of the Vicinity Wall (See Section 6.4.2), requiring fewer technological skills and tools. The uncomplicated design of the Eco Green Wall (See Section 4.3.1) also reduced maintenance, as the components are basic. In contrast, the Vicinity Wall's irrigation pipes, rope ties, and pots were easily repositioned by bypassers, leading to maintenance issues and impacting the system's workability (See Section 6.4.2). This study's findings suggest a wide application range for the Eco Green Wall system due to its benefits requiring minimal specialised installation and maintenance

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skills. This builds on the literature highlighting the importance of low-skilled labour and technology for SA and SSA (Benke and Tomkins, 2017; Botes and Breed, 2022). Moreover, the Eco Green wall, which does not require electricity, can function with basic watering such as a wick system. Systems fully reliant on electricity and water in terms of their design have limited applications for outdoor use in SSA, should the proposed location not have consistent electricity and water supply.

8.3.6 Crop selection

Song et al. (2018) found crop selection essential for increasing feasibility. In addition, the study by Beacham et al. (2019) found that small crops with short production cycles increased crop performance. The TAV species selection by the experts through questionnaires (See Section 5.3) expands on the above previous research, as the selected crops for the experimental study are mostly hemicryptophytes with short production cycles, adapted to the local climate conditions of Gauteng, South Africa and a north facing orientation in the southern hemisphere (Beacham et al., 2019; Song et al., 2018; Bustami et al., 2018; Riley, 2017; Van Mechelen et al., 2014; Yalcinalp and Meral, 2017). Traditional African vegetables are more resilient in the SSA conditions than mainstream crops due to reduced pests and diseases, lower water requirements and tolerance for hot climates. However, their popularity must be addressed through the availability of seeds or seedlings, marketing, easy preparation and recipes.

8.4 The production of TAV crops in modular LWSs in local urban environments (Gauteng, South Africa) for household food security (Research focus area 3)

This study found that *Coleus amboinicus* and *Portulacaria afra* prostrata are suitable for urban food production in LWSs in Gauteng, SA, based on the crops' yield production exceeding the control crop, *Spinacea oleracea*. Other TAV that also demonstrated suitability in terms of their production include *Vigna unguiculata* (black-eyed pea), *Asystasia gangetica* (creeping foxglove), *Mentha aquatica* (water mint), and *Diclipera clinopodia* (pink ribbons). The plant stress data analysis confirmed the findings: *Coleus amboinicus*, *Portulacaria afra* prostrata, *Spinacea oleracea*, *Mentha aquatica,* and *Vigna unguiculata* functioned at a higher optimum than the other crops in the Eco green and Vicinity Walls. *Corchorus confusus* and *Asystasia gangetica* performed at a higher optimum in the Vicinity Wall than the other crops.

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The TAV crops suitable for production in LWSs in Gauteng, South Africa, based on the biomass yield and plant stress findings, include *1) Asystasia gangetica,* creeping foxglove, Isihobo (Zulu), *2) Coleus amboinicus* (previously known as *Plectranthus amboinicus),* Indian borage, Indian mint, African thyme, broad-leaved thyme, 3) *Corchorus confusus,* Jute plant, gusha, ungibonisele, 4) *Dicliptera clinopodia,* pink ribbons *5) Mentha aquatica* water mint, koena-e-nyenyane *6) Portulacaria afra,* prostrata dwarf elephant's food, and *7) Vigna unguiculata*, black-eyed pea.

These crops should be planted in spring, with little to no shade interference with a northern aspect in the southern hemisphere in the climatic conditions applicable to Gauteng urban environments. Mean temperature ranges are generally between 10,5℃ and 31,18℃. The crops need irrigation, as an annual rainfall of 700mm is insufficient to meet the crops' water requirements. Crops should be planted in containers ideally having a soil volume of 3 litres and a minimum depth of 200mm (Poorter et al., 2012; Passioura, 2006), as larger containers support more resilient soil EC, VWC levels, nutrient uptake, and root space. The growth medium should comprise well-aerated potting soil, river sand & perlite (1:4:1). The system design should allow sufficient protection of pots to prevent soil temperature extremes due to solar radiation exposure (Passioura, 2006).

Species unsuitable for LWSs include *Amaranthus thunbergia* (Thunberg's pigweed) and *Portulaca oleracea* (purslane). These species did not survive in the LWSs, produced low biomass yields, and showed plant stress (See Sections 7.3.1iii and 7.3.7iii).

8.5 Conclusions

Chapter 8 considers how to improve the performance of outdoor modular LWSs with TAV to contribute to local household food security as EGI in urban environments (Gauteng, South Africa). This chapter, therefore, discusses the findings guided by this study's three main research focus areas.

The main findings from this study suggest that outdoor modular LWS with TAV can contribute to local household food security as EGI in urban environments (Gauteng, South Africa). LWSs with selected TAV crops can be considered a sustainable food system option to address food security and related SDGs in SSA urban environments.

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Several measures to improve the performance of outdoor modular LWSs as EGI are discussed. These measures include that the LWS structure must be locally produced, cost-effective, entail uncomplicated assembly, be flexible to accommodate varying household food requirements, and have a maximum height to allow accessibility for maintenance and harvesting. Components must be recycled and recyclable, with removable pots comprising a minimum depth of 200mm, with a drainage hole providing sufficient drainage and no loose fittings that could cause possible obstructions to the irrigation or drainage. The irrigation system must entail low technology, comprising either a drip or wick system, with harvested water as a source and equal irrigation per row or level of the LWS. Water reservoirs must be covered to prevent particles from entering and clogging drip emitters.

The impact of temperature extremes and dry spells on the plant stress of crops in LWSs is evident in the soil VWC and EC as essential indicators of the system's resilience. This can be mitigated by providing bigger soil volumes and regular and correct volumes of water to keep the soil VWC and EC at acceptable levels. The growth medium must address the plant requirements, ensuring sufficient aeration, texture, and drainage. A soil volume of 3 litres produces higher yields and resilience than smaller pots of 1.5 litres. The system must be lightweight, entail uncomplicated assembly, and use low technology to ensure a wide application for household use. Lastly, the orientation of the LWS must provide efficient sun exposure for the plant palette, although the system design must minimise sun exposure of pots to ensure optimal ambient and soil temperatures. The research findings suggest that selected TAV crops in outdoor modular LWSs in urban environments could efficiently improve household food security by producing higher yields per footprint than traditional soil-based agriculture.

The study's findings identify seven species suitable for household food production in LWSs based on yields and plant stress results. These include *Asystasia gangetica* (creeping foxglove), *Coleus amboinicus (Indian borage), Corchorus confusus (Jute plant), Dicliptera clinopodia* (pink ribbons), *Mentha aquatica* (water mint), *Portulacaria afra* prostrata (dwarf elephant's food) and *Vigna unguiculata* (black-eyed pea). These species are ornamental, have compact growth forms and short production cycles, and tolerate hot, dry climate conditions.

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Chapter 9

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9. CONCLUSIONS AND FURTHER RESEARCH

"Future research should also analyse case studies on how design and edible urbanism approaches can integrate three main principles of sustainability by fulfilling food security, resilience and social inclusion. The profound and deepest desire of using science for the good of humankind, meeting its daily needs, is a branch to healthier, happier people. As people continue to become urbanites, urban communities that foster EGI and food systems integration will better meet these needs for the next food revolution." (Russo and Cirella, 2019)

9.1 Introduction

Chapter 9, the final chapter of this thesis, summarises the significant findings and contributions, provides recommendations and concludes the study.

This study set out to determine the status of urban agriculture in terms of its contribution to household food security and related SDGs globally and SSA. Subsequently, after defining factors affecting the performance of modular LWSs negatively in contributing to food security (SDG 2) in the recent past, the study aimed to determine the technical characteristics for improved performance of modular LWSs as EGI for growing TAV in local urban conditions (Gauteng, South Africa), based on their performance in an empirical study. Furthermore, the study aspired to determine the status of TAV's efficiency in contributing to household food security globally and related SDGs in SSA and to identify factors that hampered household-scale food production and utilisation of TAV in addressing food security in the recent past. Lastly, the study aimed to identify TAV species that have the potential for household vertical food production in outdoor urban environments in Gauteng, South Africa.

The overarching question that guided the research was;

To what extent can outdoor modular LWSs with TAV contribute to local household food security as EGI in urban environments (Gauteng, South Africa)?

Figure 9.1 presents a diagram of the chapter layout and structure.

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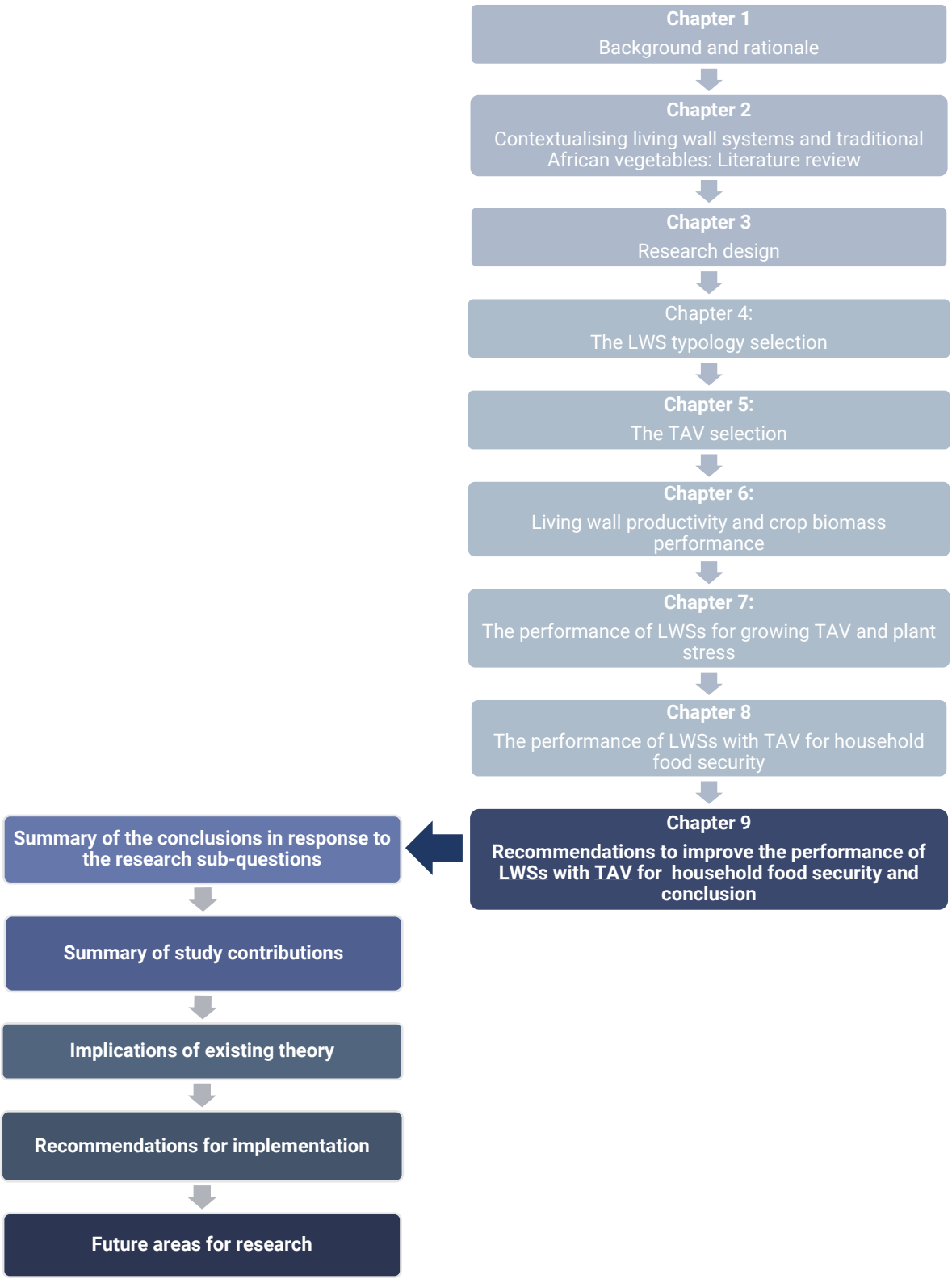


Figure 9.1: Diagram of the layout for Chapter 9, illustrating Part 1, the summary of the findings concerning the research sub-questions, Part 2, the study contributions; Part 3, the implications for existing theory. Part 4 entails recommendations for implementation, and Part 5 suggestions for future research

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The first section of the chapter concludes the research by responding to the study's research sub-questions. The second section focuses on the primary research contributions. These entail recommendations for the modular LWS technical characteristics for improved performance to grow TAV crops for household food production and TAV crops suitable for household food production in modular LWSs in Gauteng, South Africa. This chapter's third and fourth sections propose recommendations for existing theory and implementation, whereas the fifth section presents future research areas.

9.2 Conclusions in response to the research sub-questions

This study postulated that outdoor modular LWSs with TAV could contribute to local household food security as EGI in urban environments in Gauteng, South Africa. The thesis, therefore, focused on three areas to address the research questions and objectives. These focus areas included 1) urban small-scale food production's contribution to household food security and interrelated SDGs in SSA, 2) how the performance of outdoor modular LWSs as EGI can be improved and 3) the performance of the selected TAV crops in modular LWSs in local urban environments.

The literature review confirmed urban small-scale food production's contribution to household food security and interrelated SDGs in SSA, highlighting the importance of holistically considering the interaction between food security and other SDGs for sustainable food security solutions (Manandhar et al., 2018; Siddiqui et al., 2020). The literature revealed that cost efficiency, high maintenance and carbon footprint, low resilience, limited benefits, and high technology reliance negatively affect the performance of modular LWSs. Moreover, the literature confirmed taste and preparation, social perception, marketability, lack of research to improve genetic traits, lack of knowledge on cultivation and pest and disease control, and policies as factors that hampered TAV's production and consumption in the past.

The low-technology system, the Eco Green Wall, offered quicker and easier assembly, more cost-effective installation, and less maintenance required than the high-technology Vicinity Wall. This was mainly due to the Eco Green Wall's design, entailing more simplistic and fewer components than the Vicinity Wall. However, the Vicinity Wall's pots containing 3 litres of soil with a 200 mm depth produced higher yields than the low-technology system, with 1.59 litres of soil, and offered increased resilience during dry spells. The Eco Green

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Wall retained ambient and soil temperatures better than the Vicinity Wall due to its design, which entails pots less exposed to the sun than the Vicinity Wall's design, where the pots are fully exposed. The Vicinity Wall produced 20% less monthly fresh yield per square meter of the natural soil area than the Eco Green Wall's fresh monthly yield of less than half that of the natural soil area. However, considering the fresh monthly yield performance per m^2 horizontal footprint, the Vicinity Wall produced over five times the yield of the natural soil area, and the Eco Green Wall had double the yield of the natural soil area. Therefore, considering the footprint area of LWSs and the fact that LWSs occupy interstitial spaces, which makes LWSs more beneficial in terms of saving space, LWSs can efficiently contribute to local household food security as EGI in urban environments (Gauteng, South Africa).

The following section concludes and summarises each research question.

9.2.1 Research Sub-question 1: What is the status of urban agriculture in contributing to household food security and related SDGs globally and in Sub-Saharan Africa?

This study found that, as food security interacts with and depends on other SDGs and vice versa, SDG targets can only be addressed sustainably by considering interrelated targets together in response to research objective 1;

To determine the status of LWS as a form of urban agriculture in terms of its contribution to household food security and related SDGs globally and SSA.

The current slow progress in meeting SDG targets must be addressed through more research on EGI. Existing food systems need sustainable, resilient, inclusive initiatives to contribute to SDGs significantly. In addition to their biophilic benefits, LWSs with TAV as an urban agriculture solution offer ecosystem services, including cooling through evapotranspiration, air purification, their contribution to biodiversity, and food provision. LWSs with TAV can, therefore, be considered a sustainable food system option to address food security and related SDGs globally and in SSA urban environments, as they are economically and socially sustainable through their leaf biomass yields per square meter footprint and offer ecosystem services which not only address food security, but interrelated SGDs. Sustainable urban agriculture solutions such as LWSs with TAV in marginalised communities such as SSA can contribute to food security, malnutrition, gender equality and uplifting of women, good health and well-being, climate change

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adaptation, sustainable communities, biodiversity, poverty, and employment creation. Small-scale urban agriculture promotes food security (SDG 2) and related targets. These include ending poverty (SDG 1), good health and well-being (SDG 3), gender equality (SDG 5), decent work and economic growth (SDG 8), sustainable cities and communities (SDG 11), responsible consumption and production (SDG 12), climate action (SDG 13) and life on land (SDG 15).

9.2.2 Research Sub-question 2: Which factors negatively affected the performance of modular LWSs in contributing to food security (SDG 2) in the recent past?

This section discusses the conclusions relating to the low resilience and the high carbon footprint, the high installation and maintenance costs, and the limited social benefits of LWSs in response to research objective 2;

To define factors affecting the performance of modular LWSs negatively in contributing to food security (SDG 2) in the recent past.

In the past, the isolated consideration of individual LWS components, such as the wall, rainwater storage tanks, irrigation, soil structure, and plant palettes, instead of living walls being planned holistically as units or systems, impacted their resilience and sustainability. Inequal water provision on different levels, selection of unsuitable species, insufficient PAR availability, and unsuitable orientations for the species selection negatively affect crop maintenance, crop stress, yields, and LWSs' feasibility for food production. Limited species are suitable for pot growth with limited soil conditions based on their plant size, shape, root size, and structure. Also, crops with underground edible parts cannot be grown sustainably in LWSs, as plants have to be replaced after harvesting. Plants not adapted to the local temperature ranges, precipitation, relative humidity, and light quality and quantity should not be selected for growth in LWSs to limit abiotic plant stress. Plants with different requirements should not be grouped. Choosing a growth medium appropriate to the plant species is essential, considering weight, nutrients, pH, salinity, and texture.

Imported environmentally unfriendly materials impact LWSs' sustainability and local work opportunities, which are especially important in developing economies. High-technology LWSs comprising continuous systems that depend on uninterrupted electricity and water provision and effective disease control are unsuitable for use in SSA. Also, systems with complicated assembly and irrigation requiring specialised skills are problematic for

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developing communities. Moreover, system designs with fixed applications and sizes limit their use.

The high installation and maintenance costs of LWSs, with limited social benefits and crop performance, impact their economic feasibility. Importing materials impacts their installation cost and sustainability, and high water and energy usage increases their financial costs and carbon footprint during their operational phase. Living walls should not merely provide aesthetical value, as many direct and indirect benefits exist to delivering ecosystem services and increasing the sustainability of cities and human health and well-being.

Lastly, possible health risks resulting from the contamination of crops due to polluted soil, irrigation water and air in city environments are vital in positioning LWSs in urban environments.

The above factors impacting LWS performance led to the criteria for selecting the LWS typologies. The system must 1) be locally produced, 2) contain recycled / recyclable material components to limit the carbon footprint, 3) have an adequate soil volume of a minimum of 1,5 litres to support optimal growth, 4) must include a drip irrigation system to minimise potable water consumption, 5) must be cost-effective, 6) must involve uncomplicated assembly and technology, 7) must have a lightweight structure, 8) must have a structure to support plant density for full vegetation cover and vegetation continuity (easy replacement of plants), and 9) must be adjustable for different scale installations.

9.2.3 Research Sub-question 3: How can the technical characteristics of modular LWS improve their performance as EGI for growing TAV in local urban conditions (Gauteng, South Africa)?

Technical characteristics for modular LWSs to improve their performance as EGI were developed to achieve research objective 3;

To define the technical characteristics of modular LWSs for improved performance as EGI for growing TAV in local urban conditions (Gauteng, South Africa).

The study suggests that selected TAV crops in urban outdoor modular LWSs could improve household-scale food security by producing higher fresh biomass yields per square meter footprint than traditional soil-based agriculture. However, the fresh leaf biomass yield per

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square meter in LWSs is lower than in conventional soil-based production. Therefore, LWSs' potential can be improved by implementing technical characteristics identified by this study, which all play equally essential roles in the system's performance.

Cost-effectiveness and sustainability can be improved using locally produced structures with recycled or recyclable materials. The system design should be simplistic, with limited, robust, lightweight components entailing uncomplicated assembly, and allow flexibility to accommodate varying sizes for different household food requirements. The system's maximum height must allow accessibility for maintenance and harvesting.

The system should be modular, comprising individual and removable pots to ease the installation and replacement of plants and their maintenance. Pot sizes must have a capacity of at least 3 litres with a minimum soil depth of 200mm. A soil volume of 3 litres produces higher yields and resilience than smaller pots of 1.5 litres. The research found that one drainage hole is sufficient. However, the drainage hole's position must ensure drainage and limit any blockages. Although the pots' colour did not impact their performance, the pots' sun exposure should be limited. Too much exposure affects the soil temperature, leading to more extreme maximum and minimum soil temperatures. Limited exposure can be achieved through the system design, with the Eco Green Wall system as an example of pots with limited sun exposure and crop protection by the structure.

The soil should be lightweight and meet the crop requirements, ensuring sufficient aeration, texture and drainage. The irrigation system must entail low technology, comprising either a drip or wick system, with harvested water as a source and equal irrigation per row or level of the LWS. Water reservoirs must be covered to prevent particles from entering and clogging drip emitters.

The systems positioning should consider polluted environments to address possible contamination of crops. The orientation of the LWS must provide efficient sun exposure for the plant palette and consider any structures that might affect the light quality and quantity of the LWS.

Although LWSs have the potential as EGI with advantages compared to conventional soil-based agriculture, more research is required to develop systems with the above characteristics. Existing systems still need significant improvement to achieve optimal performance for the production of food crops.

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Table 9.1 summarises the technical characteristics of LWSs proposed by this study for improved performance as EGI for growing TAV in local urban conditions (Gauteng, South Africa).

Table 9.1: *The technical characteristics of LWSs proposed by this study for improved performance as EGI for growing TAV in local urban conditions (Gauteng, South Africa)*

Component	Characteristic
Structure	Freestanding or fixed
	Lightweight
	2000mm height for ease of maintenance and harvesting
	Varying width
	Uncomplicated assembly
	Recycled
	Locally manufactured
	Low technology
	North aspect (in the southern hemisphere)
	No shade interference
	Prevent polluted areas, water and soils
Irrigation	Drip/ wick system
	Non-exposed or no reservoir
	Harvested water
	Equal irrigation per row
Pots	Recycled
	Removable
	Soil depth > 200mm
	One drainage hole
	No lose fittings
Soil	Potting soil, river sand & perlite (1:4:1)
	Sufficient nutrients according to plant requirements
	PH to meet plant requirements
	Loose texture, aerated
	Lightweight
Plants	Specified TAV

9.2.4 Research Sub-question 4: To what extent do TAV contribute to household food security in SSA, and which factors have hampered household-scale food production and consumption utilising TAV in addressing food security recently?

The study identified several factors that hamper household-scale food production and consumption utilising TAV through the literature review to achieve research objective 4;

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To determine the status of TAV's efficiency in contributing to household food security globally and related SDGs in sub-Saharan Africa, and to identify factors that hampered household-scale food production and utilisation of TAV in addressing food security in the recent past.

Factors that hampered household-scale food production and TAV utilisation include a lack of research on TAV seeds and cultivars to improve their yields and negative traits. The yields and other negative traits also impact TAV's marketability. Another factor affecting TAV's marketability is a lack of knowledge of its nutritional benefits and preparation methods, with abundant indigenous knowledge of TAV's nutritional benefits limited to youth and urban populations. There is a need for TAV recipes that are easy to prepare and improve the taste. Also, the social perceptions of TAV as "poverty crops" affect their popularity amongst urban communities.

Moreover, limited research on the TAV's soil, water, sunlight, ventilation, and specific temperature range requirements for optimum production and controlling pests and diseases affecting them hampers their cultivation.

Lastly, there is a lack of implementation of policies addressing inequality and including all role-players in small-scale agriculture, especially in marginalised countries. Although the South African National Policy on Food and Nutrition Security supports promoting AOC research, development, and utilisation of AOC, including TAV, increased awareness of the importance of TAV in diets and their nutritional value among South African urban communities is required.

9.2.5 Research Sub-question 5: Which TAV species have the potential for household vertical food production in outdoor urban environments in Gauteng, South Africa?

The TAV selection entailed the last step in responding to the research question by addressing research objective 5;

To identify TAV species that have the potential for household vertical food production in outdoor urban environments in Gauteng, South Africa.

Based on the questionnaires and the literature review, important TAV characteristics include their popularity and prominence in markets, commercial availability, size and shape that should be compact, and plants must be ornamental to provide for a range of ecosystem

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services. Moreover, these crops must tolerate local climatic requirements and prefer full sun.

The study identified seven species suitable for household food production based on yield and plant stress performance.

Regarding the biomass yield, the *Coleus amboinicus* (Indian borage), *Portulacaria afra* prostrata *(dwarf elephant's food), Vigna unguiculata* (black-eyed pea), *Asystasia gangetica* (creeping foxglove), *Mentha aquatica* (water mint), and *Diclipera clinopodia* (pink ribbons) produced higher yields than the control crop in both LWSs, indicating their potential for household food security compared to commercial crops.

Considering the mean crop maximum quantum yield (Fv/Fm) values, the PSII of Indian borage), *Portulacaria afra* prostrata *(dwarf elephant's food), Mentha aquatica* (water mint), *and Vigna unguiculata* (black-eyed pea) functioned at a higher optimum than the other crops in both LWSs. *Corchorus confusus* (jute plant) and *Asystasia gangetica* (creeping foxglove) performed at a higher optimum in the Vicinity Wall than the other crops. The effect sizes of statistical differences between crops were small and can be considered statistically insignificant. The crops' overall vitality indicated that they coped with the environmental circumstances in all typologies.

Regarding the total performance index, *Asystasia gangetica* (creeping foxglove), *Dicliptera clinopodia* (pink ribbons), *Mentha aquatica* (water mint), *Coleus amboinicus* (Indian borage), *Portulacaria afra* prostrata *(dwarf elephant's food) and Vigna unguiculata* (black-eyed pea), coped exceptionally well with their environmental conditions in all three typologies.

The *Amaranthus thunbergii* (Thunberg's pigweed) had a zero per cent survival rate in all typologies. The water excess in the Vicinity wall could have contributed to the plant stress of *Amaranthus thunbergii* in the Vicinity wall and the crop's ultimate mortality in all the typologies. *A*lthough the *Portulaca oleracea* (purslane) survived in the LWSs, the crop showed plant stress in the Eco Green Wall. The *Amaranthus thunbergii* (Thunberg's pigweed) and *Portulaca oleracea* (purslane) produced low yields and showed plant stress. These crops have different water requirements than the other crops and shorter lifespans and are, therefore, not recommended in combination with TAV for vertical production.

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Table 9.2 lists the TAV species suitable for vertical food production in Gauteng, South Africa.

Table 9.2: List of TAV crops that are suitable for production in LWSs in Gauteng, South Africa, for household security

Binomial name	Common name	Family name
Asystasia gangetica	creeping foxglove, Isihobo (Zulu)	Acanthaceae
Coleus amboinicus (previously known as Plectranthus amboinicus)	Indian borage, Indian mint, African thyme, broad-leaved thyme	Lamiaceae
Corchorus confusus	Jute plant, gusha, ungibonisele	Malvaceae
Dicliptera clinopodia	pink ribbons	Acanthaceae
Mentha aquatica	water mint, koena-e-nyenyane	Lamiaceae
Portulacaria afra prostrata	dwarf elephant's food	Portulacaceae
Vigna unguiculata	black-eyed pea	Fabaceae

These crops prefer full sun, no frost, well-drained, aerated potting soil, river sand & perlite (1:4:1) and moderate irrigation to ensure sufficient plant available water and prevent soil from drying to the permanent wilting point.

9.3 Summary of study contributions

Although urban agriculture and living walls are established concepts and have been researched extensively independently, joint research on living walls and urban agriculture could not be located in the literature reviewed for this research study. To the researcher's knowledge, no studies have been undertaken on edible living walls and TAV as a resilient solution for food security in SSA. This study is the first empirical research of substantial duration that analyses the performance of living walls as edible green infrastructure and, to the researcher's knowledge, the first study assessing the production of TAV crops in LWSs.

The value of this research firstly lies in the performance guiding principles for technical characteristics of outdoor modular LWSs as EGI in local urban environments (Gauteng, South Africa). The value of this study is not limited to SA and SSA, as the performance of LWSs is a problem globally. The current sustainability and feasibility of living walls are debatable and need considerable improvement as EGI in compact urban environments. This study contributes to existing knowledge of LWSs by synthesising the factors affecting modular LWSs' efficiency and monitoring and analysing the performance of the selected LWS typologies in providing optimal growing conditions for TAV in Gauteng, SA. The

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empirical findings of this study lay the groundwork for improving LWSs as EGI which can contribute to more sustainable cities and communities. This is achieved by defining LWS technical characteristics to enhance their performance as edible green infrastructure. The study findings contribute to the edible urbanism and urban agriculture discourses by improving the performance of LWSs to provide more ecosystem services in urban environments and contributing to food security and interrelated SDGs. The successful implementation of EGI projects in SA and SSA cities will improve the health and well-being of especially disadvantaged communities through the provisioning of nutritious food. This research is valuable for national and local governments, as projects will not involve expensive land. Moreover, LWSs with TAV can be implemented at existing social housing projects, schools, early childhood development centres and clinics.

The study finally contributes to the revival of neglected crops by identifying TAV species suitable for utilisation in living walls to improve household-scale food security. TAV can contribute to the rich culture in SA and SSA, although it is acknowledged that more research on their agronomic requirements and applications in recipes needs to be addressed by researchers. Indigenous knowledge should be a vital part of future research. By synthesising barriers in growing and consuming TAV and through the monitoring and analysing of selected TAV crops in LWSs for household-scale food security in Gauteng, SA, a list of TAV species with the potential for small-scale vertical food production in outdoor urban environments was drawn up as an outcome. Developing sustainable food systems, including a broader range of crops such as TAV, is vital for marginalised economies in SSA and developed countries. Increased knowledge of TAV crops is critical given the global vulnerability of current food systems, with limited crops and increased extreme climate events due to global warming. Including TAV crops in LWSs will benefit SA and SSA in addressing food security, malnutrition, gender equality and uplifting of women, good health and well-being, climate change adaptation, sustainable communities, biodiversity, poverty, and employment creation.

9.4 Implications for existing theory

This study builds on previous research on LWSs' performance by synthesising research on factors affecting LWSs' economic feasibility (Mårtensson *et al.*, 2016; Russo *et al.*, 2017; Ling and Chiang, 2018), low resilience (Bustami et al., 2018; Riley, 2017; Beacham et al.,

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2019; Botes and Breed, 2021; Song et al., 2018; Yalcinalp and Meral, 2017), health risks (Säumel et al., 2012; Beacham et al., 2019; He, 2015; Szolnoki et al., 2013) and their environmental burden (Ottelé et al., 2011; Perini and Rosasco, 2013; Natarajan et al., 2015; Russo et al., 2017; Russo and Cirella, 2019). The above study conclusions were extended by selecting LWSs based on performance criteria from these studies and combining them with criteria based on expert opinions for use in an experimental study. The empirical study analysed and compared two LWSs in terms of their performance in providing optimal growing conditions for TAV crops. This study affirms the conclusions of previous studies and adds additional criteria by defining technical characteristics to improve the performance of LWSs for TAV production.

The results of this study furthermore affirm, support and extend the studies by Mabhaudhi et al. (2016), Mabhaudhi *et al.* (2017), Mabhaudhi *et al*. (2019), Tadele and Bartels (2019), Tadele (2019) and Jansen van Rensburg et al. (2009) by re-iterating the potential of TAV as food crops to address food and nutrition security, human health and well-being, climate change adaptation, the environment, and employment creation in poor rural communities. In addition, this study contributes to the conclusions of Cheng et al. (2017), which stressed the importance of diversifying food sources for sustainable food security by identifying TAV species that have the potential for household vertical food production in outdoor urban environments in Gauteng, SA.

Finally, this study affirms and contributes to previous empirical studies by Nagle, Echols and Tamminga (2015), Riley (2017) and Razzaghmanesh and Razzaghmanesh (2017) by extending their research findings. This is achieved by a six-month empirical study analysing and comparing two LWS typologies and nine TAV crops. This study 1) selected a 6-month empirical study period for data collection based on favourable climatic conditions for crop growth and also due to the crops' seasonal production, 2) selected the LWSs and TAV crops through a mixed method approach involving questionnaires, 3) included precipitation and daylength as secondary data, 4) included maximum and minimum temperature, relative humidity, soil temperature, volumetric water content and electrical conductivity, fresh and dry leaf biomass yield, maximum quantum yield of photosystem II (F_v/F_m) and total performance index (PI_{total}) as primary data, and 5) performed statistical data analysis and reporting. The research outputs for this study provide practical recommendations and guidelines addressing the performance of both the system and the plants. These guidelines

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can contribute to previous studies and improve the performance of LWSs with TAV as EGI in urban environments. The guidelines for improving LWSs and TAV are valuable for further empirical studies to ensure improved performance and success of these systems as EGI. Ultimately, the contribution that edible green infrastructure projects, such as LWSs with TAV, can make to the SDG targets adds to their performance. The scalability of EGI projects will only increase once their success in terms of performance through ecosystem services to contribute to SDG targets has been proven. Their success will enhance EGI integration into the urban fabric, increasing the impact and contribution to SDG targets over time.

9.5 Recommendations for implementation

Building facades offer much-needed greening opportunities, considering the limited space in urban environments and planetary concerns such as the urban heat island effect and biodiversity loss. Moreover, LWSs and greening are essential for human health and well-being. Although LWSs provide ecosystem services, their limited benefits, high installation cost, and maintenance requirements make LWSs unfeasible globally to incorporate in urban environments. Therefore, the first recommendation for implementation entails applying the recommended technical characteristics for LWSs identified by this study. These recommendations are specific to Gauteng, South Africa, and for growing TAV crops for household-scale food production. The technical recommendations are summarised as follows: 1) The system must be modular, low technology, comprising individual and removable pots with a 3-litre capacity and 200mm minimum soil depth; 2) one drainage hole per pot is sufficient, provided its position ensures drainage and limits any blockages; 3) the system's design must limit pots' sun exposure; 4) the soil should be lightweight and meet the crops' nutritional, pH and texture requirements; 5) the irrigation system must entail low technology, comprising either a drip or wick system, with harvested water as a source and equal irrigation per row or level of the LWS; 6) the system should be positioned away from polluted environments to address possible contamination of crops; 7) the LWS orientation must provide efficient sun exposure for the plant palette and consider any structures that might affect the light quality and quantity of the LWS.

The manufacturing of LWSs based on this study's technical recommendations would contribute to the discourse on edible urbanism and guide future planning.

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Concerning the optimal environment for TAV crops, the irrigation volume should be determined by the soil volume, type and texture to ensure sufficient soil water content.

The second set of recommendations for implementation entails selecting TAV crops that are suitable for vertical food production in Gauteng, South Africa or similar environments. Research has found that hemicryptophytes, typically herbaceous perennials, grow successfully in limited soil conditions (Van Mechelen et al., 2014; Yalcinalp and Meral, 2017). When selecting crops for household-scale vertical food production in urban environments, it is recommended that only plants with above-ground edible parts be considered and that plants should have compact root systems with compact growth forms suitable for limited soil conditions. Lastly, plants with similar water, sun and growth requirements should be grouped.

The TAV crops recommended for vertical food production, based on the empirical study findings, include *Asystasia gangetica* (creeping foxglove), *Corchorus confusus* (jute plant), *Coleus amboinicus* (Indian borage), *Dicliptera clinopodia* (pink ribbons), *Mentha aquatica* (water mint), *Portulacaria afra* prostrata *(dwarf elephant's food) and Vigna unguiculata* (black-eyed pea). Except for *Corchorus confusus* (jute plant), these species produced higher yields than the control crop (*Spinacea oleracea*). Concerning plant stress, all the above species, including *Corchorus confusus* (jute plant), performed at a higher optimum than the other species in the LWSs. All the species are ornamental and commercially available. Moreover, these species have short production cycles, prefer full sun, tolerate frost and short dry periods, and are relatively disease- and pest-resistant.

9.6 Future Areas for Research

This study raised several important questions, which are elaborated on below.

This study focused on the short-term performance of selected LWSs and TAV crops for household-scale food security based on the crop yield and plant stress findings. Limited studies have been done to understand perceptions of TAV crops, focusing on their consumption. To the researcher's knowledge, no studies have been conducted to determine SA communities' perceptions of using LWSs with TAV crops as EGI. Further research on SA communities' perceptions of using LWSs with TAV for household-scale food production would be fruitful in understanding possible applications for LWSs with TAV. Possible research topics could include the long-term effect of root restrictions, soil volume and

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higher density on long-term performance, crop physiology and other biological parameters, barriers to using LWSs as EGI for urban agriculture, the perception of TAV as poverty crops, and basic skills and technical knowledge for growing TAV in LWSs. Moreover, there is a need for research on TAV's functional traits and physiological properties and their impact on cultivation, nutritional value, and preparation to improve the taste and to create more straightforward methods based on local indigenous knowledge. Rare TAV crops that could contribute to niche production due to their cultural value could be researched. TAV's cultural identity and heritage value need further research based on indigenous knowledge. Research on these topics would assist in overcoming current barriers to cultivating and consuming TAV.

Another barrier affecting the growing and consumption of LWSs with TAV in urban areas is the risk of contamination of crops. Although research has been conducted on the impact of pollution on vegetation growth, it would be fruitful to extend this research to edible crops and TAV.

Comparing more variables as part of the experimental study would be beneficial in developing a comprehensive understanding of the efficiency of LWSs for TAV production. This includes measuring the photosynthetic active radiation (PAR) to understand the light requirements of the TAV crops. Also, measuring the volumetric water content (VWC) and plant available water on the top and bottom levels of LWSs would guide the zoning of plants in LWSs.

Finally, a natural progression of this study would include analysing more TAV species for suitability in LWSs. This study focused on 9 TAV species out of 31 proposed species. In addition, experts included recommended species for possible consideration for inclusion in the experimental study. Although the experts suggested additional unsuitable species not adhering to the selection criteria, the species list of the experts involved in the questionnaires proposed could be reconsidered for future research. Such research could add a more extensive list of TAV for production in LWSs as EGI. Also, empirical research entailing the testing of improved low-technology systems based on this study's recommendations would benefit system performance. Lastly, more urban applications could be considered, including rooftop gardens.

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11 APPENDICES

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Appendix A: Questionnaire regarding LWSs

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PROJECT TITLE –
A TECHNICAL ANALYSIS OF THE POTENTIAL OF AFRICAN ORPHAN CROPS AND INDIGENOUS LEAFY VEGETABLES IN VERTICAL INFRASTRUCTURE SYSTEMS FOR FOOD PRODUCTION

DETAILS OF RESEARCHER:

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QUESTIONS

AFRICAN ORPHAN CROPS

1. African Orphan Crops comprises underutilised crops important to local diets in Africa and entails cereals, legumes, vegetables and root crops. Are you familiar with the term “African orphan crop”?

Yes	
No	

2. If yes, are there any African orphan crop or indigenous leafy vegetables that you are familiar with which has the potential to be grown in vertical gardens in your opinion? Please elaborate on the growth requirements and habitats for these species. Would they in your opinion tolerate urban environmental and local climatic conditions? Please describe their growing season and life cycle.

3. Do you think African Orphan crops and indigenous leafy vegetables have commercial or economic value? Please motivate your answer.

Yes	
No	

4. Do you think African Orphan crops and indigenous leafy vegetables have high nutritional value and health benefits? Please motivate your answer.

Yes	
No	

5. Can consumer awareness in terms of the benefits of using African food crops and indigenous leafy vegetables be improved? If the case, how in your opinion?

Yes	
No	

6. Do you think African Orphan crops and indigenous leafy vegetables are high maintenance? Please motivate your answer.

Yes	
No	

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7. Does the use of African Orphan Crops and indigenous leafy vegetables have benefits in terms of the environment when used in vertical farming in urban areas in your opinion?

Yes	
No	

8. What would you recommend in terms of technical requirements for vertical farming with these species?

GREEN WALL SYSTEMS

9. Which qualities and technical specifications should green wall systems have to ensure the optimal growing conditions for urban farming with African Orphan Crops and indigenous leafy vegetables?

10. Are there preferred systems supplied in South Africa which adhere to the qualities and specifications referred to in question 9?

11. What maintenance is required on these systems?

12. Are you aware of any specific or potential challenges associated with these systems? If yes, please list.

13. What should the ideal dimensions entail for green wall systems walls with African Orphan crops and indigenous leafy vegetables, to ensure accessibility?

14. Which orientation/s would be the most beneficial for green walls with African Orphan crops and indigenous leafy vegetables?

North		South		East		West	

PROJECT EXAMPLES

15. Please provide names and locations of projects where these systems have been implemented successfully. Please specify whether the vertical system is in or outdoors, the vegetation species used and installation date.

PROJECT	LOCATION	INDOORS/ OUTDOORS	VEGETATION SPECIES	INSTALLATION DATE

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16. Do you think the client would consider edible plants as an alternative to the vegetation species installed? Please motivate your answer.

Yes	
No	

FEASIBILITY

17. How can the economic feasibility for green wall systems be improved?

RESEARCH

18. Can you recommend other people or reading material that might be able to assist with information on my study?

NAME/ TITLE	CONTACT DETAILS/ LINK

19. Do you think a study on the potential of African orphan crops and indigenous leafy vegetables in vertical infrastructure systems for food production would be feasible and valuable? Why do you say so?

Yes	
No	

20. Do you have any final comments or wish to add information?

Thank you for your time.

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Appendix B: Questionnaire regarding TAV

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PROJECT TITLE –

A performance assessment of selected African Orphan Crop and Traditional African Vegetable species in modular living wall systems in Gauteng, South Africa

DETAILS OF RESEARCHER:

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Kindly return via email to karen.botes@up.ac.za

QUESTIONS

1. From the list below, are there any African orphan crop (AOC) and Traditional African Vegetables (TAV) that you are familiar with/ would recommend which has the potential to be grown in living walls in your opinion?

SHORTLIST OF AOC AND TAV FOR USE IN MODULAR LIVING WALL SYSTEMS			
NAME	**COMMON NAME**	**YES**	**NO**
Aervia leucera	Aambeibossie		
Amaranthus	Amaranth		
Ancylobotrys capensis	Wild apricot		
Asystasia gangetica	Creeping Foxglove		
Asystasia schimperii	Longevity Spinach		
Athrixia elata	Daisy tea bush		
Centella asiatica	Pennywort		
Chorchorus confusus	Ungibonisele (Zulu)		
Cucumis metuliferus	Horned Melon		
Cucumis zeyheri	Wild cucumber		
Cynanchum virens	Liane calle		
Cyperus esculentus	Nutsedge/ Tiger nut		
Dicliptera clinopodia	Pink Ribbons		
Diclis reptans	Dwarf snapdragon		
Diospyros austro-africana	Firesticks		
Gazania krebsiana	Terracotta Gazania		
Hilliardiella oligocepalla (Vernonia)	Bicoloured-leaved Vernonia		
Hypoestes aristata	Ribbon Bush		
Hypoxis argentea	Yellow stars		
Imperata cylindrica	Cogon grass		
Lantana rugosa	Bird's Brandy		
Mentha aquatica	Water mint		
Mentha longifolia	Wild mint		
Nemesia fruticans	Wild nemesia		
Plectranthus amboinicus	Indian Borage		
Portulaca oleracea	Purslane		
Portulacaria afra Prostrata	Porkbush		
Rhoicissus tomentosa	Wild Grape		
Rhoicissus tridentata	Bushman's Grape		
Vigna unguiculata	Cowpea		
Vigna subterranea	Bambara nut		

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2. Please list any other species that you would add to the above list.

3. In your opinion, which of the above species have high nutritional value and health benefits? Please elaborate.

4. Can you recommend other people or reading material that might be able to assist with information on my study?

NAME/ TITLE	CONTACT DETAILS/ LINK

5. Do you have any final or additional comments or information to add?

Thank you for your time.

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Appendix C: Approval letter from the EBIT Research Ethics Committee (Reference no EBIT/84/2019)

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Faculty of Engineering, Built Environment and Information Technology

Fakulteit Ingenieurswese, Bou-omgewing en Inligtingtegnologie / Lefapha la Boetšenere, Tikologo ya Kago le Theknolotši ya Tshedimošo

Reference number: EBIT/84/2019

Mrs KL Botes
Department: Architecture
University of Pretoria
Pretoria
0083

Dear Mrs KL Botes

FACULTY COMMITTEE FOR RESEARCH ETHICS AND INTEGRITY

Your recent application to the EBIT Research Ethics Committee refers.

Conditional approval is granted.

This means that the research project entitled "" is approved under the strict conditions indicated below. If these conditions are not met, approval is withdrawn automatically.

Conditions for approval
Item 8.1 Answer = NO. Confirmation is required that your proposal has been approved.

Item 8.6 Answer = NO. Ethics clearance covers only interviews with individuals, but if employees of companies are to be interviewed, company permission is required. Company permission letters are to be submitted as an amendment to the application. Without these, the ethics clearance restricts the study to interviews with individuals that are not employees of companies.

This approval does not imply that the researcher, student or lecturer is relieved of any accountability in terms of the Code of Ethics for Scholarly Activities of the University of Pretoria, or the Policy and Procedures for Responsible Research of the University of Pretoria. These documents are available on the website of the EBIT Ethics Committee.

If action is taken beyond the approved application, approval is withdrawn automatically.

According to the regulations, any relevant problem arising from the study or research methodology as well as any amendments or changes, must be brought to the attention of the EBIT Research Ethics Office.

The Committee must be notified on completion of the project.

The Committee wishes you every success with the research project.

Prof JJ Hanekom
Chair: Faculty Committee for Research Ethics and Integrity
FACULTY OF ENGINEERING, BUILT ENVIRONMENT AND INFORMATION TECHNOLOGY

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Appendix D: Biomass statistical analysis results

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Installing the necessary modules

In [1]:
```
import pandas as pd
import numpy as np
```

In [2]:
```
# Start with loading all necessary libraries
from os import path

import matplotlib.pyplot as plt
%matplotlib inline
```

In [3]:
```
import pandas as pd
import statsmodels.api as sm
from statsmodels.formula.api import ols
```

Importing the data set

In [4]:
```
df = pd.read_excel('KBotes_data_Nov21 to Apr22_DrMoyo_final_rev04_27092022_dmedits.xlsx')
df.head(3)
```

Out[4]:

	Crop	Position	Typology	Month	freshmass_leaves	drymass_leaves	Soil_WC	Soil_Temp	Soil_SE	local_maxtemp	local_mintemp	local_RH	total_precip	daylength	daylength_sec
0	1	1	1	2021-11-15	3.105	0.738	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092
1	1	2	1	2021-11-15	0.390	0.087	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092
2	1	3	1	2021-11-15	1.423	0.329	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092

In [5]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 540 entries, 0 to 539
Data columns (total 15 columns):
 #   Column            Non-Null Count  Dtype         
---  ------            --------------  -----         
 0   Crop              540 non-null    int64         
 1   Position          540 non-null    int64         
 2   Typology          540 non-null    int64         
 3   Month             540 non-null    datetime64[ns]
 4   freshmass_leaves  540 non-null    float64       
 5   drymass_leaves    540 non-null    float64       
 6   Soil_WC           540 non-null    float64       
 7   Soil_Temp         540 non-null    float64       
 8   Soil_SE           540 non-null    float64       
 9   local_maxtemp     540 non-null    float64       
 10  local_mintemp     540 non-null    float64       
 11  local_RH          540 non-null    float64       
 12  total_precip      540 non-null    float64       
 13  daylength         540 non-null    object        
 14  daylength_sec     540 non-null    int64         
dtypes: datetime64[ns](1), float64(9), int64(4), object(1)
memory usage: 63.4+ KB
```

In [6]:
```
df['hour'] = pd.to_datetime(df['daylength'], format='%H:%M:%S').dt.hour
df
```

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Out[6]:

	Crop	Position	Typology	Month	freshmass_leaves	drymass_leaves	Soil_WC	Soil_Temp	Soil_SE	local_maxtemp	local_mintemp	local_RH	total_precip	daylength	daylength_sec	hour
0	1	1	1	2021-11-15	3.105	0.738	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13
1	1	2	1	2021-11-15	0.390	0.087	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13
2	1	3	1	2021-11-15	1.423	0.329	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13
3	1	1	2	2021-11-15	1.504	0.244	0.254	22.6	0.212	37.4	16.5	51.2	0.0	13:21:32	48092	13
4	1	2	2	2021-11-15	1.589	0.242	0.254	22.6	0.212	37.4	16.5	51.2	0.0	13:21:32	48092	13
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
535	10	2	2	2022-04-15	6.810	1.170	0.261	15.6	0.341	27.2	10.7	80.6	0.0	11:22:04	40924	11
536	10	3	2	2022-04-15	9.700	1.850	0.261	15.6	0.341	27.2	10.7	80.6	0.0	11:22:04	40924	11
537	10	4	3	2022-04-15	0.000	0.000	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11
538	10	4	3	2022-04-15	10.606	2.620	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11
539	10	4	3	2022-04-15	12.192	2.280	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11

540 rows × 16 columns

In [7]:
```
df['minute'] = pd.to_datetime(df['daylength'], format='%H:%M:%S').dt.minute
df
```

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Out[7]:

	Crop	Position	Typology	Month	freshmass_leaves	drymass_leaves	Soil_WC	Soil_Temp	Soil_SE	local_maxtemp	local_mintemp	local_RH	total_precip	daylength	daylength_sec	hour	minute
0	1	1	1	2021-11-15	3.105	0.738	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13	21
1	1	2	1	2021-11-15	0.390	0.087	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13	21
2	1	3	1	2021-11-15	1.423	0.329	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13	21
3	1	1	2	2021-11-15	1.504	0.244	0.254	22.6	0.212	37.4	16.5	51.2	0.0	13:21:32	48092	13	21
4	1	2	2	2021-11-15	1.589	0.242	0.254	22.6	0.212	37.4	16.5	51.2	0.0	13:21:32	48092	13	21
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
535	10	2	2	2022-04-15	6.810	1.170	0.261	15.6	0.341	27.2	10.7	80.6	0.0	11:22:04	40924	11	22
536	10	3	2	2022-04-15	9.700	1.850	0.261	15.6	0.341	27.2	10.7	80.6	0.0	11:22:04	40924	11	22
537	10	4	3	2022-04-15	0.000	0.000	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11	22
538	10	4	3	2022-04-15	10.606	2.620	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11	22
539	10	4	3	2022-04-15	12.192	2.280	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11	22

540 rows × 17 columns

In [8]:
```
df['seconds'] = pd.to_datetime(df['daylength'], format='%H:%M:%S').dt.second
df
```

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Out[8]:

	Crop	Position	Typology	Month	freshmass_leaves	drymass_leaves	Soil_WC	Soil_Temp	Soil_SE	local_maxtemp	local_mintemp	local_RH	total_precip	daylength	daylength_sec	hour	minute	seconds
0	1	1	1	2021-11-15	3.105	0.738	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13	21	32
1	1	2	1	2021-11-15	0.390	0.087	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13	21	32
2	1	3	1	2021-11-15	1.423	0.329	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13	21	32
3	1	1	2	2021-11-15	1.504	0.244	0.254	22.6	0.212	37.4	16.5	51.2	0.0	13:21:32	48092	13	21	32
4	1	2	2	2021-11-15	1.589	0.242	0.254	22.6	0.212	37.4	16.5	51.2	0.0	13:21:32	48092	13	21	32
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
535	10	2	2	2022-04-15	6.810	1.170	0.261	15.6	0.341	27.2	10.7	80.6	0.0	11:22:04	40924	11	22	4
536	10	3	2	2022-04-15	9.700	1.850	0.261	15.6	0.341	27.2	10.7	80.6	0.0	11:22:04	40924	11	22	4
537	10	4	3	2022-04-15	0.000	0.000	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11	22	4
538	10	4	3	2022-04-15	10.606	2.620	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11	22	4
539	10	4	3	2022-04-15	12.192	2.280	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11	22	4

540 rows × 18 columns

In [ ]:

In [9]:
```
df.info()
```

```
<class 'pandas.core.frame.DataFrame'>
RangeIndex: 540 entries, 0 to 539
Data columns (total 18 columns):
 #   Column            Non-Null Count  Dtype         
---  ------            --------------  -----         
 0   Crop              540 non-null    int64         
 1   Position          540 non-null    int64         
 2   Typology          540 non-null    int64         
 3   Month             540 non-null    datetime64[ns]
 4   freshmass_leaves  540 non-null    float64       
 5   drymass_leaves    540 non-null    float64       
 6   Soil_WC           540 non-null    float64       
 7   Soil_Temp         540 non-null    float64       
 8   Soil_SE           540 non-null    float64       
 9   local_maxtemp     540 non-null    float64       
 10  local_mintemp     540 non-null    float64       
 11  local_RH          540 non-null    float64       
 12  total_precip      540 non-null    float64       
 13  daylength         540 non-null    object        
 14  daylength_sec     540 non-null    int64         
 15  hour              540 non-null    int64         
 16  minute            540 non-null    int64         
 17  seconds           540 non-null    int64         
dtypes: datetime64[ns](1), float64(9), int64(7), object(1)
memory usage: 76.1+ KB
```

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DESCRIPTIVE STATISTICS FOR ALL NUMERIC VARIABLES IN THE DATASET

In [10]:
```
df.describe()
```

Out[10]:

	Crop	Position	Typology	freshmass_leaves	drymass_leaves	Soil_WC	Soil_Temp	Soil_SE	local_maxtemp	local_mintemp	local_RH	total_precip	daylength_sec	hour	minute	seconds
count	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000	540.000000
mean	5.500000	2.666667	2.000000	13.819235	1.812263	0.249333	20.877778	0.349500	30.505556	14.627778	73.894444	7.566667	46273.166667	12.333333	31.000000	13.166667
std	2.874945	1.155771	0.817254	33.439901	4.062137	0.072630	3.570216	0.256936	4.367311	2.411661	12.585019	10.748931	3000.807521	0.746047	14.550788	10.504439
min	1.000000	1.000000	1.000000	0.000000	0.000000	0.079000	15.600000	0.000000	24.500000	10.400000	50.300000	0.000000	40924.000000	11.000000	12.000000	0.000000
25%	3.000000	2.000000	1.000000	1.033500	0.203000	0.230000	17.000000	0.147000	27.100000	12.200000	63.700000	0.000000	43929.000000	12.000000	21.000000	4.000000
50%	5.500000	3.000000	2.000000	3.004500	0.611500	0.257500	21.750000	0.313000	29.650000	15.500000	79.800000	4.100000	47275.000000	12.500000	27.000000	12.500000
75%	8.000000	4.000000	3.000000	10.254250	1.586500	0.309000	22.700000	0.643000	35.300000	16.400000	81.500000	6.200000	48736.000000	13.000000	45.000000	18.000000
max	10.000000	4.000000	3.000000	254.760000	38.919000	0.337000	26.900000	0.747000	37.400000	17.500000	89.300000	31.000000	49500.000000	13.000000	54.000000	32.000000

In [ ]:

In [11]:
```
agg_func_describe_fm = {'freshmass_leaves': ['describe']}
df.groupby(['Crop']).agg(agg_func_describe_fm).round(2)
```

Out[11]:

	freshmass_leaves							
	describe							
	count	mean	std	min	25%	50%	75%	max
Crop								
1	54.0	1.88	3.85	0.00	0.02	0.68	1.64	24.30
2	54.0	24.60	52.28	1.27	2.56	3.40	13.42	231.82
3	54.0	1.23	1.32	0.07	0.36	0.83	1.55	6.36
4	54.0	4.87	6.65	0.06	1.44	2.16	4.32	32.96
5	54.0	5.85	5.82	0.59	2.45	3.84	6.48	26.01
6	54.0	56.20	52.97	6.14	25.16	33.40	70.64	254.76
7	54.0	2.64	4.30	0.00	0.34	1.36	2.81	22.12
8	54.0	10.14	6.99	0.65	5.15	9.82	12.51	31.91
9	54.0	23.32	54.31	0.00	0.60	1.65	4.66	239.48
10	54.0	7.47	6.79	0.00	1.72	7.04	10.27	33.59

In [12]:
```
agg_func_describe_dm = {'drymass_leaves': ['describe']}
df.groupby(['Crop']).agg(agg_func_describe_dm).round(2)
```

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Out[12]:

	drymass_leaves							
	describe							
	count	mean	std	min	25%	50%	75%	max
Crop								
1	54.0	0.39	0.72	0.00	0.02	0.12	0.34	4.24
2	54.0	4.41	9.15	0.18	0.50	0.68	2.65	38.92
3	54.0	0.34	0.33	0.01	0.07	0.27	0.53	1.36
4	54.0	1.07	1.42	0.05	0.33	0.50	1.16	7.83
5	54.0	1.78	1.83	0.10	0.76	1.15	1.88	8.44
6	54.0	3.93	4.28	0.38	1.37	1.85	5.92	22.13
7	54.0	0.38	0.63	0.00	0.03	0.17	0.40	3.03
8	54.0	1.36	0.95	0.09	0.78	1.24	1.58	4.92
9	54.0	2.83	6.02	0.00	0.10	0.25	0.81	22.02
10	54.0	1.63	1.54	0.00	0.37	1.44	2.25	6.83

In [ ]:

In [13]:
```
agg_func_fm = {
    'freshmass_leaves':
    ['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'prod']
}
df.groupby(['Crop']).agg(agg_func_fm).round(2)
```

Out[13]:

	freshmass_leaves								
	sum	mean	median	min	max	std	var	mad	prod
Crop									
1	101.55	1.88	0.68	0.00	24.30	3.85	14.81	2.11	0.000000e+00
2	1328.22	24.60	3.40	1.27	231.82	52.28	2732.76	32.20	2.045515e+44
3	66.29	1.23	0.83	0.07	6.36	1.32	1.75	0.94	0.000000e+00
4	263.24	4.87	2.16	0.06	32.96	6.65	44.29	4.50	4.617971e+22
5	315.85	5.85	3.84	0.59	26.01	5.82	33.90	3.97	5.531981e+32
6	3034.54	56.20	33.40	6.14	254.76	52.97	2806.11	39.78	2.246921e+86
7	142.47	2.64	1.36	0.00	22.12	4.30	18.47	2.55	0.000000e+00
8	547.52	10.14	9.82	0.65	31.91	6.99	48.88	5.13	1.603660e+47
9	1259.38	23.32	1.65	0.00	239.48	54.31	2949.82	35.17	0.000000e+00
10	403.33	7.47	7.04	0.00	33.59	6.79	46.17	5.13	0.000000e+00

In [14]:
```
agg_func_dm = {
    'drymass_leaves':
    ['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'prod']
}
df.groupby(['Crop']).agg(agg_func_dm).round(2)
```

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Out[14]:

	drymass_leaves								
	sum	mean	median	min	max	std	var	mad	prod
Crop									
1	21.07	0.39	0.12	0.00	4.24	0.72	0.51	0.44	0.000000e+00
2	238.39	4.41	0.68	0.18	38.92	9.15	83.81	5.69	7.498622e+04
3	18.37	0.34	0.27	0.01	1.36	0.33	0.11	0.26	0.000000e+00
4	57.51	1.07	0.50	0.05	7.83	1.42	2.02	0.96	0.000000e+00
5	95.95	1.78	1.15	0.10	8.44	1.83	3.36	1.21	3.018158e+04
6	212.31	3.93	1.85	0.38	22.13	4.28	18.35	3.15	5.383446e+21
7	20.39	0.38	0.17	0.00	3.03	0.63	0.40	0.38	0.000000e+00
8	73.45	1.36	1.24	0.09	4.92	0.95	0.90	0.66	5.940000e+00
9	153.04	2.83	0.25	0.00	22.02	6.02	36.27	4.12	0.000000e+00
10	88.15	1.63	1.44	0.00	6.83	1.54	2.37	1.12	0.000000e+00

In [ ]:

In [15]:
```
agg_func_ty = {
    'freshmass_leaves':
    ['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'prod']
}
df.groupby(['Typology']).agg(agg_func_ty).round(2)
```

Out[15]:

	freshmass_leaves								
	sum	mean	median	min	max	std	var	mad	prod
Typology									
1	1042.77	5.79	2.10	0.0	54.49	9.19	84.43	6.16	0.0
2	1140.99	6.34	2.38	0.0	102.79	11.61	134.73	6.74	0.0
3	5278.62	29.33	8.19	0.0	254.76	52.77	2785.17	35.29	0.0

In [16]:
```
agg_func_ty = {
    'drymass_leaves':
    ['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'prod']
}
df.groupby(['Typology']).agg(agg_func_ty).round(2)
```

Out[16]:

	drymass_leaves								
	sum	mean	median	min	max	std	var	mad	prod
Typology									
1	137.55	0.76	0.46	0.0	6.03	0.96	0.92	0.64	0.0
2	147.73	0.82	0.44	0.0	22.13	1.75	3.07	0.73	0.0
3	693.34	3.85	1.61	0.0	38.92	6.28	39.43	3.95	0.0

In [ ]:

VITAL DATA GENERATED USING THE GROUPBY FUNCTION

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In [17]:
```
df.groupby('Crop').freshmass_leaves.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'prod'])
```

Out[17]:

Crop	sum	mean	median	min	max	std	var	mad	prod
1	101.547	1.880500	0.6750	0.000	24.305	3.848072	14.807660	2.107241	0.000000e+00
2	1328.216	24.596593	3.4025	1.271	231.820	52.275808	2732.760115	32.196336	2.045515e+44
3	66.291	1.227611	0.8260	0.066	6.362	1.321389	1.746069	0.939615	2.413798e-08
4	263.243	4.874870	2.1605	0.058	32.960	6.654771	44.285979	4.496692	4.617971e+22
5	315.849	5.849056	3.8365	0.590	26.013	5.822784	33.904813	3.971039	5.531981e+32
6	3034.544	56.195259	33.3990	6.135	254.760	52.972717	2806.108744	39.782152	2.246921e+86
7	142.473	2.638389	1.3600	0.000	22.123	4.297347	18.467188	2.545673	0.000000e+00
8	547.517	10.139204	9.8210	0.650	31.908	6.991353	48.879012	5.134523	1.603660e+47
9	1259.379	23.321833	1.6475	0.000	239.481	54.312260	2949.821536	35.168753	0.000000e+00
10	403.328	7.469037	7.0425	0.000	33.592	6.794905	46.170730	5.128558	0.000000e+00

In [18]:
```
df.groupby('Crop').drymass_leaves.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'prod'])
```

Out[18]:

Crop	sum	mean	median	min	max	std	var	mad	prod
1	21.0669	0.390128	0.1205	0.000	4.240	0.715864	0.512461	0.442268	0.000000e+00
2	238.3890	4.414611	0.6805	0.180	38.919	9.154798	83.810326	5.691663	7.498622e+04
3	18.3650	0.340093	0.2715	0.010	1.364	0.325859	0.106184	0.255235	6.397279e-39
4	57.5130	1.065056	0.4990	0.050	7.827	1.420401	2.017539	0.958675	1.194599e-12
5	95.9490	1.776833	1.1480	0.095	8.440	1.833149	3.360436	1.212420	3.018158e+04
6	212.3080	3.931630	1.8515	0.379	22.127	4.283761	18.350606	3.149988	5.383446e+21
7	20.3900	0.377593	0.1675	0.000	3.032	0.631425	0.398698	0.379886	0.000000e+00
8	73.4500	1.360185	1.2365	0.092	4.915	0.950738	0.903903	0.660102	5.939637e+00
9	153.0440	2.834148	0.2510	0.000	22.021	6.022202	36.266918	4.122353	0.000000e+00
10	88.1470	1.632352	1.4430	0.000	6.830	1.538469	2.366887	1.124997	0.000000e+00

In [19]:
```
df.groupby('Crop').Soil_WC.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

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Out[19]:

Crop	sum	mean	median	min	max	std	var	mad	count
1	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54
2	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54
3	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54
4	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54
5	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54
6	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54
7	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54
8	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54
9	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54
10	13.464	0.249333	0.2575	0.079	0.337	0.073244	0.005365	0.053704	54

In [20]:
```
df.groupby('Crop').Soil_Temp.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[20]:

Crop	sum	mean	median	min	max	std	var	mad	count
1	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54
2	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54
3	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54
4	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54
5	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54
6	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54
7	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54
8	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54
9	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54
10	1127.4	20.877778	21.75	15.6	26.9	3.600402	12.962893	3.046914	54

In [21]:
```
df.groupby('Crop').Soil_SE.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

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Out[21]:

Crop	sum	mean	median	min	max	std	var	mad	count
1	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54
2	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54
3	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54
4	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54
5	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54
6	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54
7	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54
8	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54
9	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54
10	18.873	0.3495	0.313	0.0	0.747	0.259108	0.067137	0.223833	54

In [22]:
```
df.groupby('Crop').local_mintemp.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[22]:

Crop	sum	mean	median	min	max	std	var	mad	count
1	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54
2	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54
3	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54
4	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54
5	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54
6	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54
7	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54
8	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54
9	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54
10	789.9	14.627778	15.5	10.4	17.5	2.432051	5.914874	2.140741	54

In [23]:
```
df.groupby('Crop').local_maxtemp.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

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Out[23]:

Crop	sum	mean	median	min	max	std	var	mad	count
1	1647.3	30.505556	29.65	24.5	37.4	4.415556	19.497138	3.850617	54
2	1647.3	30.505556	29.65	24.5	37.4	4.402976	19.386195	3.839506	54
3	1647.3	30.505556	29.65	24.5	37.4	4.402976	19.386195	3.839506	54
4	1647.3	30.505556	29.65	24.5	37.4	4.402976	19.386195	3.839506	54
5	1647.3	30.505556	29.65	24.5	37.4	4.402976	19.386195	3.839506	54
6	1647.3	30.505556	29.65	24.5	37.4	4.402976	19.386195	3.839506	54
7	1647.3	30.505556	29.65	24.5	37.4	4.402976	19.386195	3.839506	54
8	1647.3	30.505556	29.65	24.5	37.4	4.402976	19.386195	3.839506	54
9	1647.3	30.505556	29.65	24.5	37.4	4.402976	19.386195	3.839506	54
10	1647.3	30.505556	29.65	24.5	37.4	4.402976	19.386195	3.839506	54

In [24]:
```
df.groupby('Crop').local_RH.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[24]:

Crop	sum	mean	median	min	max	std	var	mad	count
1	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54
2	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54
3	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54
4	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54
5	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54
6	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54
7	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54
8	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54
9	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54
10	3990.3	73.894444	79.8	50.3	89.3	12.691424	161.072233	10.92963	54

In [25]:
```
df.groupby('Crop').total_precip.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

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Out[25]:

Crop	sum	mean	median	min	max	std	var	mad	count
1	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54
2	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54
3	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54
4	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54
5	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54
6	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54
7	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54
8	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54
9	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54
10	408.6	7.566667	4.1	0.0	31.0	10.839811	117.501509	7.811111	54

In [26]:
```
df.groupby('Typology').freshmass_leaves.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[26]:

Typology	sum	mean	median	min	max	std	var	mad	count
1	1042.774	5.793189	2.0975	0.0	54.487	9.188735	84.432842	6.158267	180
2	1140.991	6.338839	2.3790	0.0	102.791	11.607275	134.728824	6.737616	180
3	5278.622	29.325678	8.1915	0.0	254.760	52.774750	2785.174237	35.290259	180

In [27]:
```
df.groupby('Typology').drymass_leaves.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[27]:

Typology	sum	mean	median	min	max	std	var	mad	count
1	137.5510	0.764172	0.4605	0.0	6.029	0.957331	0.916483	0.637033	180
2	147.7310	0.820728	0.4355	0.0	22.127	1.751799	3.068801	0.725651	180
3	693.3399	3.851888	1.6105	0.0	38.919	6.278963	39.425381	3.946726	180

In [28]:
```
df.groupby('Typology').Soil_WC.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[28]:

Typology	sum	mean	median	min	max	std	var	mad	count
1	36.93	0.205167	0.2365	0.101	0.262	0.060682	0.003682	0.055111	180
2	40.98	0.227667	0.2515	0.079	0.307	0.071837	0.005161	0.053444	180
3	56.73	0.315167	0.3125	0.289	0.337	0.015796	0.000250	0.012833	180

In [29]:
```
df.groupby('Typology').Soil_Temp.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

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Out[29]:

Typology	sum	mean	median	min	max	std	var	mad	count
1	3636.0	20.200000	21.05	15.6	24.1	3.156265	9.962011	2.833333	180
2	3510.0	19.500000	20.10	15.6	22.6	2.985440	8.912849	2.833333	180
3	4128.0	22.933333	23.15	17.0	26.9	3.589868	12.887151	3.200000	180

In [30]:
```
df.groupby('Typology').Soil_SE.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[30]:

Typology	sum	mean	median	min	max	std	var	mad	count
1	19.53	0.108500	0.1190	0.000	0.173	0.059147	0.003498	0.050833	180
2	46.56	0.258667	0.3130	0.000	0.373	0.126972	0.016122	0.101778	180
3	122.64	0.681333	0.6755	0.629	0.747	0.041656	0.001735	0.037000	180

In [31]:
```
df.groupby('Typology').local_maxtemp.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[31]:

Typology	sum	mean	median	min	max	std	var	mad	count
1	5338.5	29.658333	29.2	24.5	36.4	4.706253	22.148813	4.182500	180
2	5612.7	31.181667	31.1	24.9	37.4	4.405221	19.405975	3.918333	180
3	5521.8	30.676667	29.6	24.8	37.0	3.829831	14.667609	3.172556	180

In [32]:
```
df.groupby('Typology').local_mintemp.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[32]:

Typology	sum	mean	median	min	max	std	var	mad	count
1	2631.0	14.616667	15.60	10.4	17.5	2.470214	6.101955	2.177778	180
2	2634.0	14.633333	15.50	10.7	17.4	2.391091	5.717318	2.122222	180
3	2634.0	14.633333	15.55	10.7	17.4	2.386180	5.693855	2.122222	180

In [33]:
```
df.groupby('Typology').local_RH.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[33]:

Typology	sum	mean	median	min	max	std	var	mad	count
1	13359.0	74.216667	78.70	52.7	89.3	12.429117	154.482961	10.811111	180
2	13365.0	74.250000	80.30	51.2	88.4	12.728416	162.012570	11.166667	180
3	13179.0	73.216667	78.25	50.3	87.9	12.638385	159.728771	10.811111	180

In [34]:
```
df.groupby('Typology').total_precip.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

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Out[34]:

Typology	sum	mean	median	min	max	std	var	mad	count
1	1362.0	7.566667	4.1	0.0	31.0	10.768929	115.969832	7.811111	180
2	1362.0	7.566667	4.1	0.0	31.0	10.768929	115.969832	7.811111	180
3	1362.0	7.566667	4.1	0.0	31.0	10.768929	115.969832	7.811111	180

In [35]:
```
df.groupby('Position').freshmass_leaves.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[35]:

Position	sum	mean	median	min	max	std	var	mad	count
1	781.802	6.515017	2.4100	0.0	54.487	10.697102	114.427996	7.069576	120
2	671.081	5.592342	2.1600	0.0	45.360	8.997720	80.958965	5.935957	120
3	730.882	6.090683	2.0855	0.0	102.791	11.578921	134.071401	6.355019	120
4	5278.622	29.325678	8.1915	0.0	254.760	52.774750	2785.174237	35.290259	180

In [36]:
```
df.groupby('Position').drymass_leaves.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[36]:

Position	sum	mean	median	min	max	std	var	mad	count
1	95.5200	0.796000	0.4785	0.0	6.029	0.993946	0.987930	0.678067	120
2	79.2380	0.660317	0.4225	0.0	4.288	0.730975	0.534324	0.539756	120
3	110.5240	0.921033	0.4295	0.0	22.127	2.107260	4.440544	0.828028	120
4	693.3399	3.851888	1.6105	0.0	38.919	6.278963	39.425381	3.946726	180

In [37]:
```
df.groupby('Position').Soil_WC.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[37]:

Position	sum	mean	median	min	max	std	var	mad	count
1	25.97	0.216417	0.2460	0.079	0.307	0.067538	0.004561	0.054278	120
2	25.97	0.216417	0.2460	0.079	0.307	0.067538	0.004561	0.054278	120
3	25.97	0.216417	0.2460	0.079	0.307	0.067538	0.004561	0.054278	120
4	56.73	0.315167	0.3125	0.289	0.337	0.015796	0.000250	0.012833	180

In [38]:
```
df.groupby('Position').Soil_Temp.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[38]:

Position	sum	mean	median	min	max	std	var	mad	count
1	2382.0	19.850000	20.80	15.6	24.1	3.096352	9.587395	2.833333	120
2	2382.0	19.850000	20.80	15.6	24.1	3.096352	9.587395	2.833333	120
3	2382.0	19.850000	20.80	15.6	24.1	3.096352	9.587395	2.833333	120
4	4128.0	22.933333	23.15	17.0	26.9	3.589868	12.887151	3.200000	180

In [39]:
```
df.groupby('Position').Soil_SE.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

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Out[39]:

Position	sum	mean	median	min	max	std	var	mad	count
1	22.03	0.183583	0.1655	0.000	0.373	0.124589	0.015522	0.105681	120
2	22.03	0.183583	0.1655	0.000	0.373	0.124589	0.015522	0.105681	120
3	22.03	0.183583	0.1655	0.000	0.373	0.124589	0.015522	0.105681	120
4	122.64	0.681333	0.6755	0.629	0.747	0.041656	0.001735	0.037000	180

In [40]:
```
df.groupby('Position').local_maxtemp.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[40]:

Position	sum	mean	median	min	max	std	var	mad	count
1	3650.4	30.420000	29.7	24.5	37.4	4.628240	21.420605	4.164667	120
2	3650.4	30.420000	29.7	24.5	37.4	4.628240	21.420605	4.164667	120
3	3650.4	30.420000	29.7	24.5	37.4	4.628240	21.420605	4.164667	120
4	5521.8	30.676667	29.6	24.8	37.0	3.829831	14.667609	3.172556	180

In [41]:
```
df.groupby('Position').local_mintemp.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[41]:

Position	sum	mean	median	min	max	std	var	mad	count
1	1755.0	14.625000	15.50	10.4	17.5	2.434391	5.926261	2.150000	120
2	1755.0	14.625000	15.50	10.4	17.5	2.434391	5.926261	2.150000	120
3	1755.0	14.625000	15.50	10.4	17.5	2.434391	5.926261	2.150000	120
4	2634.0	14.633333	15.55	10.7	17.4	2.386180	5.693855	2.122222	180

In [42]:
```
df.groupby('Position').local_RH.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[42]:

Position	sum	mean	median	min	max	std	var	mad	count
1	8908.0	74.233333	79.80	51.2	89.3	12.597274	158.691317	10.988889	120
2	8908.0	74.233333	79.80	51.2	89.3	12.597274	158.691317	10.988889	120
3	8908.0	74.233333	79.80	51.2	89.3	12.597274	158.691317	10.988889	120
4	13179.0	73.216667	78.25	50.3	87.9	12.638385	159.728771	10.811111	180

In [43]:
```
df.groupby('Position').total_precip.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

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Out[43]:

Position	sum	mean	median	min	max	std	var	mad	count
1	908.0	7.566667	4.1	0.0	31.0	10.784001	116.294678	7.811111	120
2	908.0	7.566667	4.1	0.0	31.0	10.784001	116.294678	7.811111	120
3	908.0	7.566667	4.1	0.0	31.0	10.784001	116.294678	7.811111	120
4	1362.0	7.566667	4.1	0.0	31.0	10.768929	115.969832	7.811111	180

In [44]:
```
df.groupby('daylength').total_precip.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[44]:

daylength	sum	mean	median	min	max	std	var	mad	count
11:22:04	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000000e+00	90
12:12:09	2790.0	31.0	31.0	31.0	31.0	0.0	0.0	0.000000e+00	90
12:54:18	270.0	3.0	3.0	3.0	3.0	0.0	0.0	0.000000e+00	90
13:21:32	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.000000e+00	90
13:32:16	468.0	5.2	5.2	5.2	5.2	0.0	0.0	7.993606e-15	90
13:45:00	558.0	6.2	6.2	6.2	6.2	0.0	0.0	3.552714e-15	90

In [45]:
```
df.groupby('daylength_sec').freshmass_leaves.agg(['sum', 'mean', 'median', 'min', 'max', 'std', 'var', 'mad', 'count'])
```

Out[45]:

daylength_sec	sum	mean	median	min	max	std	var	mad	count
40924	1161.425	12.904722	2.2215	0.000	197.890	31.211734	974.172367	16.068301	90
43929	1448.342	16.092689	2.8485	0.000	254.760	42.935837	1843.486104	21.105933	90
46458	1056.209	11.735656	2.4015	0.000	212.990	30.428998	925.923915	14.708020	90
48092	1325.995	14.733278	4.1720	0.099	239.481	35.149855	1235.512308	16.984127	90
48736	1159.620	12.884667	3.2570	0.000	151.663	27.206474	740.192245	15.067422	90
49500	1310.796	14.564400	3.7290	0.000	153.642	32.251276	1040.144782	17.663093	90

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Appendix E: Statistical analysis results testing the correlation between crop positioning and biomass

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POSITION - Fresh Mass of leaves

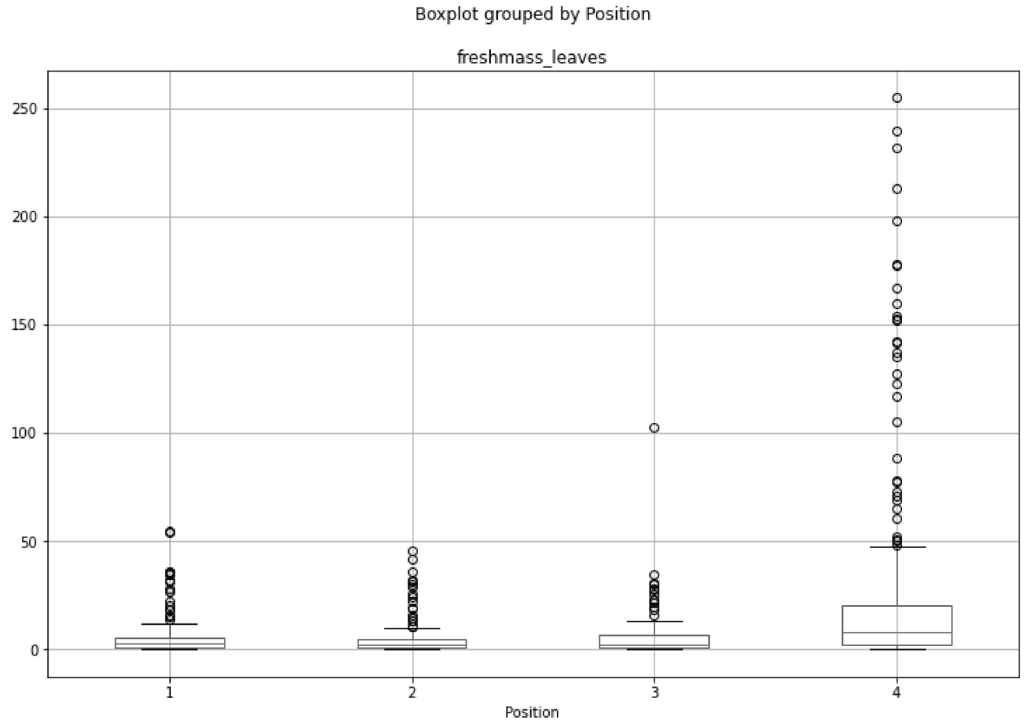
In [113]:
```
aov = pg.anova(data=df, dv='freshmass_leaves', between='Position', detailed=True)
print(aov)
```

```
      Source             SS   DF            MS          F         p-unc  \
0   Position   64972.625001    3  21657.541667  21.586992  3.266429e-13
1     Within  537751.733494  536   1003.268160        NaN           NaN

        np2
0  0.107798
1       NaN
```

In [114]:
```
#Create a boxplot
df.boxplot('freshmass_leaves', by='Position', figsize=(12, 8))
```

Out[114]: <AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Position'>



In [ ]:

Nway ANOVA

In [115]:
```
df.anova(dv='drymass_leaves', between=['Crop', 'Typology'], ss_type=3).round(3)
```

Out[115]:

	Source	SS	DF	MS	F	p-unc	np2
0	Crop	1045.037	9	116.115	11.601	0.0	0.170
1	Typology	1123.507	2	561.754	56.125	0.0	0.180
2	Crop * Typology	1620.890	18	90.049	8.997	0.0	0.241
3	Residual	5104.583	510	10.009	NaN	NaN	NaN

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In [ ]:

Post hoc Comaparison - Fresh Mass of leaves comparison

In [116]:
```
pt = pg.pairwise_tukey(dv='freshmass_leaves', between='Position', data=df).round(3)
print(pt)
```

```
   A  B  mean(A)  mean(B)    diff     se      T  p-tukey  hedges
0  1  2    6.515    5.592   0.923  4.089  0.226    0.996   0.029
1  1  3    6.515    6.091   0.424  4.089  0.104    1.000   0.013
2  1  4    6.515   29.326 -22.811  3.733 -6.111    0.000  -0.718
3  2  3    5.592    6.091  -0.498  4.089 -0.122    0.999  -0.016
4  2  4    5.592   29.326 -23.733  3.733 -6.358    0.000  -0.747
5  3  4    6.091   29.326 -23.235  3.733 -6.224    0.000  -0.732
```

In [ ]:

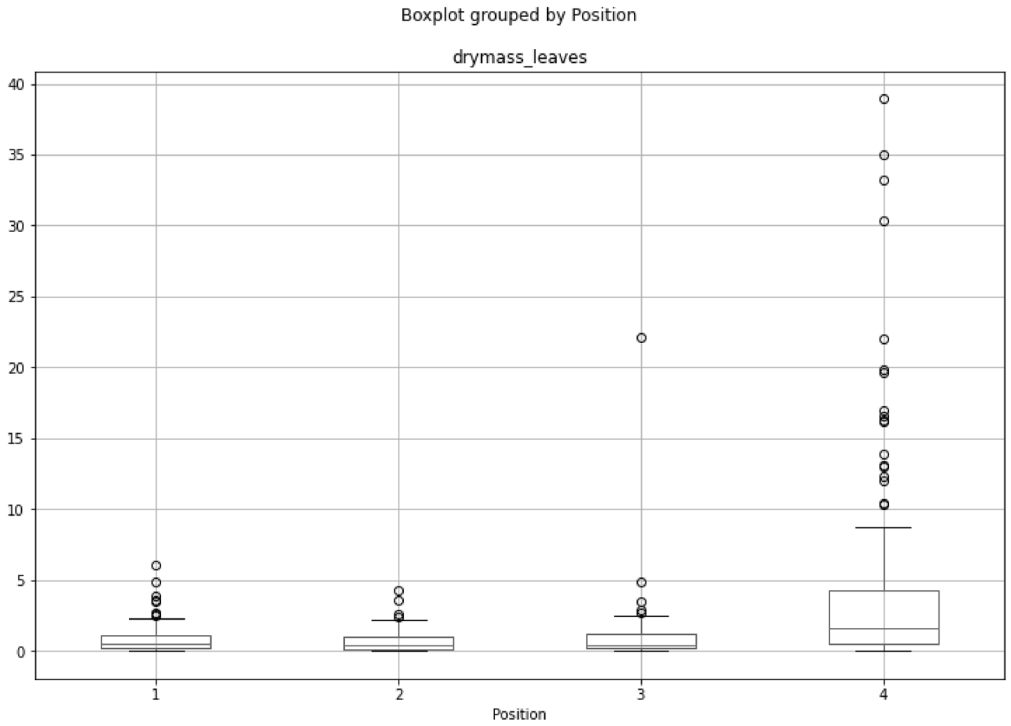
POSITION - Dry Mass of leaves

In [117]:
```
aov = pg.anova(data=df, dv='drymass_leaves', between='Position', detailed=True).round(3)
print(aov)
```

```
      Source        SS   DF       MS       F  p-unc    np2
0   Position  1127.300    3  375.767  25.933    0.0  0.127
1     Within  7766.716  536   14.490     NaN    NaN    NaN
```

In [118]:
```
#Create a boxplot
df.boxplot('drymass_leaves', by='Position', figsize=(12, 8))
```

Out[118]:
```
<AxesSubplot:title={'center':'drymass_leaves'}, xlabel='Position'>
```



Post Hoc Comparison - Dry Mass Leaves

In [119]:
```
pt = pg.pairwise_tukey(dv='drymass_leaves', between='Position', data=df).round(3)
print(pt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	hedges
0	1	2	0.796	0.660	0.136	0.491	0.276	0.993	0.036
1	1	3	0.796	0.921	-0.125	0.491	-0.254	0.994	-0.033
2	1	4	0.796	3.852	-3.056	0.449	-6.812	0.000	-0.801
3	2	3	0.660	0.921	-0.261	0.491	-0.531	0.952	-0.068
4	2	4	0.660	3.852	-3.192	0.449	-7.114	0.000	-0.836
5	3	4	0.921	3.852	-2.931	0.449	-6.533	0.000	-0.768

N-way ANOVA

In [120]:
```
df.anova(dv='drymass_leaves', between=['Crop', 'Typology'], ss_type=3).round(3)
```

Out[120]:

	Source	SS	DF	MS	F	p-unc	np2
0	Crop	1045.037	9	116.115	11.601	0.0	0.170
1	Typology	1123.507	2	561.754	56.125	0.0	0.180
2	Crop * Typology	1620.890	18	90.049	8.997	0.0	0.241
3	Residual	5104.583	510	10.009	NaN	NaN	NaN

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Is there a correlation between the position of a crop (top row, second row, and third row) and the fresh and dry mass (in other words performance of crops)?

In [197]:
```
df[['Position','freshmass_leaves', 'drymass_leaves']].pcorr().round(3)
```

Out[197]:

	Position	freshmass_leaves	drymass_leaves
Position	1.000	0.009	0.136
freshmass_leaves	0.009	1.000	0.873
drymass_leaves	0.136	0.873	1.000

In [184]:
```
W1_fm[['Position', 'freshmass_leaves', 'drymass_leaves']].pcorr().round(3)
```

Out[184]:

	Position	freshmass_leaves	drymass_leaves
Position	1.000	0.018	-0.037
freshmass_leaves	0.018	1.000	0.802
drymass_leaves	-0.037	0.802	1.000

In [185]:
```
W2_fm[['Position', 'freshmass_leaves', 'drymass_leaves']].pcorr().round(3)
```

Out[185]:

	Position	freshmass_leaves	drymass_leaves
Position	1.000	-0.131	0.152
freshmass_leaves	-0.131	1.000	0.807
drymass_leaves	0.152	0.807	1.000

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Appendix F: Statistical analysis results comparing typologies and biomass

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Fresh Mass of leaves

Subsetting the dataset

In [50]:
```
W1_fm = df.loc[df['Typology'] == 1]
```

In [51]:
```
W1_fm
```

Out[51]:

	Crop	Position	Typology	Month	freshmass_leaves	drymass_leaves	Soil_WC	Soil_Temp	Soil_SE	local_maxtemp	local_mintemp	local_RH	total_precip	daylength	daylength_sec	hour	minute	seconds
0	1	1	1	2021-11-15	3.105	0.738	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13	21	32
1	1	2	1	2021-11-15	0.390	0.087	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13	21	32
2	1	3	1	2021-11-15	1.423	0.329	0.243	22.7	0.091	36.4	16.3	52.7	0.0	13:21:32	48092	13	21	32
9	1	1	1	2021-12-15	0.068	0.012	0.144	16.7	0.082	24.5	12.3	82.6	6.2	13:45:00	49500	13	45	0
10	1	2	1	2021-12-15	0.669	0.096	0.144	16.7	0.082	24.5	12.3	82.6	6.2	13:45:00	49500	13	45	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
523	10	2	1	2022-03-15	2.484	0.404	0.251	19.8	0.173	29.2	15.3	89.3	31.0	12:12:09	43929	12	12	9
524	10	3	1	2022-03-15	1.694	0.261	0.251	19.8	0.173	29.2	15.3	89.3	31.0	12:12:09	43929	12	12	9
531	10	1	1	2022-04-15	8.275	1.470	0.230	15.6	0.158	27.1	10.4	77.8	0.0	11:22:04	40924	11	22	4
532	10	2	1	2022-04-15	14.475	2.620	0.230	15.6	0.158	27.1	10.4	77.8	0.0	11:22:04	40924	11	22	4
533	10	3	1	2022-04-15	8.281	1.460	0.230	15.6	0.158	27.1	10.4	77.8	0.0	11:22:04	40924	11	22	4

180 rows × 18 columns

Comparisons of freshmass and drymass production by the different crops grown in different positions in Wall 1

In [52]:
```
aov = pg.anova(data=W1_fm, dv='freshmass_leaves', between='Crop', detailed=True)
print(aov)
```

```
   Source            SS   DF           MS          F         p-unc       np2
0    Crop  10684.248240    9  1187.138693  45.564027  7.925895e-41  0.706935
1  Within   4429.230447  170    26.054297        NaN           NaN       NaN
```

When the ANOVA result *p-value < 0.05*, it means **there are statistical significant differences between the groups** and that means **you should then interpret the post-hoc analysis results** to determine which crop produces the best performance in terms of fresh mass and dry masses production.

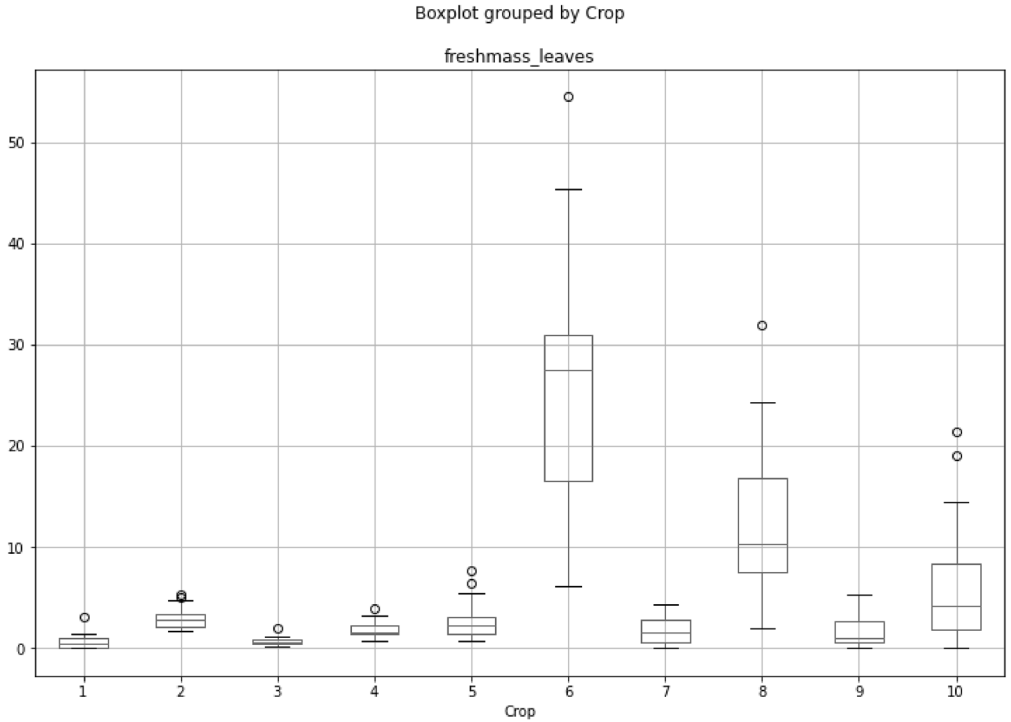
When the ANOVA result *p-value > 0.05*, it means **there are no statistical significant differences between the groups** and that means **you should not interpret the post-hoc analysis results** even if the results are indicated.

YOU SHOULD USE THE SAME LOGIC TO INTERPRET THE RESULTS FOR THE COMPARISONS OF PLANT POSITIONS.

In [53]:
```
#Create a boxplot
W1_fm.boxplot('freshmass_leaves', by='Crop', figsize=(12, 8))
```

Out[53]:
```
<AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Crop'>
```

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In [54]:
```
pt = pg.pairwise_tukey(dv='freshmass_leaves', between='Crop', data=W1_fm)
print(pt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	hedges
0	1	2	0.644222	2.989333	-2.345111	1.701447	-1.378304	9.322762e-01	-0.449225
1	1	3	0.644222	0.684222	-0.040000	1.701447	-0.023509	1.000000e+00	-0.007662
2	1	4	0.644222	1.871556	-1.227333	1.701447	-0.721347	9.993454e-01	-0.235106
3	1	5	0.644222	2.735667	-2.091444	1.701447	-1.229215	9.666546e-01	-0.400633
4	1	6	0.644222	26.471944	-25.827722	1.701447	-15.179857	0.000000e+00	-4.947509
5	1	7	0.644222	1.718667	-1.074444	1.701447	-0.631489	9.997791e-01	-0.205819
6	1	8	0.644222	12.725000	-12.080778	1.701447	-7.100296	1.456077e-09	-2.314171
7	1	9	0.644222	1.810000	-1.165778	1.701447	-0.685168	9.995685e-01	-0.223314
8	1	10	0.644222	6.281278	-5.637056	1.701447	-3.313095	3.655759e-02	-1.079824
9	2	3	2.989333	0.684222	2.305111	1.701447	1.354795	9.388639e-01	0.441563
10	2	4	2.989333	1.871556	1.117778	1.701447	0.656957	9.996940e-01	0.214119
11	2	5	2.989333	2.735667	0.253667	1.701447	0.149089	1.000000e+00	0.048592
12	2	6	2.989333	26.471944	-23.482611	1.701447	-13.801553	0.000000e+00	-4.498284
13	2	7	2.989333	1.718667	1.270667	1.701447	0.746815	9.991354e-01	0.243406
14	2	8	2.989333	12.725000	-9.735667	1.701447	-5.721992	2.060327e-06	-1.864946
15	2	9	2.989333	1.810000	1.179333	1.701447	0.693136	9.995260e-01	
16	2	10	2.989333	6.281278	-3.291944	1.701447	-1.934791	6.454074e-01	
17	3	4	0.684222	1.871556	-1.187333	1.701447	-0.697837	9.994992e-01	
18	3	5	0.684222	2.735667	-2.051444	1.701447	-1.205706	9.705895e-01	
19	3	6	0.684222	26.471944	-25.787722	1.701447	-15.156348	0.000000e+00	
20	3	7	0.684222	1.718667	-1.034444	1.701447	-0.607979	9.998387e-01	
21	3	8	0.684222	12.725000	-12.040778	1.701447	-7.076787	1.659869e-09	
22	3	9	0.684222	1.810000	-1.125778	1.701447	-0.661659	9.996756e-01	
23	3	10	0.684222	6.281278	-5.597056	1.701447	-3.289586	3.920832e-02	
24	4	5	1.871556	2.735667	-0.864111	1.701447	-0.507868	9.999646e-01	
25	4	6	1.871556	26.471944	-24.600389	1.701447	-14.458510	0.000000e+00	
26	4	7	1.871556	1.718667	0.152889	1.701447	0.089858	1.000000e+00	
27	4	8	1.871556	12.725000	-10.853444	1.701447	-6.378950	7.273059e-08	
28	4	9	1.871556	1.810000	0.061556	1.701447	0.036178	1.000000e+00	
29	4	10	1.871556	6.281278	-4.409722	1.701447	-2.591748	2.297502e-01	
30	5	6	2.735667	26.471944	-23.736278	1.701447	-13.950642	0.000000e+00	
31	5	7	2.735667	1.718667	1.017000	1.701447	0.597727	9.998600e-01	
32	5	8	2.735667	12.725000	-9.989333	1.701447	-5.871081	9.842594e-07	
33	5	9	2.735667	1.810000	0.925667	1.701447	0.544047	9.999365e-01	
34	5	10	2.735667	6.281278	-3.545611	1.701447	-2.083880	5.414193e-01	
35	6	7	26.471944	1.718667	24.753278	1.701447	14.548368	0.000000e+00	
36	6	8	26.471944	12.725000	13.746944	1.701447	8.079561	5.114686e-12	
37	6	9	26.471944	1.810000	24.661944	1.701447	14.494689	0.000000e+00	
38	6	10	26.471944	6.281278	20.190667	1.701447	11.866762	0.000000e+00	
39	7	8	1.718667	12.725000	-11.006333	1.701447	-6.468808	4.525895e-08	
40	7	9	1.718667	1.810000	-0.091333	1.701447	-0.053680	1.000000e+00	
41	7	10	1.718667	6.281278	-4.562611	1.701447	-2.681606	1.896943e-01	
42	8	9	12.725000	1.810000	10.915000	1.701447	6.415128	6.011387e-08	
43	8	10	12.725000	6.281278	6.443722	1.701447	3.787201	7.851374e-03	
44	9	10	1.810000	6.281278	-4.471278	1.701447	-2.627927	2.129882e-01	

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```
15  0.225911
16 -0.630599
17 -0.227443
18 -0.392971
19 -4.939847
20 -0.198156
21 -2.306508
22 -0.215652
23 -1.072161
24 -0.165527
25 -4.712403
26  0.029287
27 -2.079065
28  0.011791
29 -0.844718
30 -4.546876
31  0.194815
32 -1.913538
33  0.177319
34 -0.679190
35  4.741690
36  2.633338
37  4.724195
38  3.867685
39 -2.108352
40 -0.017496
41 -0.874005
42  2.090856
43  1.234347
44 -0.856509
```

In [ ]:

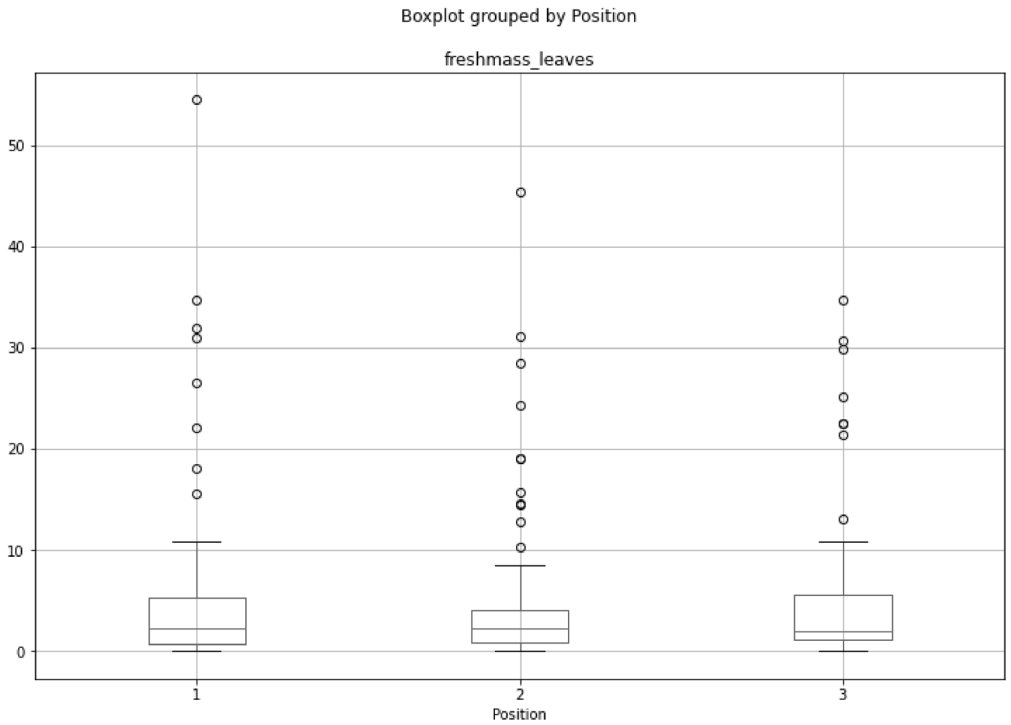
In [55]:
```
aov = pg.anova(data=W1_fm, dv='freshmass_leaves', between='Position', detailed=True)
print(aov)
```

```
     Source            SS   DF         MS         F     p-unc       np2
0  Position      9.124329    2   4.562165  0.053462  0.947958  0.000604
1    Within  15104.354359  177  85.335335       NaN       NaN       NaN
```

In [56]:
```
#Create a boxplot
W1_fm.boxplot('freshmass_leaves', by='Position', figsize=(12, 8))
```

Out[56]:
```
<AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Position'>
```

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In [57]:
```
pt = pg.pairwise_tukey(dv='freshmass_leaves', between='Position', data=W1_fm)
print(pt)
```

```
   A  B   mean(A)   mean(B)      diff        se         T   p-tukey    hedges
0  1  2  6.109683  5.604783  0.504900  1.686568  0.299365  0.951813  0.054308
1  1  3  6.109683  5.665100  0.444583  1.686568  0.263602  0.962428  0.047820
2  2  3  5.604783  5.665100 -0.060317  1.686568 -0.035763  0.999295 -0.006488
```

In [ ]:

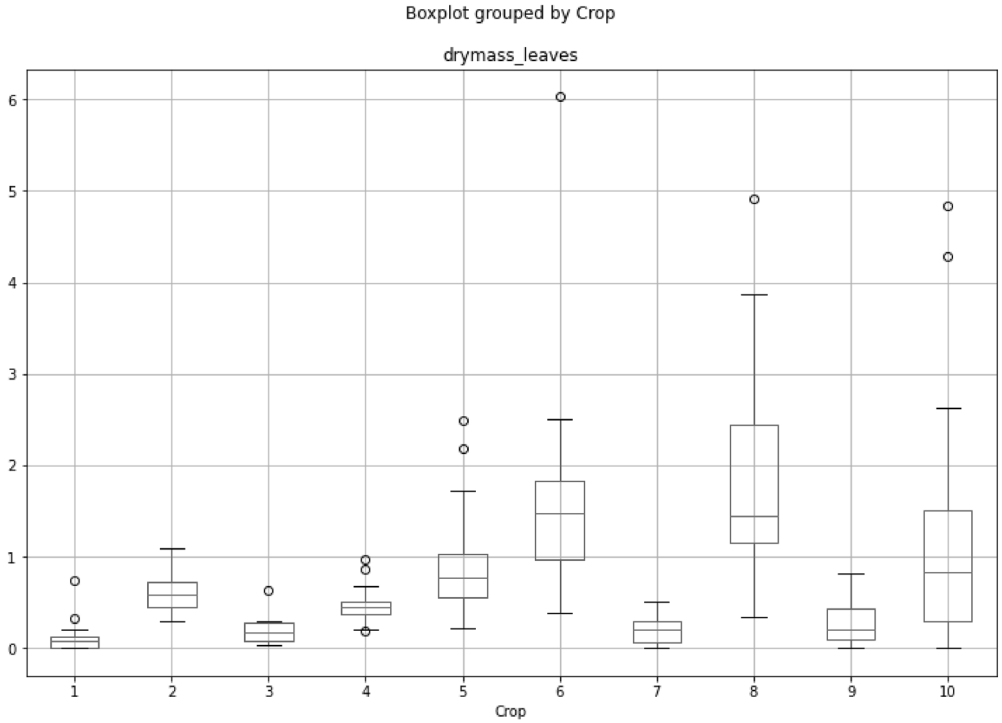
In [58]:
```
aov = pg.anova(data=W1_fm, dv='drymass_leaves', between='Crop', detailed=True)
print(aov)
```

```
   Source         SS   DF        MS          F         p-unc       np2
0    Crop  67.513156    9  7.501462  13.209915  6.744391e-16  0.411539
1  Within  96.537224  170  0.567866        NaN           NaN       NaN
```

In [59]:
```
#Create a boxplot
W1_fm.boxplot('drymass_leaves', by='Crop', figsize=(12, 8))
```

Out[59]:
```
<AxesSubplot:title={'center':'drymass_leaves'}, xlabel='Crop'>
```

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In [60]:
```
pt = pg.pairwise_tukey(dv='drymass_leaves', between='Crop', data=W1_fm)
print(pt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	hedges
0	1	2	0.119611	0.603056	-0.483444	0.25119	-1.924620	6.523631e-01	-0.627283
1	1	3	0.119611	0.191778	-0.072167	0.25119	-0.287300	9.999998e-01	-0.093638
2	1	4	0.119611	0.475444	-0.355833	0.25119	-1.416593	9.205442e-01	-0.461704
3	1	5	0.119611	0.912833	-0.793222	0.25119	-3.157862	5.735899e-02	-1.029229
4	1	6	0.119611	1.666722	-1.547111	0.25119	-6.159136	2.282714e-07	-2.007422
5	1	7	0.119611	0.204722	-0.085111	0.25119	-0.338832	9.999989e-01	-0.110434
6	1	8	0.119611	1.864944	-1.745333	0.25119	-6.948270	3.383188e-09	-2.264621
7	1	9	0.119611	0.284500	-0.164889	0.25119	-0.656432	9.996960e-01	-0.213948
8	1	10	0.119611	1.318111	-1.198500	0.25119	-4.771296	1.666992e-04	-1.555089
9	2	3	0.603056	0.191778	0.411278	0.25119	1.637320	8.278798e-01	0.533645
10	2	4	0.603056	0.475444	0.127611	0.25119	0.508027	9.999645e-01	0.165579
11	2	5	0.603056	0.912833	-0.309778	0.25119	-1.233243	9.659433e-01	-0.401946
12	2	6	0.603056	1.666722	-1.063667	0.25119	-4.234517	1.506552e-03	-1.380139
13	2	7	0.603056	0.204722	0.398333	0.25119	1.585787	8.533002e-01	0.516849
14	2	8	0.603056	1.864944	-1.261889	0.25119	-5.023651	5.500378e-05	-1.637338
15	2	9	0.603056	0.284500	0.318556	0.25119	1.268188	9.592956e-01	
16	2	10	0.603056	1.318111	-0.715056	0.25119	-2.846676	1.295826e-01	
17	3	4	0.191778	0.475444	-0.283667	0.25119	-1.129293	9.810114e-01	
18	3	5	0.191778	0.912833	-0.721056	0.25119	-2.870563	1.222584e-01	
19	3	6	0.191778	1.666722	-1.474944	0.25119	-5.871837	9.805503e-07	
20	3	7	0.191778	0.204722	-0.012944	0.25119	-0.051533	1.000000e+00	
21	3	8	0.191778	1.864944	-1.673167	0.25119	-6.660971	1.620420e-08	
22	3	9	0.191778	0.284500	-0.092722	0.25119	-0.369132	9.999978e-01	
23	3	10	0.191778	1.318111	-1.126333	0.25119	-4.483996	5.568806e-04	
24	4	5	0.475444	0.912833	-0.437389	0.25119	-1.741270	7.702346e-01	
25	4	6	0.475444	1.666722	-1.191278	0.25119	-4.742544	1.886061e-04	
26	4	7	0.475444	0.204722	0.270722	0.25119	1.077760	9.862459e-01	
27	4	8	0.475444	1.864944	-1.389500	0.25119	-5.531678	5.193930e-06	
28	4	9	0.475444	0.284500	0.190944	0.25119	0.760161	9.990043e-01	
29	4	10	0.475444	1.318111	-0.842667	0.25119	-3.354703	3.224855e-02	
30	5	6	0.912833	1.666722	-0.753889	0.25119	-3.001274	8.776277e-02	
31	5	7	0.912833	0.204722	0.708111	0.25119	2.819030	1.384785e-01	
32	5	8	0.912833	1.864944	-0.952111	0.25119	-3.790408	7.764086e-03	
33	5	9	0.912833	0.284500	0.628333	0.25119	2.501430	2.753026e-01	
34	5	10	0.912833	1.318111	-0.405278	0.25119	-1.613434	8.399381e-01	
35	6	7	1.666722	0.204722	1.462000	0.25119	5.820304	1.267593e-06	
36	6	8	1.666722	1.864944	-0.198222	0.25119	-0.789134	9.986612e-01	
37	6	9	1.666722	0.284500	1.382222	0.25119	5.502704	5.967880e-06	
38	6	10	1.666722	1.318111	0.348611	0.25119	1.387840	9.294714e-01	
39	7	8	0.204722	1.864944	-1.660222	0.25119	-6.609438	2.137845e-08	
40	7	9	0.204722	0.284500	-0.079778	0.25119	-0.317600	9.999994e-01	
41	7	10	0.204722	1.318111	-1.113389	0.25119	-4.432464	6.867876e-04	
42	8	9	1.864944	0.284500	1.580444	0.25119	6.291838	1.147665e-07	
43	8	10	1.864944	1.318111	0.546833	0.25119	2.176974	4.766492e-01	
44	9	10	0.284500	1.318111	-1.033611	0.25119	-4.114864	2.384137e-03	

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```
15  0.413335
16 -0.927806
17 -0.368066
18 -0.935591
19 -1.913784
20 -0.016796
21 -2.170983
22 -0.120310
23 -1.461451
24 -0.567525
25 -1.545718
26  0.351270
27 -1.802917
28  0.247756
29 -1.093385
30 -0.978193
31  0.918795
32 -1.235392
33  0.815281
34 -0.525860
35  1.896988
36 -0.257199
37  1.793474
38  0.452333
39 -2.154187
40 -0.103514
41 -1.444655
42  2.050673
43  0.709532
44 -1.341141
```

In [ ]:

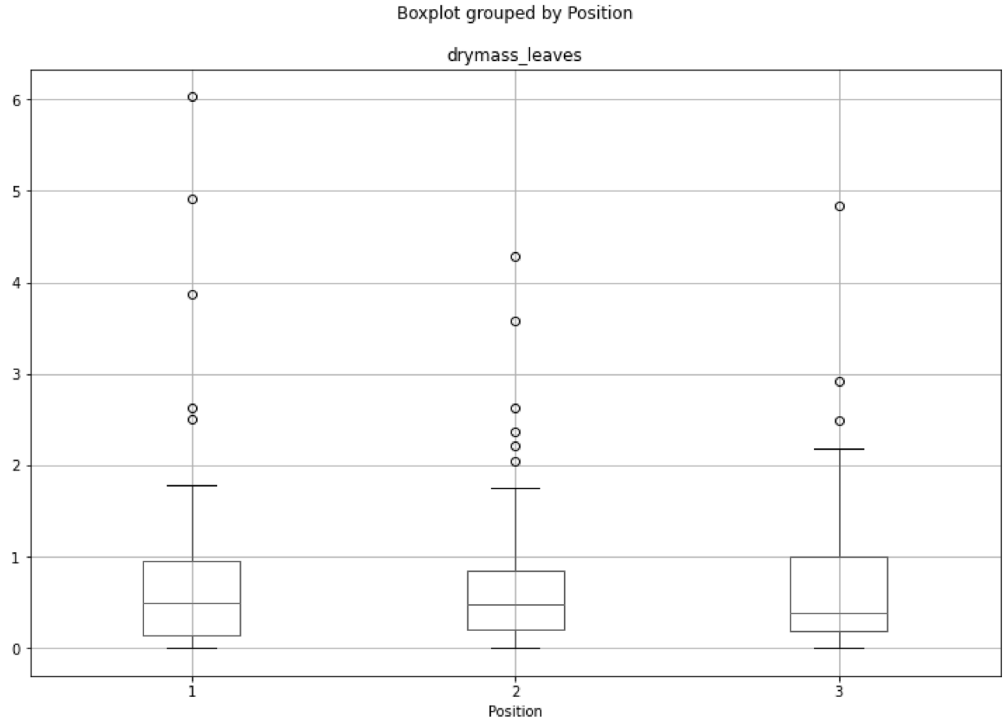
In [61]:
```
aov = pg.anova(data=W1_fm, dv='drymass_leaves', between='Position', detailed=True)
print(aov)
```

```
      Source          SS   DF        MS        F     p-unc       np2
0   Position    0.341329    2  0.170664  0.18452  0.831663  0.002081
1     Within  163.709051  177  0.924910      NaN       NaN       NaN
```

In [62]:
```
#Create a boxplot
W1_fm.boxplot('drymass_leaves', by='Position', figsize=(12, 8))
```

Out[62]:
```
<AxesSubplot:title={'center':'drymass_leaves'}, xlabel='Position'>
```

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In [63]:
```
pt = pg.pairwise_tukey(dv='drymass_leaves', between='Position', data=W1_fm)
print(pt)
```

```
   A  B   mean(A)   mean(B)      diff        se         T   p-tukey    hedges
0  1  2  0.825617  0.729867  0.095750  0.175586  0.545318  0.849001  0.098927
1  1  3  0.825617  0.737033  0.088583  0.175586  0.504502  0.869238  0.091522
2  2  3  0.729867  0.737033 -0.007167  0.175586 -0.040816  0.999082 -0.007404
```

In [ ]:

SUBSETTING THE DATASET 2 FOR TYPOLOGY 2

In [64]:
```
W2_fm = df.loc[df['Typology'] == 2]
```

In [65]:
```
W2_fm
```

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Out[65]:

	Crop	Position	Typology	Month	freshmass_leaves	drymass_leaves	Soil_WC	Soil_Temp	Soil_SE	local_maxtemp	local_mintemp	local_RH	total_precip	daylength	daylength_sec	hour	minute	seconds
3	1	1	2	2021-11-15	1.504	0.244	0.254	22.6	0.212	37.4	16.5	51.2	0.0	13:21:32	48092	13	21	32
4	1	2	2	2021-11-15	1.589	0.242	0.254	22.6	0.212	37.4	16.5	51.2	0.0	13:21:32	48092	13	21	32
5	1	3	2	2021-11-15	1.658	0.347	0.254	22.6	0.212	37.4	16.5	51.2	0.0	13:21:32	48092	13	21	32
12	1	1	2	2021-12-15	0.775	0.180	0.307	16.0	0.287	24.9	12.2	81.5	6.2	13:45:00	49500	13	45	0
13	1	2	2	2021-12-15	0.370	0.091	0.307	16.0	0.287	24.9	12.2	81.5	6.2	13:45:00	49500	13	45	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
526	10	2	2	2022-03-15	3.839	0.687	0.249	18.4	0.339	29.7	15.3	88.4	31.0	12:12:09	43929	12	12	9
527	10	3	2	2022-03-15	10.244	2.663	0.249	18.4	0.339	29.7	15.3	88.4	31.0	12:12:09	43929	12	12	9
534	10	1	2	2022-04-15	18.547	3.480	0.261	15.6	0.341	27.2	10.7	80.6	0.0	11:22:04	40924	11	22	4
535	10	2	2	2022-04-15	6.810	1.170	0.261	15.6	0.341	27.2	10.7	80.6	0.0	11:22:04	40924	11	22	4
536	10	3	2	2022-04-15	9.700	1.850	0.261	15.6	0.341	27.2	10.7	80.6	0.0	11:22:04	40924	11	22	4

180 rows × 18 columns

Comparisons of freshmass and drymass production by the different crops grown in different positions in Wall 2

In [66]:
```
aov = pg.anova(data=W2_fm, dv='freshmass_leaves', between='Crop', detailed=True)
print(aov)
```

```
   Source            SS   DF           MS         F         p-unc      np2
0    Crop  16306.587286    9  1811.843032  39.43897  3.301382e-37  0.67616
1  Within   7809.872278  170    45.940425       NaN           NaN      NaN
```

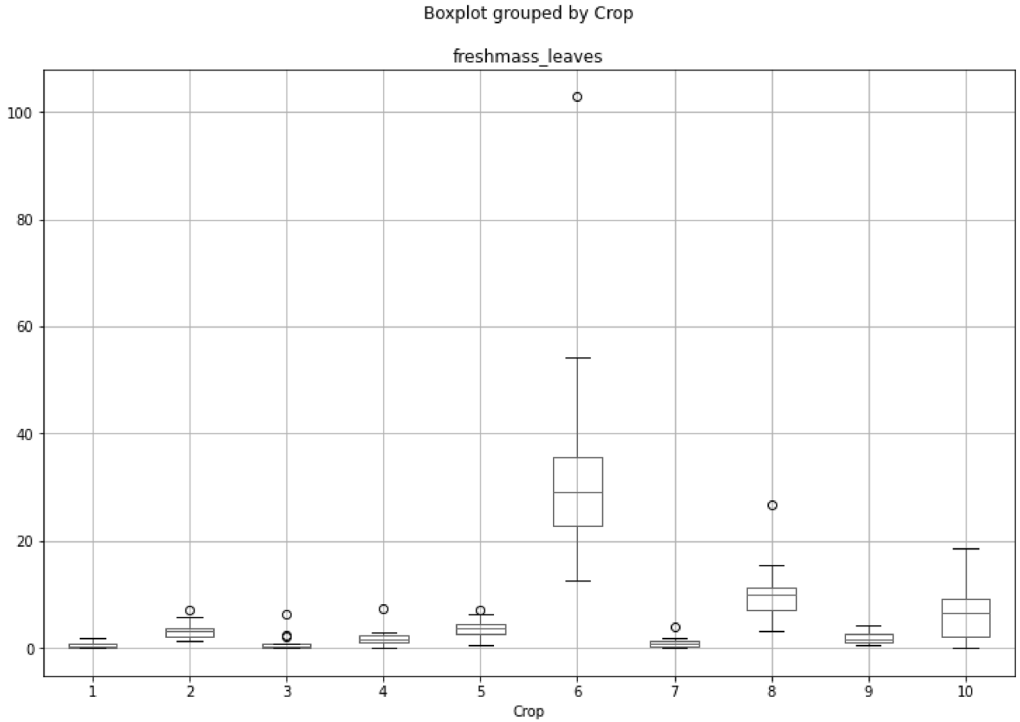
When the ANOVA result *p-value < 0.05*, it means **there are statistical significant differences between the groups** and that means **you should then interpret the post-hoc analysis results** to determine which crop produces the best performance in terms of fresh mass and dry masses production.

When the ANOVA result *p-value > 0.05*, it means **there are no statistical significant differences between the groups** and that means **you should not interpret the post-hoc analysis results** even if the results are indicated.

In [67]:
```
#Create a boxplot
W2_fm.boxplot('freshmass_leaves', by='Crop', figsize=(12, 8))
```

Out[67]:
```
<AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Crop'>
```

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In [68]:
```
pt = pg.pairwise_tukey(dv='freshmass_leaves', between='Crop', data=W2_fm)
print(pt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	hedges
0	1	2	0.632056	3.154333	-2.522278	2.259312	-1.116392	0.982446	-0.363861
1	1	3	0.632056	0.900889	-0.268833	2.259312	-0.118989	1.000000	-0.038782
2	1	4	0.632056	1.902611	-1.270556	2.259312	-0.562364	0.999916	-0.183289
3	1	5	0.632056	3.809722	-3.177667	2.259312	-1.406475	0.923767	-0.458407
4	1	6	0.632056	33.652000	-33.019944	2.259312	-14.615043	0.000000	-4.763421
5	1	7	0.632056	1.013333	-0.381278	2.259312	-0.168758	1.000000	-0.055003
6	1	8	0.632056	9.927556	-9.295500	2.259312	-4.114305	0.002389	-1.340959
7	1	9	0.632056	1.836833	-1.204778	2.259312	-0.533250	0.999946	-0.173800
8	1	10	0.632056	6.559056	-5.927000	2.259312	-2.623365	0.215055	-0.855023
9	2	3	3.154333	0.900889	2.253444	2.259312	0.997403	0.992083	0.325079
10	2	4	3.154333	1.902611	1.251722	2.259312	0.554028	0.999926	0.180572
11	2	5	3.154333	3.809722	-0.655389	2.259312	-0.290083	1.000000	-0.094546
12	2	6	3.154333	33.652000	-30.497667	2.259312	-13.498651	0.000000	-4.399560
13	2	7	3.154333	1.013333	2.141000	2.259312	0.947634	0.994562	0.308858
14	2	8	3.154333	9.927556	-6.773222	2.259312	-2.997913	0.088538	-0.977098
15	2	9	3.154333	1.836833	1.317500	2.259312	0.583142	0.999886	
16	2	10	3.154333	6.559056	-3.404722	2.259312	-1.506973	0.887768	
17	3	4	0.900889	1.902611	-1.001722	2.259312	-0.443375	0.999989	
18	3	5	0.900889	3.809722	-2.908833	2.259312	-1.287486	0.955245	
19	3	6	0.900889	33.652000	-32.751111	2.259312	-14.496054	0.000000	
20	3	7	0.900889	1.013333	-0.112444	2.259312	-0.049769	1.000000	
21	3	8	0.900889	9.927556	-9.026667	2.259312	-3.995316	0.003725	
22	3	9	0.900889	1.836833	-0.935944	2.259312	-0.414261	0.999994	
23	3	10	0.900889	6.559056	-5.658167	2.259312	-2.504376	0.273735	
24	4	5	1.902611	3.809722	-1.907111	2.259312	-0.844111	0.997736	
25	4	6	1.902611	33.652000	-31.749389	2.259312	-14.052679	0.000000	
26	4	7	1.902611	1.013333	0.889278	2.259312	0.393606	0.999996	
27	4	8	1.902611	9.927556	-8.024944	2.259312	-3.551941	0.017344	
28	4	9	1.902611	1.836833	0.065778	2.259312	0.029114	1.000000	
29	4	10	1.902611	6.559056	-4.656444	2.259312	-2.061001	0.557477	
30	5	6	3.809722	33.652000	-29.842278	2.259312	-13.208567	0.000000	
31	5	7	3.809722	1.013333	2.796389	2.259312	1.237717	0.965140	
32	5	8	3.809722	9.927556	-6.117833	2.259312	-2.707830	0.178996	
33	5	9	3.809722	1.836833	1.972889	2.259312	0.873225	0.997062	
34	5	10	3.809722	6.559056	-2.749333	2.259312	-1.216890	0.968763	
35	6	7	33.652000	1.013333	32.638667	2.259312	14.446284	0.000000	
36	6	8	33.652000	9.927556	23.724444	2.259312	10.500737	0.000000	
37	6	9	33.652000	1.836833	31.815167	2.259312	14.081793	0.000000	
38	6	10	33.652000	6.559056	27.092944	2.259312	11.991678	0.000000	
39	7	8	1.013333	9.927556	-8.914222	2.259312	-3.945547	0.004468	
40	7	9	1.013333	1.836833	-0.823500	2.259312	-0.364491	0.999998	
41	7	10	1.013333	6.559056	-5.545722	2.259312	-2.454606	0.300948	
42	8	9	9.927556	1.836833	8.090722	2.259312	3.581055	0.015771	
43	8	10	9.927556	6.559056	3.368500	2.259312	1.490940	0.894110	
44	9	10	1.836833	6.559056	-4.722222	2.259312	-2.090115	0.537047	

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```
15  0.190061
16 -0.491162
17 -0.144507
18 -0.419625
19 -4.724640
20 -0.016221
21 -1.302177
22 -0.135018
23 -0.816241
24 -0.275118
25 -4.580132
26  0.128286
27 -1.157670
28  0.009489
29 -0.671734
30 -4.305015
31  0.403404
32 -0.882552
33  0.284607
34 -0.396616
35  4.708419
36  3.422463
37  4.589621
38  3.908399
39 -1.285956
40 -0.118797
41 -0.800020
42  1.167159
43  0.485936
44 -0.681223
```

In [ ]:

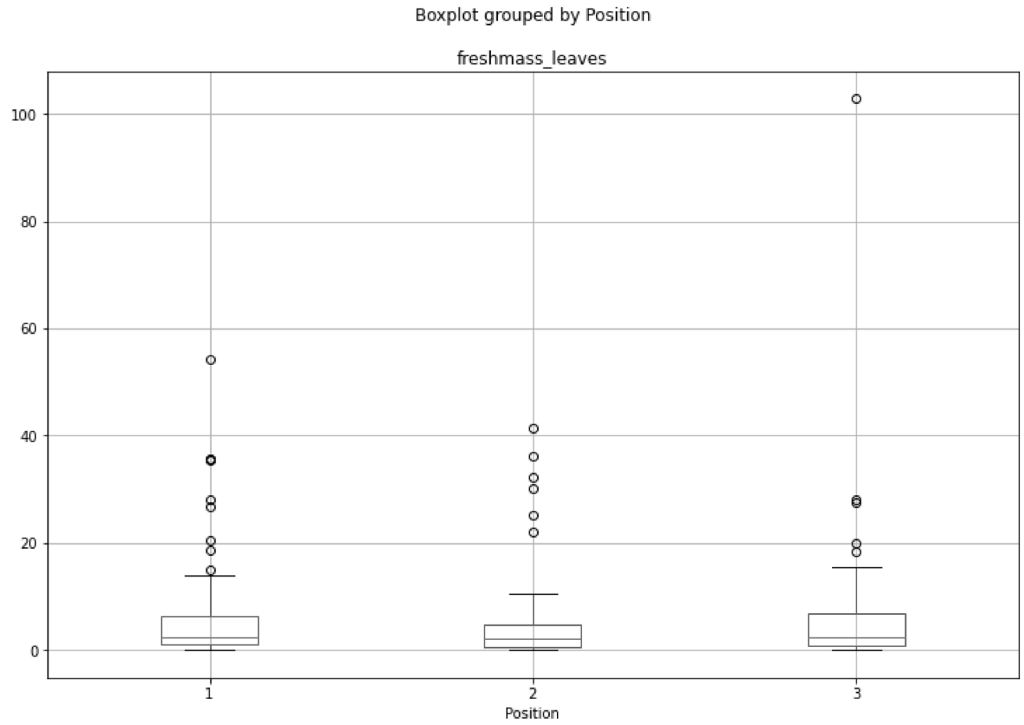
In [69]:
```
aov = pg.anova(data=W2_fm, dv='freshmass_leaves', between='Position', detailed=True)
print(aov)
```

```
     Source            SS   DF          MS       F     p-unc       np2
0  Position     56.737442    2   28.368721  0.2087  0.811838  0.002353
1    Within  24059.722123  177  135.930633     NaN       NaN       NaN
```

In [70]:
```
#Create a boxplot
W2_fm.boxplot('freshmass_leaves', by='Position', figsize=(12, 8))
```

Out[70]:
```
<AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Position'>
```

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In [71]:
```
pt = pg.pairwise_tukey(dv='freshmass_leaves', between='Position', data=W2_fm)
print(pt)
```

```
   A  B  mean(A)   mean(B)      diff       se         T   p-tukey    hedges
0  1  2  6.92035  5.579900  1.340450  2.12862  0.629727  0.803981  0.114240
1  1  3  6.92035  6.516267  0.404083  2.12862  0.189834  0.980332  0.034438
2  2  3  5.57990  6.516267 -0.936367  2.12862 -0.439894  0.898905 -0.079802
```

In [ ]:

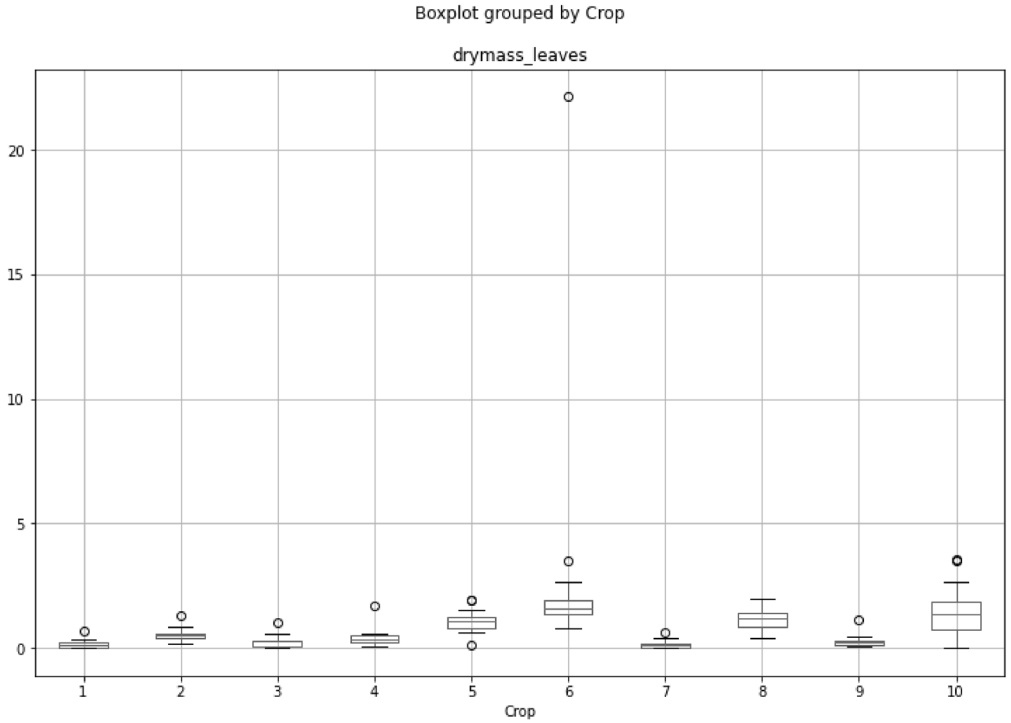
In [72]:
```
aov = pg.anova(data=W2_fm, dv='drymass_leaves', between='Crop', detailed=True)
print(aov)
```

```
   Source          SS   DF         MS         F     p-unc       np2
0    Crop  116.565735    9  12.951748  5.087923  0.000004  0.212202
1  Within  432.749679  170   2.545586       NaN       NaN       NaN
```

In [73]:
```
#Create a boxplot
W2_fm.boxplot('drymass_leaves', by='Crop', figsize=(12, 8))
```

Out[73]:
```
<AxesSubplot:title={'center':'drymass_leaves'}, xlabel='Crop'>
```

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In [74]:
```
pt = pg.pairwise_tukey(dv='drymass_leaves', between='Crop', data=W2_fm)
print(pt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	hedges
0	1	2	0.159722	0.551111	-0.391389	0.53183	-0.735929	0.999231	-0.239858
1	1	3	0.159722	0.185611	-0.025889	0.53183	-0.048679	1.000000	-0.015866
2	1	4	0.159722	0.397167	-0.237444	0.53183	-0.446467	0.999988	-0.145515
3	1	5	0.159722	1.071167	-0.911444	0.53183	-1.713790	0.786246	-0.558569
4	1	6	0.159722	2.846500	-2.686778	0.53183	-5.051950	0.000048	-1.646562
5	1	7	0.159722	0.143778	0.015944	0.53183	0.029980	1.000000	0.009771
6	1	8	0.159722	1.125278	-0.965556	0.53183	-1.815535	0.724543	-0.591730
7	1	9	0.159722	0.288000	-0.128278	0.53183	-0.241201	1.000000	-0.078614
8	1	10	0.159722	1.438944	-1.279222	0.53183	-2.405323	0.329360	-0.783957
9	2	3	0.551111	0.185611	0.365500	0.53183	0.687250	0.999558	0.223993
10	2	4	0.551111	0.397167	0.153944	0.53183	0.289462	1.000000	0.094343
11	2	5	0.551111	1.071167	-0.520056	0.53183	-0.977861	0.993146	-0.318710
12	2	6	0.551111	2.846500	-2.295389	0.53183	-4.316022	0.001094	-1.406703
13	2	7	0.551111	0.143778	0.407333	0.53183	0.765909	0.998943	0.249630
14	2	8	0.551111	1.125278	-0.574167	0.53183	-1.079606	0.986080	-0.351872
15	2	9	0.551111	0.288000	0.263111	0.53183	0.494728	0.999972	0.161245
16	2	10	0.551111	1.438944	-0.887833	0.53183	-1.669394	0.810964	-0.544099
17	3	4	0.185611	0.397167	-0.211556	0.53183	-0.397788	0.999996	-0.129649
18	3	5	0.185611	1.071167	-0.885556	0.53183	-1.665111	0.813270	-0.542703
19	3	6	0.185611	2.846500	-2.660889	0.53183	-5.003272	0.000060	-1.630696
20	3	7	0.185611	0.143778	0.041833	0.53183	0.078659	1.000000	0.025637
21	3	8	0.185611	1.125278	-0.939667	0.53183	-1.766856	0.754873	-0.575864
22	3	9	0.185611	0.288000	-0.102389	0.53183	-0.192522	1.000000	-0.062748
23	3	10	0.185611	1.438944	-1.253333	0.53183	-2.356644	0.358763	-0.768091
24	4	5	0.397167	1.071167	-0.674000	0.53183	-1.267323	0.959471	-0.413053
25	4	6	0.397167	2.846500	-2.449333	0.53183	-4.605484	0.000337	-1.501046
26	4	7	0.397167	0.143778	0.253389	0.53183	0.476447	0.999979	0.155287
27	4	8	0.397167	1.125278	-0.728111	0.53183	-1.369068	0.934919	-0.446215
28	4	9	0.397167	0.288000	0.109167	0.53183	0.205266	1.000000	0.066902
29	4	10	0.397167	1.438944	-1.041778	0.53183	-1.958856	0.628842	-0.638442
30	5	6	1.071167	2.846500	-1.775333	0.53183	-3.338161	0.033905	-1.087993
31	5	7	1.071167	0.143778	0.927389	0.53183	1.743770	0.768752	0.568340
32	5	8	1.071167	1.125278	-0.054111	0.53183	-0.101745	1.000000	-0.033161
33	5	9	1.071167	0.288000	0.783167	0.53183	1.472589	0.901089	0.479955
34	5	10	1.071167	1.438944	-0.367778	0.53183	-0.691533	0.999535	-0.225388
35	6	7	2.846500	0.143778	2.702722	0.53183	5.081931	0.000042	1.656333
36	6	8	2.846500	1.125278	1.721222	0.53183	3.236416	0.045827	1.054832
37	6	9	2.846500	0.288000	2.558500	0.53183	4.810750	0.000141	1.567948
38	6	10	2.846500	1.438944	1.407556	0.53183	2.646628	0.204659	0.862605
39	7	8	0.143778	1.125278	-0.981500	0.53183	-1.845515	0.705222	-0.601501
40	7	9	0.143778	0.288000	-0.144222	0.53183	-0.271181	1.000000	-0.088385
41	7	10	0.143778	1.438944	-1.295167	0.53183	-2.435303	0.311907	-0.793728
42	8	9	1.125278	0.288000	0.837278	0.53183	1.574334	0.858645	0.513116
43	8	10	1.125278	1.438944	-0.313667	0.53183	-0.589788	0.999875	-0.192227
44	9	10	0.288000	1.438944	-1.150944	0.53183	-2.164122	0.485501	-0.705343

In [ ]:

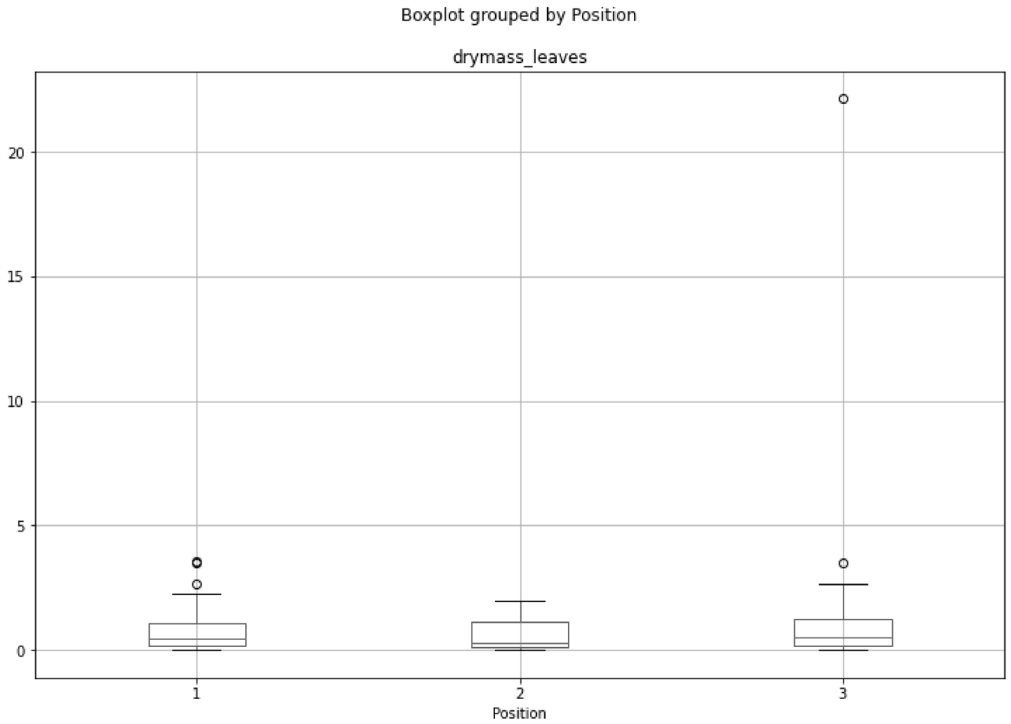
In [75]:
```
aov = pg.anova(data=W2_fm, dv='drymass_leaves', between='Position', detailed=True)
print(aov)
```

	Source	SS	DF	MS	F	p-unc	np2
0	Position	8.199905	2	4.099952	1.341103	0.264202	0.014927
1	Within	541.115509	177	3.057150	NaN	NaN	NaN

In [76]:
```
#Create a boxplot
W2_fm.boxplot('drymass_leaves', by='Position', figsize=(12, 8))
```

Out[76]:
```
<AxesSubplot:title={'center':'drymass_leaves'}, xlabel='Position'>
```

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In [77]:
```
pt = pg.pairwise_tukey(dv='drymass_leaves', between='Position', data=W2_fm)
print(pt)
```

```
   A  B   mean(A)   mean(B)      diff        se         T   p-tukey   hedges
0  1  2  0.766383  0.590767  0.175617  0.319226  0.550133  0.846544  0.09980
1  1  3  0.766383  1.105033 -0.338650  0.319226 -1.060848  0.539642 -0.19245
2  2  3  0.590767  1.105033 -0.514267  0.319226 -1.610982  0.243664 -0.29225
```

SUBSETTING THE DATASET 3 FOR TYPOLOGY 3

In [78]:
```
W3_fm = df.loc[df['Typology'] == 3]
```

In [79]:
```
W3_fm
```

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Out[79]:

	Crop	Position	Typology	Month	freshmass_leaves	drymass_leaves	Soil_WC	Soil_Temp	Soil_SE	local_maxtemp	local_mintemp	local_RH	total_precip	daylength	daylength_sec	hour	minute	seconds
6	1	4	3	2021-11-15	7.010	1.340	0.289	26.9	0.643	37.0	16.4	50.3	0.0	13:21:32	48092	13	21	32
7	1	4	3	2021-11-15	10.120	1.939	0.289	26.9	0.643	37.0	16.4	50.3	0.0	13:21:32	48092	13	21	32
8	1	4	3	2021-11-15	24.305	4.240	0.289	26.9	0.643	37.0	16.4	50.3	0.0	13:21:32	48092	13	21	32
15	1	4	3	2021-12-15	7.247	1.582	0.316	20.5	0.629	24.8	12.2	80.7	6.2	13:45:00	49500	13	45	0
16	1	4	3	2021-12-15	8.838	1.863	0.316	20.5	0.629	24.8	12.2	80.7	6.2	13:45:00	49500	13	45	0
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
529	10	4	3	2022-03-15	33.592	6.830	0.331	21.7	0.747	28.4	15.3	87.9	31.0	12:12:09	43929	12	12	9
530	10	4	3	2022-03-15	17.544	6.030	0.331	21.7	0.747	28.4	15.3	87.9	31.0	12:12:09	43929	12	12	9
537	10	4	3	2022-04-15	0.000	0.000	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11	22	4
538	10	4	3	2022-04-15	10.606	2.620	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11	22	4
539	10	4	3	2022-04-15	12.192	2.280	0.337	17.0	0.690	25.1	10.7	75.8	0.0	11:22:04	40924	11	22	4

180 rows × 18 columns

Comparisons of freshmass and drymass production by the different crops grown in Wall 3 (Natural soil)

In [80]:
```
aov = pg.anova(data=W3_fm, dv='freshmass_leaves', between='Crop', detailed=True)
print(aov)
```

```
   Source             SS   DF            MS         F         p-unc       np2
0    Crop  226423.598754    9  25158.177639  15.716778  1.580090e-18  0.454168
1  Within  272122.589729  170   1600.721116       NaN           NaN       NaN
```

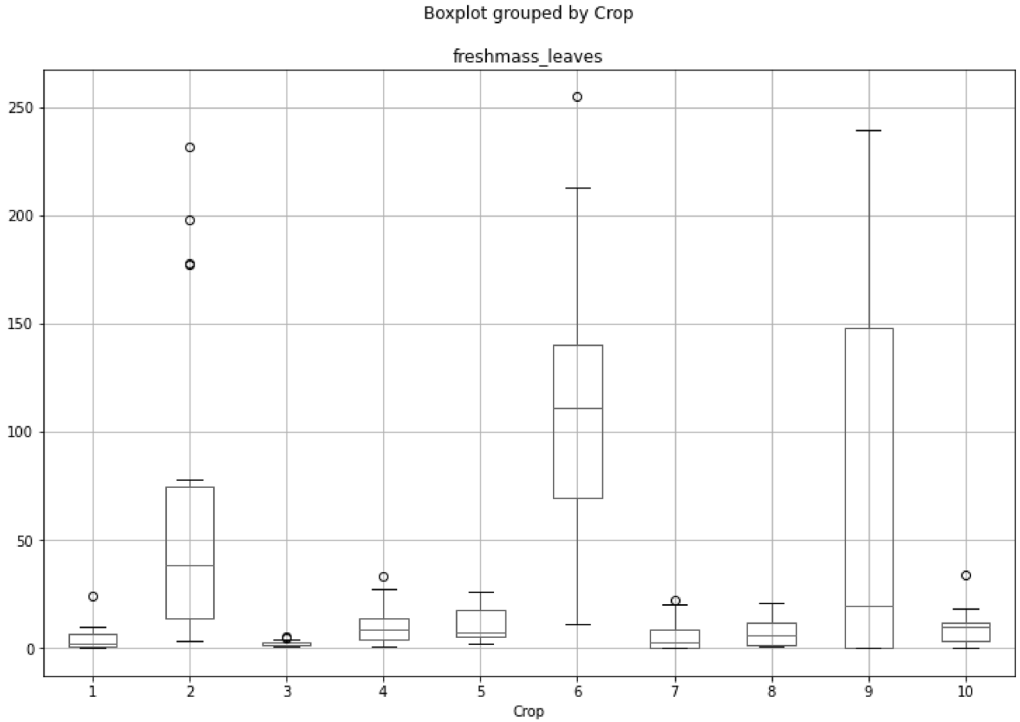
When the ANOVA result *p-value < 0.05*, it means **there are statistical significant differences between the groups** and that means **you should then interpret the post-hoc analysis results** to determine which crop produces the best performance in terms of fresh mass and dry masses production.

When the ANOVA result *p-value > 0.05*, it means **there are no statistical significant differences between the groups** and that means **you should not interpret the post-hoc analysis results** even if the results are indicated.

In [81]:
```
#Create a boxplot
W3_fm.boxplot('freshmass_leaves', by='Crop', figsize=(12, 8))
```

Out[81]:
```
<AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Crop'>
```

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In [82]:
```
pt = pg.pairwise_tukey(dv='freshmass_leaves', between='Crop', data=W3_fm)
print(pt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	hedges
0	1	2	4.365222	67.646111	-63.280889	13.336338	-4.744998	1.866336e-04	-1.546518
1	1	3	4.365222	2.097722	2.267500	13.336338	0.170024	1.000000e+00	0.055415
2	1	4	4.365222	10.850444	-6.485222	13.336338	-0.486282	9.999756e-01	-0.158492
3	1	5	4.365222	11.001778	-6.636556	13.336338	-0.497630	9.999702e-01	-0.162190
4	1	6	4.365222	108.461833	-104.096611	13.336338	-7.805487	2.590050e-11	-2.544011
5	1	7	4.365222	5.183167	-0.817944	13.336338	-0.061332	1.000000e+00	-0.019990
6	1	8	4.365222	7.765056	-3.399833	13.336338	-0.254930	9.999999e-01	-0.083088
7	1	9	4.365222	66.318667	-61.953444	13.336338	-4.645462	2.848863e-04	-1.514076
8	1	10	4.365222	9.566778	-5.201556	13.336338	-0.390029	9.999964e-01	-0.127120
9	2	3	67.646111	2.097722	65.548389	13.336338	4.915022	8.913335e-05	1.601933
10	2	4	67.646111	10.850444	56.795667	13.336338	4.258715	1.370969e-03	1.388026
11	2	5	67.646111	11.001778	56.644333	13.336338	4.247368	1.433045e-03	1.384327
12	2	6	67.646111	108.461833	-40.815722	13.336338	-3.060490	7.498860e-02	-0.997493
13	2	7	67.646111	5.183167	62.462944	13.336338	4.683665	2.424075e-04	1.526528
14	2	8	67.646111	7.765056	59.881056	13.336338	4.490067	5.432186e-04	1.463429
15	2	9	67.646111	66.318667	1.327444	13.336338	0.099536		
16	2	10	67.646111	9.566778	58.079333	13.336338	4.354969		
17	3	4	2.097722	10.850444	-8.752722	13.336338	-0.656306		
18	3	5	2.097722	11.001778	-8.904056	13.336338	-0.667654		
19	3	6	2.097722	108.461833	-106.364111	13.336338	-7.975511		
20	3	7	2.097722	5.183167	-3.085444	13.336338	-0.231356		
21	3	8	2.097722	7.765056	-5.667333	13.336338	-0.424954		
22	3	9	2.097722	66.318667	-64.220944	13.336338	-4.815486		
23	3	10	2.097722	9.566778	-7.469056	13.336338	-0.560053		
24	4	5	10.850444	11.001778	-0.151333	13.336338	-0.011347		
25	4	6	10.850444	108.461833	-97.611389	13.336338	-7.319205		
26	4	7	10.850444	5.183167	5.667278	13.336338	0.424950		
27	4	8	10.850444	7.765056	3.085389	13.336338	0.231352		
28	4	9	10.850444	66.318667	-55.468222	13.336338	-4.159180		
29	4	10	10.850444	9.566778	1.283667	13.336338	0.096253		
30	5	6	11.001778	108.461833	-97.460056	13.336338	-7.307858		
31	5	7	11.001778	5.183167	5.818611	13.336338	0.436298		
32	5	8	11.001778	7.765056	3.236722	13.336338	0.242699		
33	5	9	11.001778	66.318667	-55.316889	13.336338	-4.147832		
34	5	10	11.001778	9.566778	1.435000	13.336338	0.107601		
35	6	7	108.461833	5.183167	103.278667	13.336338	7.744155		
36	6	8	108.461833	7.765056	100.696778	13.336338	7.550557		
37	6	9	108.461833	66.318667	42.143167	13.336338	3.160025		
38	6	10	108.461833	9.566778	98.895056	13.336338	7.415458		
39	7	8	5.183167	7.765056	-2.581889	13.336338	-0.193598		
40	7	9	5.183167	66.318667	-61.135500	13.336338	-4.584130		
41	7	10	5.183167	9.566778	-4.383611	13.336338	-0.328697		
42	8	9	7.765056	66.318667	-58.553611	13.336338	-4.390532		
43	8	10	7.765056	9.566778	-1.801722	13.336338	-0.135099		
44	9	10	66.318667	9.566778	56.751889	13.336338	4.255433		

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```
15  1.000000e+00  0.032441
16  9.376367e-04  1.419397
17  9.996965e-01 -0.213907
18  9.996507e-01 -0.217606
19  9.514944e-12 -2.599426
20  1.000000e+00 -0.075405
21  9.999923e-01 -0.138504
22  1.377258e-04 -1.569492
23  9.999189e-01 -0.182536
24  1.000000e+00 -0.003698
25  4.254663e-10 -2.385519
26  9.999923e-01  0.138502
27  1.000000e+00  0.075404
28  2.014280e-03 -1.355584
29  1.000000e+00  0.031371
30  4.536937e-10 -2.381820
31  9.999904e-01  0.142201
32  9.999999e-01  0.079102
33  2.103471e-03 -1.351886
34  1.000000e+00  0.035070
35  3.705192e-11  2.524021
36  1.136164e-10  2.460922
37  5.701111e-02  1.029934
38  2.462438e-10  2.416890
39  1.000000e+00 -0.063099
40  3.683477e-04 -1.494087
41  9.999992e-01 -0.107131
42  8.132887e-04 -1.430988
43  1.000000e+00 -0.044032
44  1.388660e-03  1.386956
```

In [ ]:

In [83]:
```
aov = pg.anova(data=W3_fm, dv='drymass_leaves', between='Crop', detailed=True)
print(aov)
```

```
   Source           SS   DF          MS          F         p-unc       np2
0    Crop  2481.847422    9  275.760825  10.246188  1.491750e-12  0.351679
1  Within  4575.295816  170   26.913505        NaN           NaN       NaN
```

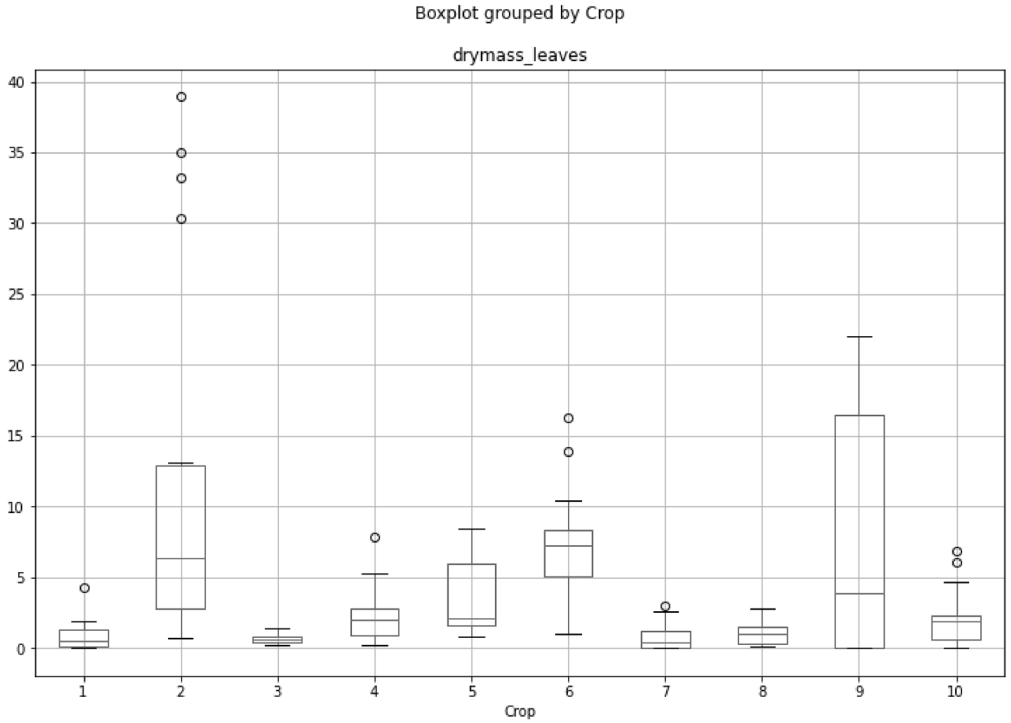
When the ANOVA result *p-value < 0.05*, it means **there are statistical significant differences between the groups** and that means **you should then interpret the post-hoc analysis results** to determine which crop produces the best performance in terms of fresh mass and dry masses production.

When the ANOVA result *p-value > 0.05*, it means **there are no statistical significant differences between the groups** and that means **you should not interpret the post-hoc analysis results** even if the results are indicated.

In [84]:
```
#Create a boxplot
W3_fm.boxplot('drymass_leaves', by='Crop', figsize=(12, 8))
```

Out[84]:
```
<AxesSubplot:title={'center':'drymass_leaves'}, xlabel='Crop'>
```

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In [85]:
```
pt = pg.pairwise_tukey(dv='drymass_leaves', between='Crop', data=W3_fm)
print(pt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	\
0	1	2	0.891050	12.089667	-11.198617	1.729274	-6.475906	4.358735e-08	
1	1	3	0.891050	0.642889	0.248161	1.729274	0.143506	1.000000e+00	
2	1	4	0.891050	2.322556	-1.431506	1.729274	-0.827807	9.980533e-01	
3	1	5	0.891050	3.346500	-2.455450	1.729274	-1.419931	9.194613e-01	
4	1	6	0.891050	7.281667	-6.390617	1.729274	-3.695548	1.076190e-02	
5	1	7	0.891050	0.784278	0.106772	1.729274	0.061744	1.000000e+00	
6	1	8	0.891050	1.090333	-0.199283	1.729274	-0.115241	1.000000e+00	
7	1	9	0.891050	7.929944	-7.038894	1.729274	-4.070433	2.818313e-03	
8	1	10	0.891050	2.140000	-1.248950	1.729274	-0.722239	9.993389e-01	
9	2	3	12.089667	0.642889	11.446778	1.729274	6.619411	2.026401e-08	
10	2	4	12.089667	2.322556	9.767111	1.729274	5.648098	2.957558e-06	
11	2	5	12.089667	3.346500	8.743167	1.729274	5.055975	4.757037e-05	
12	2	6	12.089667	7.281667	4.808000	1.729274	2.780357	1.516958e-01	
13	2	7	12.089667	0.784278	11.305389	1.729274	6.537649	3.138712e-08	
14	2	8	12.089667	1.090333	10.999333	1.729274	6.360665	8.006299e-08	
15	2	9	12.089667	7.929944	4.159722	1.729274	2.405473	3.292710e-01	
16	2	10	12.089667	2.140000	9.949667	1.729274	5.753666	1.762902e-06	
17	3	4	0.642889	2.322556	-1.679667	1.729274	-0.971313	9.934755e-01	
18	3	5	0.642889	3.346500	-2.703611	1.729274	-1.563437	8.636259e-01	
19	3	6	0.642889	7.281667	-6.638778	1.729274	-3.839054	6.544955e-03	
20	3	7	0.642889	0.784278	-0.141389	1.729274	-0.081762	1.000000e+00	
21	3	8	0.642889	1.090333	-0.447444	1.729274	-0.258747	9.999999e-01	
22	3	9	0.642889	7.929944	-7.287056	1.729274	-4.213939	1.631718e-03	
23	3	10	0.642889	2.140000	-1.497111	1.729274	-0.865745	9.972492e-01	
24	4	5	2.322556	3.346500	-1.023944	1.729274	-0.592124	9.998706e-01	
25	4	6	2.322556	7.281667	-4.959111	1.729274	-2.867741	1.231063e-01	
26	4	7	2.322556	0.784278	1.538278	1.729274	0.889551	9.966169e-01	
27	4	8	2.322556	1.090333	1.232222	1.729274	0.712566	9.994070e-01	
28	4	9	2.322556	7.929944	-5.607389	1.729274	-3.242626	4.500746e-02	
29	4	10	2.322556	2.140000	0.182556	1.729274	0.105568	1.000000e+00	
30	5	6	3.346500	7.281667	-3.935167	1.729274	-2.275617	4.103361e-01	
31	5	7	3.346500	0.784278	2.562222	1.729274	1.481675	8.976709e-01	
32	5	8	3.346500	1.090333	2.256167	1.729274	1.304690	9.513973e-01	
33	5	9	3.346500	7.929944	-4.583444	1.729274	-2.650502	2.029627e-01	
34	5	10	3.346500	2.140000	1.206500	1.729274	0.697692	9.995001e-01	
35	6	7	7.281667	0.784278	6.497389	1.729274	3.757292	8.710145e-03	
36	6	8	7.281667	1.090333	6.191333	1.729274	3.580307	1.580983e-02	
37	6	9	7.281667	7.929944	-0.648278	1.729274	-0.374884	9.999974e-01	
38	6	10	7.281667	2.140000	5.141667	1.729274	2.973309	9.438652e-02	
39	7	8	0.784278	1.090333	-0.306056	1.729274	-0.176985	1.000000e+00	
40	7	9	0.784278	7.929944	-7.145667	1.729274	-4.132177	2.232634e-03	
41	7	10	0.784278	2.140000	-1.355722	1.729274	-0.783983	9.987285e-01	
42	8	9	1.090333	7.929944	-6.839611	1.729274	-3.955192	4.314137e-03	
43	8	10	1.090333	2.140000	-1.049667	1.729274	-0.606998	9.998409e-01	
44	9	10	7.929944	2.140000	5.789944	1.729274	3.348193	3.289181e-02	

	hedges
0	-2.110666
1	0.046772
2	-0.269804
3	-0.462792
4	-1.204475
5	0.020124
6	-0.037560
7	-1.326660
8	-0.235397
9	2.157438
10	1.840862
11	1.647873
12	0.906190
13	2.130789
14	2.073105

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```
15  0.784006
16  1.875269
17 -0.316576
18 -0.509565
19 -1.251247
20 -0.026648
21 -0.084332
22 -1.373432
23 -0.282169
24 -0.192988
25 -0.934671
26  0.289928
27  0.232244
28 -1.056856
29  0.034407
30 -0.741683
31  0.482916
32  0.425232
33 -0.863867
34  0.227396
35  1.224599
36  1.166915
37 -0.122185
38  0.969078
39 -0.057684
40 -1.346784
41 -0.255521
42 -1.289100
43 -0.197837
44  1.091263
```

In [ ]:

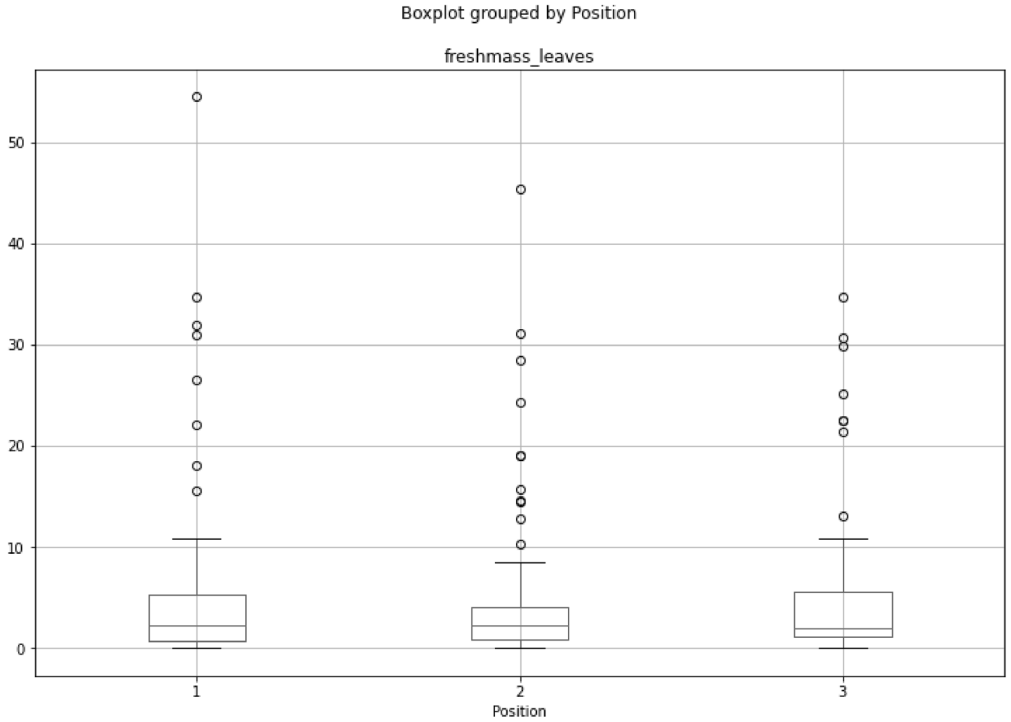
In [86]:
```
aov = pg.anova(data=W1_fm, dv='freshmass_leaves', between='Position', detailed=True)
print(aov)
```

```
     Source            SS   DF         MS         F     p-unc       np2
0  Position      9.124329    2   4.562165  0.053462  0.947958  0.000604
1    Within  15104.354359  177  85.335335       NaN       NaN       NaN
```

In [87]:
```
#Create a boxplot
W1_fm.boxplot('freshmass_leaves', by='Position', figsize=(12, 8))
```

Out[87]:
```
<AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Position'>
```

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In [ ]:

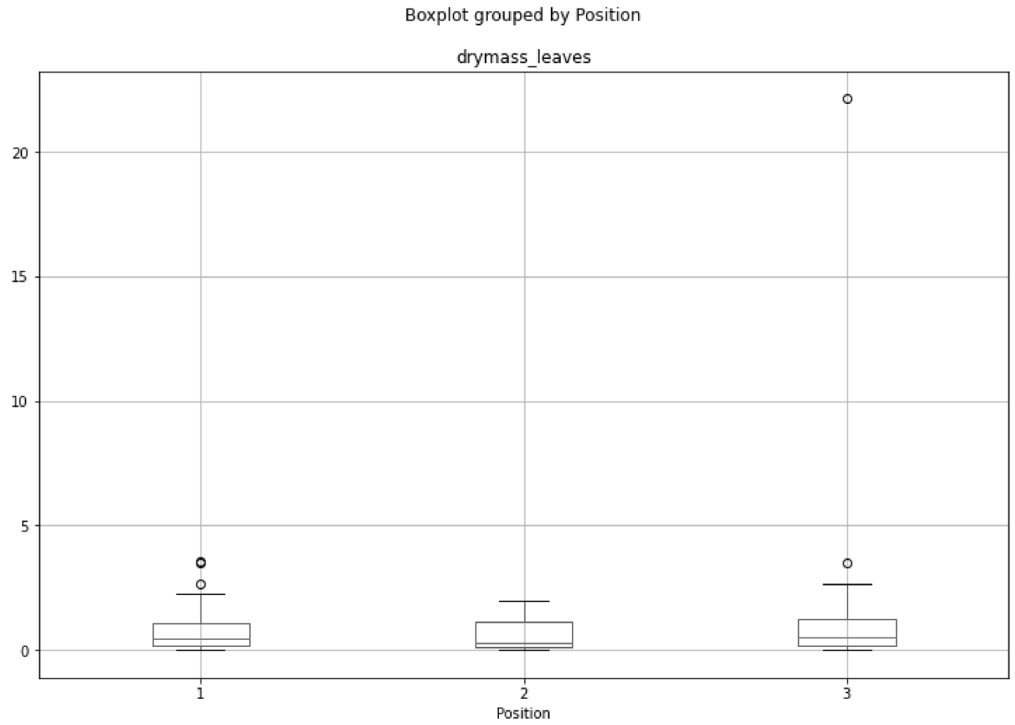
In [88]:
```
aov = pg.anova(data=W2_fm, dv='drymass_leaves', between='Position', detailed=True)
print(aov)
```

```
      Source          SS   DF        MS         F     p-unc       np2
0   Position    8.199905    2  4.099952  1.341103  0.264202  0.014927
1     Within  541.115509  177  3.057150       NaN       NaN       NaN
```

In [89]:
```
#Create a boxplot
W2_fm.boxplot('drymass_leaves', by='Position', figsize=(12, 8))
```

Out[89]:
```
<AxesSubplot:title={'center':'drymass_leaves'}, xlabel='Position'>
```

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In [ ]:

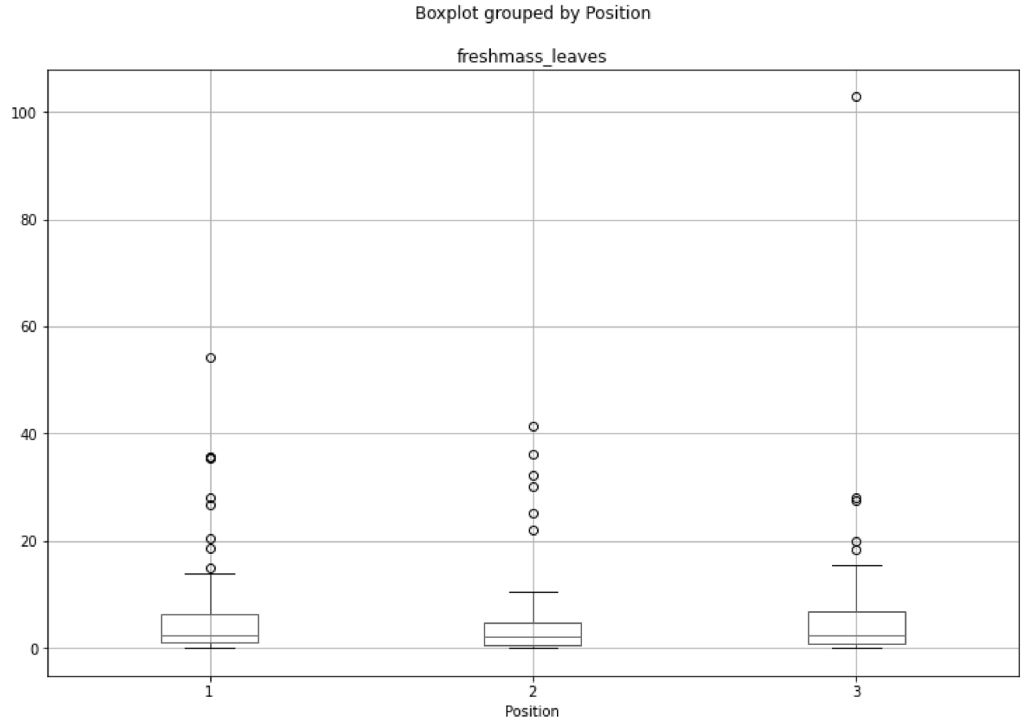
In [90]:
```
aov = pg.anova(data=W2_fm, dv='freshmass_leaves', between='Position', detailed=True)
print(aov)
```

```
      Source            SS   DF          MS       F     p-unc       np2
0   Position     56.737442    2   28.368721  0.2087  0.811838  0.002353
1     Within  24059.722123  177  135.930633     NaN       NaN       NaN
```

In [91]:
```
#Create a boxplot
W2_fm.boxplot('freshmass_leaves', by='Position', figsize=(12, 8))
```

Out[91]:
```
<AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Position'>
```

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In [ ]:

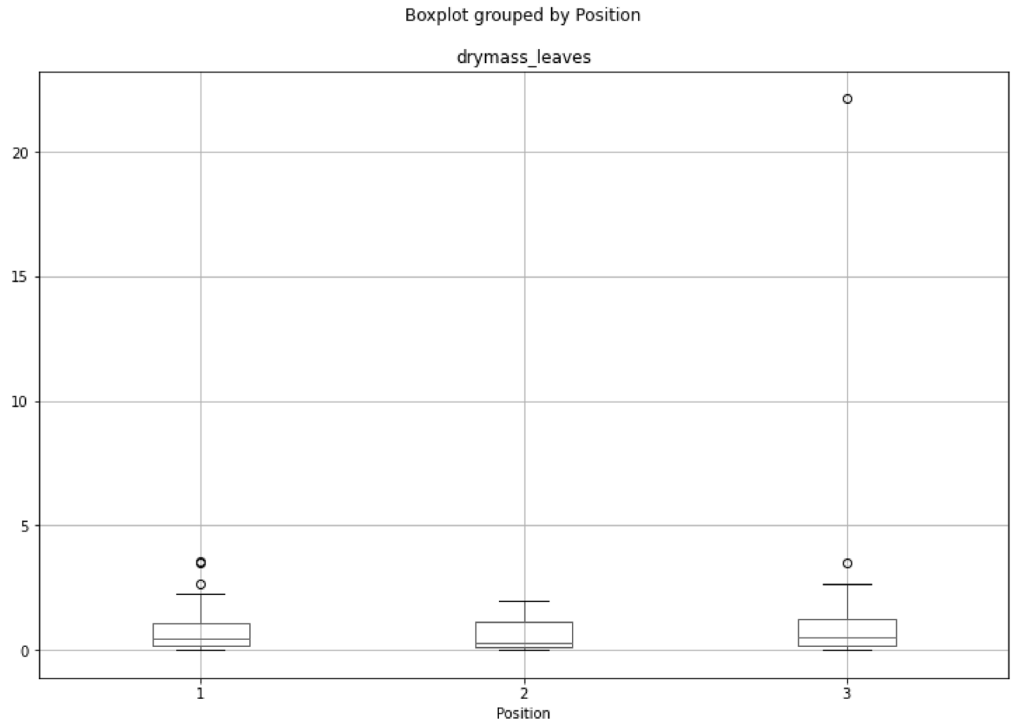
In [92]:
```
aov = pg.anova(data=W2_fm, dv='drymass_leaves', between='Position', detailed=True)
print(aov)
```

```
      Source          SS   DF        MS         F     p-unc       np2
0   Position    8.199905    2  4.099952  1.341103  0.264202  0.014927
1     Within  541.115509  177  3.057150       NaN       NaN       NaN
```

In [93]:
```
#Create a boxplot
W2_fm.boxplot('drymass_leaves', by='Position', figsize=(12, 8))
```

Out[93]:
```
<AxesSubplot:title={'center':'drymass_leaves'}, xlabel='Position'>
```

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In [ ]:

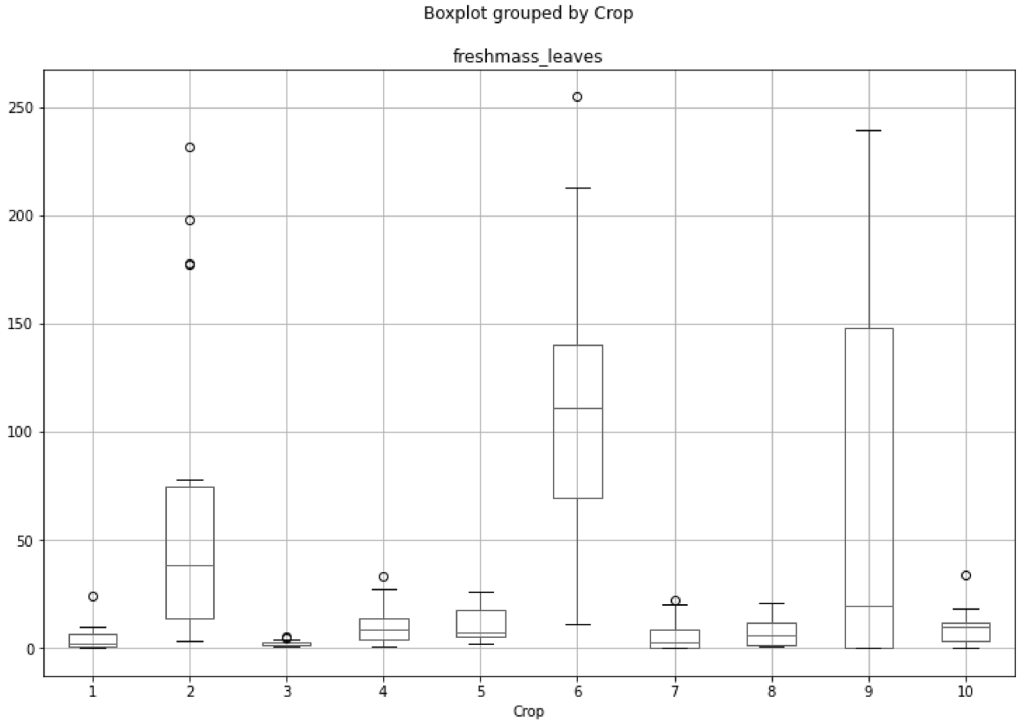
In [94]:
```
aov = pg.anova(data=W3_fm, dv='freshmass_leaves', between='Crop', detailed=True)
print(aov)
```

```
   Source             SS   DF            MS          F         p-unc       np2
0    Crop  226423.598754    9  25158.177639  15.716778  1.580090e-18  0.454168
1  Within  272122.589729  170   1600.721116        NaN           NaN       NaN
```

In [95]:
```
#Create a boxplot
W3_fm.boxplot('freshmass_leaves', by='Crop', figsize=(12, 8))
```

Out[95]:
```
<AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Crop'>
```

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In [ ]:

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Appendix G: Statistical analysis results comparing the different crops and biomass

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Comparison of crop species in terms of Fresh Mass and Dry Mass Production

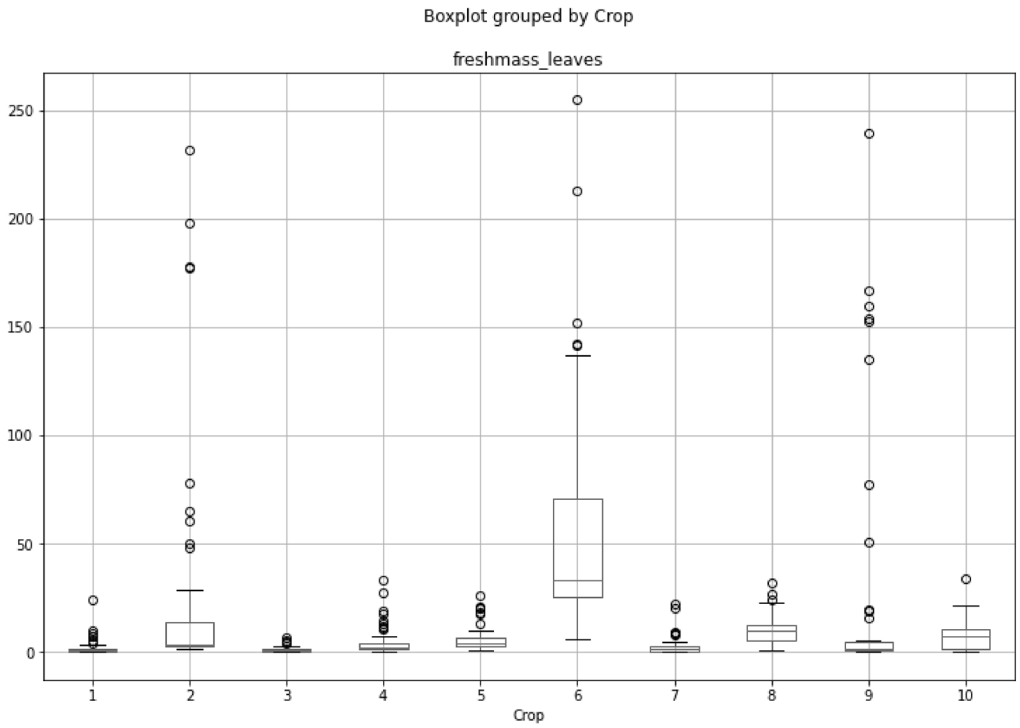
Anova for the crops - fresh mass

In [121]:
```
aov = pg.anova(data=df, dv='freshmass_leaves', between='Crop', detailed=True).round(3)
print(aov)
```

```
     Source          SS   DF         MS       F  p-unc    np2
0      Crop  141785.911    9  15753.990  18.114    0.0  0.235
1    Within  460938.448  530    869.695     NaN    NaN    NaN
```

In [122]:
```
#Create a boxplot
df.boxplot('freshmass_leaves', by='Crop', figsize=(12, 8))
```

Out[122]:
```
<AxesSubplot:title={'center':'freshmass_leaves'}, xlabel='Crop'>
```



Post hoc comparisons - fresh mass of leaves

In [123]:
```
pt = pg.pairwise_tukey(dv='freshmass_leaves', between='Crop', data=df).round(3)
print(pt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	hedges
0	1	2	1.880	24.597	-22.716	5.675	-4.003	0.003	-0.765
1	1	3	1.880	1.228	0.653	5.675	0.115	1.000	0.022
2	1	4	1.880	4.875	-2.994	5.675	-0.528	1.000	-0.101
3	1	5	1.880	5.849	-3.969	5.675	-0.699	1.000	-0.134
4	1	6	1.880	56.195	-54.315	5.675	-9.570	0.000	-1.829
5	1	7	1.880	2.638	-0.758	5.675	-0.134	1.000	-0.026
6	1	8	1.880	10.139	-8.259	5.675	-1.455	0.909	-0.278
7	1	9	1.880	23.322	-21.441	5.675	-3.778	0.007	-0.722
8	1	10	1.880	7.469	-5.589	5.675	-0.985	0.993	-0.188
9	2	3	24.597	1.228	23.369	5.675	4.118	0.002	0.787
10	2	4	24.597	4.875	19.722	5.675	3.475	0.020	0.664
11	2	5	24.597	5.849	18.748	5.675	3.303	0.034	0.631
12	2	6	24.597	56.195	-31.599	5.675	-5.568	0.000	-1.064
13	2	7	24.597	2.638	21.958	5.675	3.869	0.005	0.739
14	2	8	24.597	10.139	14.457	5.675	2.547	0.246	0.487
15	2	9	24.597	23.322	1.275	5.675	0.225	1.000	0.043
16	2	10	24.597	7.469	17.128	5.675	3.018	0.079	0.577
17	3	4	1.228	4.875	-3.647	5.675	-0.643	1.000	-0.123
18	3	5	1.228	5.849	-4.621	5.675	-0.814	0.998	-0.156
19	3	6	1.228	56.195	-54.968	5.675	-9.685	0.000	-1.851
20	3	7	1.228	2.638	-1.411	5.675	-0.249	1.000	-0.047
21	3	8	1.228	10.139	-8.912	5.675	-1.570	0.862	-0.300
22	3	9	1.228	23.322	-22.094	5.675	-3.893	0.004	-0.744
23	3	10	1.228	7.469	-6.241	5.675	-1.100	0.985	-0.210
24	4	5	4.875	5.849	-0.974	5.675	-0.172	1.000	-0.033
25	4	6	4.875	56.195	-51.320	5.675	-9.042	0.000	-1.728
26	4	7	4.875	2.638	2.236	5.675	0.394	1.000	0.075
27	4	8	4.875	10.139	-5.264	5.675	-0.928	0.996	-0.177
28	4	9	4.875	23.322	-18.447	5.675	-3.250	0.040	-0.621
29	4	10	4.875	7.469	-2.594	5.675	-0.457	1.000	-0.087
30	5	6	5.849	56.195	-50.346	5.675	-8.871	0.000	-1.695
31	5	7	5.849	2.638	3.211	5.675	0.566	1.000	0.108
32	5	8	5.849	10.139	-4.290	5.675	-0.756	0.999	-0.144
33	5	9	5.849	23.322	-17.473	5.675	-3.079	0.067	-0.588
34	5	10	5.849	7.469	-1.620	5.675	-0.285	1.000	-0.055
35	6	7	56.195	2.638	53.557	5.675	9.437	0.000	1.803
36	6	8	56.195	10.139	46.056	5.675	8.115	0.000	1.551
37	6	9	56.195	23.322	32.873	5.675	5.792	0.000	1.107
38	6	10	56.195	7.469	48.726	5.675	8.585	0.000	1.641
39	7	8	2.638	10.139	-7.501	5.675	-1.322	0.948	-0.253
40	7	9	2.638	23.322	-20.683	5.675	-3.644	0.011	-0.696
41	7	10	2.638	7.469	-4.831	5.675	-0.851	0.998	-0.163
42	8	9	10.139	23.322	-13.183	5.675	-2.323	0.376	-0.444
43	8	10	10.139	7.469	2.670	5.675	0.470	1.000	0.090
44	9	10	23.322	7.469	15.853	5.675	2.793	0.141	0.534

In [ ]:

ANOVA for Dry Mass of leaves

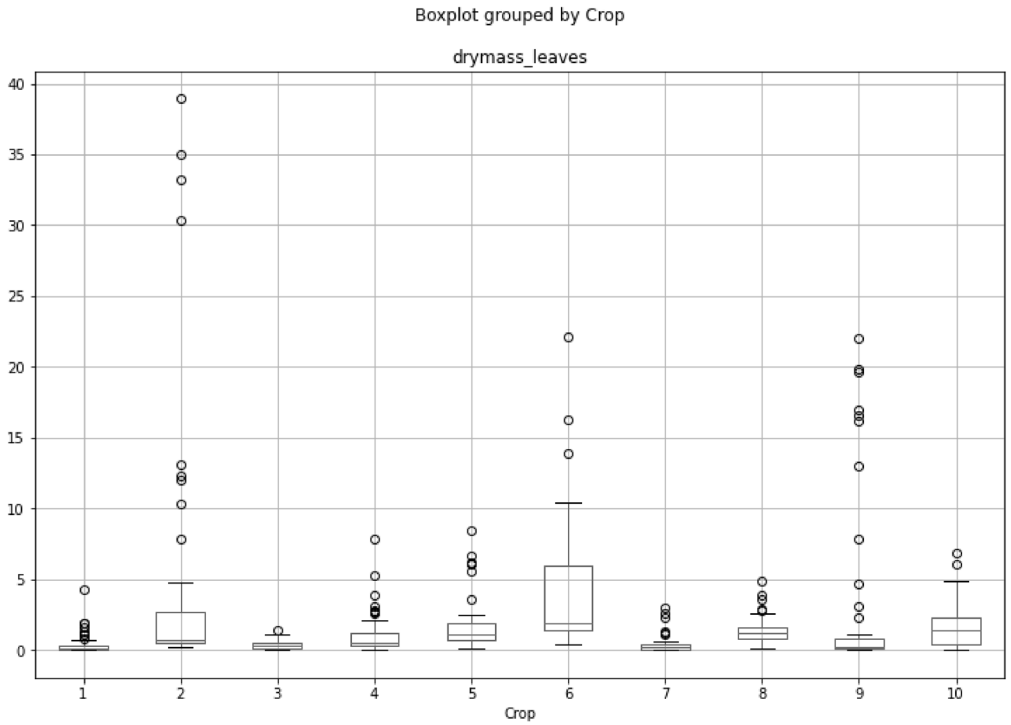
In [124]:
```
aov = pg.anova(data=df, dv='drymass_leaves', between='Crop', detailed=True).round(3)
print(aov)
```

	Source	SS	DF	MS	F	p-unc	np2
0	Crop	1045.037	9	116.115	7.841	0.0	0.117
1	Within	7848.980	530	14.809	NaN	NaN	NaN

In [125]:
```
#Create a boxplot
df.boxplot('drymass_leaves', by='Crop', figsize=(12, 8))
```

Out[125]:
```
<AxesSubplot:title={'center':'drymass_leaves'}, xlabel='Crop'>
```

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Post hoc Comparison

In [126]:
```
pt = pg.pairwise_tukey(dv='drymass_leaves', between='Crop', data=df).round(3)
print(pt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	hedges
0	1	2	0.390	4.415	-4.024	0.741	-5.434	0.000	-1.038
1	1	3	0.390	0.340	0.050	0.741	0.068	1.000	0.013
2	1	4	0.390	1.065	-0.675	0.741	-0.911	0.996	-0.174
3	1	5	0.390	1.777	-1.387	0.741	-1.872	0.688	-0.358
4	1	6	0.390	3.932	-3.542	0.741	-4.782	0.000	-0.914
5	1	7	0.390	0.378	0.013	0.741	0.017	1.000	0.003
6	1	8	0.390	1.360	-0.970	0.741	-1.310	0.951	-0.250
7	1	9	0.390	2.834	-2.444	0.741	-3.300	0.034	-0.631
8	1	10	0.390	1.632	-1.242	0.741	-1.677	0.808	-0.321
9	2	3	4.415	0.340	4.075	0.741	5.502	0.000	1.051
10	2	4	4.415	1.065	3.350	0.741	4.523	0.000	0.864
11	2	5	4.415	1.777	2.638	0.741	3.562	0.015	0.681
12	2	6	4.415	3.932	0.483	0.741	0.652	1.000	0.125
13	2	7	4.415	0.378	4.037	0.741	5.451	0.000	1.042
14	2	8	4.415	1.360	3.054	0.741	4.124	0.002	0.788
15	2	9	4.415	2.834	1.580	0.741	2.134	0.504	0.408
16	2	10	4.415	1.632	2.782	0.741	3.757	0.007	0.718
17	3	4	0.340	1.065	-0.725	0.741	-0.979	0.993	-0.187
18	3	5	0.340	1.777	-1.437	0.741	-1.940	0.642	-0.371
19	3	6	0.340	3.932	-3.592	0.741	-4.849	0.000	-0.927
20	3	7	0.340	0.378	-0.037	0.741	-0.051	1.000	-0.010
21	3	8	0.340	1.360	-1.020	0.741	-1.377	0.934	-0.263
22	3	9	0.340	2.834	-2.494	0.741	-3.368	0.028	-0.643
23	3	10	0.340	1.632	-1.292	0.741	-1.745	0.769	-0.333
24	4	5	1.065	1.777	-0.712	0.741	-0.961	0.994	-0.184
25	4	6	1.065	3.932	-2.867	0.741	-3.871	0.005	-0.740
26	4	7	1.065	0.378	0.687	0.741	0.928	0.996	0.177
27	4	8	1.065	1.360	-0.295	0.741	-0.398	1.000	-0.076
28	4	9	1.065	2.834	-1.769	0.741	-2.389	0.335	-0.456
29	4	10	1.065	1.632	-0.567	0.741	-0.766	0.999	-0.146
30	5	6	1.777	3.932	-2.155	0.741	-2.910	0.105	-0.556
31	5	7	1.777	0.378	1.399	0.741	1.889	0.676	0.361
32	5	8	1.777	1.360	0.417	0.741	0.563	1.000	0.108
33	5	9	1.777	2.834	-1.057	0.741	-1.428	0.918	-0.273
34	5	10	1.777	1.632	0.144	0.741	0.195	1.000	0.037
35	6	7	3.932	0.378	3.554	0.741	4.799	0.000	0.917
36	6	8	3.932	1.360	2.571	0.741	3.472	0.020	0.663
37	6	9	3.932	2.834	1.097	0.741	1.482	0.899	0.283
38	6	10	3.932	1.632	2.299	0.741	3.105	0.062	0.593
39	7	8	0.378	1.360	-0.983	0.741	-1.327	0.947	-0.254
40	7	9	0.378	2.834	-2.457	0.741	-3.317	0.033	-0.634
41	7	10	0.378	1.632	-1.255	0.741	-1.694	0.799	-0.324
42	8	9	1.360	2.834	-1.474	0.741	-1.990	0.606	-0.380
43	8	10	1.360	1.632	-0.272	0.741	-0.367	1.000	-0.070
44	9	10	2.834	1.632	1.202	0.741	1.623	0.837	0.310

In [127]:
```
# Note, if we want another type of effect size we can add the argument effsize
# and choose between six different effect sizes (or none): cohen, hedges, glass,
# eta-square, odds-ratio, and AUC. In the last code example we change the default
# effect size (hedges) to cohen:


cpt = pg.pairwise_tukey(dv='drymass_leaves', between='Crop', effsize='cohen', data=df).round(3)
print(cpt)
```

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	A	B	mean(A)	mean(B)	diff	se	T	p-tukey	cohen
0	1	2	0.390	4.415	-4.024	0.741	-5.434	0.000	-1.046
1	1	3	0.390	0.340	0.050	0.741	0.068	1.000	0.013
2	1	4	0.390	1.065	-0.675	0.741	-0.911	0.996	-0.175
3	1	5	0.390	1.777	-1.387	0.741	-1.872	0.688	-0.360
4	1	6	0.390	3.932	-3.542	0.741	-4.782	0.000	-0.920
5	1	7	0.390	0.378	0.013	0.741	0.017	1.000	0.003
6	1	8	0.390	1.360	-0.970	0.741	-1.310	0.951	-0.252
7	1	9	0.390	2.834	-2.444	0.741	-3.300	0.034	-0.635
8	1	10	0.390	1.632	-1.242	0.741	-1.677	0.808	-0.323
9	2	3	4.415	0.340	4.075	0.741	5.502	0.000	1.059
10	2	4	4.415	1.065	3.350	0.741	4.523	0.000	0.870
11	2	5	4.415	1.777	2.638	0.741	3.562	0.015	0.685
12	2	6	4.415	3.932	0.483	0.741	0.652	1.000	0.126
13	2	7	4.415	0.378	4.037	0.741	5.451	0.000	1.049
14	2	8	4.415	1.360	3.054	0.741	4.124	0.002	0.794
15	2	9	4.415	2.834	1.580	0.741	2.134	0.504	0.411
16	2	10	4.415	1.632	2.782	0.741	3.757	0.007	0.723
17	3	4	0.340	1.065	-0.725	0.741	-0.979	0.993	-0.188
18	3	5	0.340	1.777	-1.437	0.741	-1.940	0.642	-0.373
19	3	6	0.340	3.932	-3.592	0.741	-4.849	0.000	-0.933
20	3	7	0.340	0.378	-0.037	0.741	-0.051	1.000	-0.010
21	3	8	0.340	1.360	-1.020	0.741	-1.377	0.934	-0.265
22	3	9	0.340	2.834	-2.494	0.741	-3.368	0.028	-0.648
23	3	10	0.340	1.632	-1.292	0.741	-1.745	0.769	-0.336
24	4	5	1.065	1.777	-0.712	0.741	-0.961	0.994	-0.185
25	4	6	1.065	3.932	-2.867	0.741	-3.871	0.005	-0.745
26	4	7	1.065	0.378	0.687	0.741	0.928	0.996	0.179
27	4	8	1.065	1.360	-0.295	0.741	-0.398	1.000	-0.077
28	4	9	1.065	2.834	-1.769	0.741	-2.389	0.335	-0.460
29	4	10	1.065	1.632	-0.567	0.741	-0.766	0.999	-0.147
30	5	6	1.777	3.932	-2.155	0.741	-2.910	0.105	-0.560
31	5	7	1.777	0.378	1.399	0.741	1.889	0.676	0.364
32	5	8	1.777	1.360	0.417	0.741	0.563	1.000	0.108
33	5	9	1.777	2.834	-1.057	0.741	-1.428	0.918	-0.275
34	5	10	1.777	1.632	0.144	0.741	0.195	1.000	0.038
35	6	7	3.932	0.378	3.554	0.741	4.799	0.000	0.924
36	6	8	3.932	1.360	2.571	0.741	3.472	0.020	0.668
37	6	9	3.932	2.834	1.097	0.741	1.482	0.899	0.285
38	6	10	3.932	1.632	2.299	0.741	3.105	0.062	0.597
39	7	8	0.378	1.360	-0.983	0.741	-1.327	0.947	-0.255
40	7	9	0.378	2.834	-2.457	0.741	-3.317	0.033	-0.638
41	7	10	0.378	1.632	-1.255	0.741	-1.694	0.799	-0.326
42	8	9	1.360	2.834	-1.474	0.741	-1.990	0.606	-0.383
43	8	10	1.360	1.632	-0.272	0.741	-0.367	1.000	-0.071
44	9	10	2.834	1.632	1.202	0.741	1.623	0.837	0.312

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Appendix H: Statistical analysis results comparing F_vF_m of crops in all typologies

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Oneway ANOVA
Study site = Eco green wall

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error
max_quantum_yield	Amaranthus thunbergii	11	.76627	.020867	.006292
	Asystasia gangetica	44	.78968	.010456	.001576
	Corchorus confusus	25	.79752	.016460	.003292
	Dicliptera clinopodia	17	.79006	.010071	.002443
	Mentha aquatica	42	.81100	.017452	.002693
	Plectranthus amboinicus	59	.83580	.017719	.002307
	Portulaca oleracea	40	.76590	.030255	.004784
	Portulacaria afra prostrata	62	.83173	.028469	.003616
	Spinacea oleracea	37	.82105	.018416	.003028
	Vigna unguilata	33	.80852	.026537	.004619
	Total	370	.80860	.031573	.001641
Study_site	Amaranthus thunbergii	11	1.00	.000	.000
	Asystasia gangetica	44	1.00	.000	.000
	Corchorus confusus	25	1.00	.000	.000
	Dicliptera clinopodia	17	1.00	.000	.000
	Mentha aquatica	42	1.00	.000	.000
	Plectranthus amboinicus	59	1.00	.000	.000
	Portulaca oleracea	40	1.00	.000	.000
	Portulacaria afra prostrata	62	1.00	.000	.000
	Spinacea oleracea	37	1.00	.000	.000
	Vigna unguilata	33	1.00	.000	.000
	Total	370	1.00	.000	.000

Descriptives[a]

		95% Confidence Interval for Mean		
		Lower Bound	Upper Bound	Minimum
max_quantum_yield	Amaranthus thunbergii	.75225	.78029	.716
	Asystasia gangetica	.78650	.79286	.753
	Corchorus confusus	.79073	.80431	.769
	Dicliptera clinopodia	.78488	.79524	.774
	Mentha aquatica	.80556	.81644	.765
	Plectranthus amboinicus	.83118	.84041	.770
	Portulaca oleracea	.75622	.77558	.657
	Portulacaria afra prostrata	.82450	.83896	.670
	Spinacea oleracea	.81491	.82719	.766
	Vigna unguilata	.79911	.81792	.738
	Total	.80537	.81182	.657
Study_site	Amaranthus thunbergii	1.00	1.00	1
	Asystasia gangetica	1.00	1.00	1
	Corchorus confusus	1.00	1.00	1
	Dicliptera clinopodia	1.00	1.00	1
	Mentha aquatica	1.00	1.00	1
	Plectranthus amboinicus	1.00	1.00	1
	Portulaca oleracea	1.00	1.00	1
	Portulacaria afra prostrata	1.00	1.00	1
	Spinacea oleracea	1.00	1.00	1
	Vigna unguilata	1.00	1.00	1
	Total	1.00	1.00	1

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Descriptives[a]

		Maximum
max_quantum_yield	Amaranthus thunbergii	.790
	Asystasia gangetica	.804
	Corchorus confusus	.827
	Dicliptera clinopodia	.806
	Mentha aquatica	.832
	Plectranthus amboinicus	.877
	Portulaca oleracea	.808
	Portulacaria afra prostrata	.865
	Spinacea oleracea	.854
	Vigna unguilata	.849
	Total	.877
Study_site	Amaranthus thunbergii	1
	Asystasia gangetica	1
	Corchorus confusus	1
	Dicliptera clinopodia	1
	Mentha aquatica	1
	Plectranthus amboinicus	1
	Portulaca oleracea	1
	Portulacaria afra prostrata	1
	Spinacea oleracea	1
	Vigna unguilata	1
	Total	1

a. Study_site = Eco green wall

ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.200	9	.022	47.705
	Within Groups	.168	360	.000	
	Total	.368	369		
Study_site	Between Groups	.000	9	.000	.
	Within Groups	.000	360	.000	
	Total	.000	369		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
Study_site	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall

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ANOVA Effect Sizes[a,b]

		Point Estimate	95% Confidence Interval Lower	Upper
max_quantum_yield	Eta-squared	.544	.468	.589
	Epsilon-squared	.533	.454	.578
	Omega-squared Fixed-effect	.532	.454	.578
	Omega-squared Random-effect	.112	.084	.132
Study_site	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Eco green wall

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Crop	(J) Crop	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
max_quantum_yield	Amaranthus thunbergii	Asystasia gangetica	-.023409*	.007277	.045	-.04658	-.00024
		Corchorus confusus	-.031247*	.007811	.003	-.05611	-.00638
		Dicliptera clinopodia	-.023786	.008353	.125	-.05038	.00281
		Mentha aquatica	-.044727*	.007312	<,001	-.06801	-.02145
		Plectranthus amboinicus	-.069524*	.007090	<,001	-.09210	-.04695
		Portulaca oleracea	.000373	.007349	1.000	-.02303	.02377
		Portulacaria afra prostrata	-.065453*	.007063	<,001	-.08794	-.04297
		Spinacea oleracea	-.054781*	.007413	<,001	-.07838	-.03118
		Vigna unguilata	-.042242*	.007516	<,001	-.06617	-.01831
	Asystasia gangetica	Amaranthus thunbergii	.023409*	.007277	.045	.00024	.04658
		Corchorus confusus	-.007838	.005407	.910	-.02505	.00937
		Dicliptera clinopodia	-.000377	.006165	1.000	-.02000	.01925
		Mentha aquatica	-.021318*	.004657	<,001	-.03614	-.00649
		Plectranthus amboinicus	-.046115*	.004300	<,001	-.05980	-.03243
		Portulaca oleracea	.023782*	.004716	<,001	.00877	.03880
		Portulacaria afra	-.042044*	.00425	<,001	-.05559	-.02850

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		prostrata		5			
		Spinacea oleracea	-.031372*	.004815	<,001	-.04670	-.01604
		Vigna unguilata	-.018833*	.004971	.007	-.03466	-.00301
	Corchorus confusus	Amaranthus thunbergii	.031247*	.007811	.003	.00638	.05611
		Asystasia gangetica	.007838	.005407	.910	-.00937	.02505
		Dicliptera clinopodia	.007461	.006786	.985	-.01414	.02907
		Mentha aquatica	-.013480	.005453	.287	-.03084	.00388
		Plectranthus amboinicus	-.038277*	.005152	<,001	-.05468	-.02188
		Portulaca oleracea	.031620*	.005504	<,001	.01410	.04914
		Portulacaria afra prostrata	-.034206*	.005114	<,001	-.05049	-.01792
		Spinacea oleracea	-.023534*	.005589	.001	-.04133	-.00574
		Vigna unguilata	-.010995	.005724	.655	-.02922	.00723
	Dicliptera clinopodia	Amaranthus thunbergii	.023786	.008353	.125	-.00281	.05038
		Asystasia gangetica	.000377	.006165	1.000	-.01925	.02000
		Corchorus confusus	-.007461	.006786	.985	-.02907	.01414
		Mentha aquatica	-.020941*	.006205	.028	-.04070	-.00118
		Plectranthus amboinicus	-.045738*	.005942	<,001	-.06466	-.02682
		Portulaca oleracea	.024159*	.006250	.005	.00426	.04406
		Portulacaria afra prostrata	-.041667*	.005910	<,001	-.06048	-.02285
		Spinacea oleracea	-.030995*	.006325	<,001	-.05113	-.01086
		Vigna unguilata	-.018456	.006445	.120	-.03897	.00206
	Mentha aquatica	Amaranthus thunbergii	.044727*	.007312	<,001	.02145	.06801
		Asystasia gangetica	.021318*	.004657	<,001	.00649	.03614
		Corchorus confusus	.013480	.005453	.287	-.00388	.03084
		Dicliptera clinopodia	.020941*	.006205	.028	.00118	.04070
		Plectranthus amboinicus	-.024797*	.004358	<,001	-.03867	-.01092
		Portulaca oleracea	.045100*	.004769	<,001	.02992	.06028
		Portulacaria afra prostrata	-.020726*	.004314	<,001	-.03446	-.00699
		Spinacea oleracea	-.010054	.004867	.553	-.02555	.00544

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		Vigna unguilata	.002485	.005022	1.000	-.01350	.01847
	Plectranthus amboinicus	Amaranthus thunbergii	.069524*	.007090	<,001	.04695	.09210
		Asystasia gangetica	.046115*	.004300	<,001	.03243	.05980
		Corchorus confusus	.038277*	.005152	<,001	.02188	.05468
		Dicliptera clinopodia	.045738*	.005942	<,001	.02682	.06466
		Mentha aquatica	.024797*	.004358	<,001	.01092	.03867
		Portulaca oleracea	.069897*	.004421	<,001	.05582	.08397
		Portulacaria afra prostrata	.004071	.003926	.990	-.00843	.01657
		Spinacea oleracea	.014743*	.004527	.040	.00033	.02916
		Vigna unguilata	.027281*	.004693	<,001	.01234	.04222
	Portulaca oleracea	Amaranthus thunbergii	-.000373	.007349	1.000	-.02377	.02303
		Asystasia gangetica	-.023782*	.004716	<,001	-.03880	-.00877
		Corchorus confusus	-.031620*	.005504	<,001	-.04914	-.01410
		Dicliptera clinopodia	-.024159*	.006250	.005	-.04406	-.00426
		Mentha aquatica	-.045100*	.004769	<,001	-.06028	-.02992
		Plectranthus amboinicus	-.069897*	.004421	<,001	-.08397	-.05582
		Portulacaria afra prostrata	-.065826*	.004378	<,001	-.07976	-.05189
		Spinacea oleracea	-.055154*	.004924	<,001	-.07083	-.03948
		Vigna unguilata	-.042615*	.005077	<,001	-.05878	-.02645
	Portulacaria afra prostrata	Amaranthus thunbergii	.065453*	.007063	<,001	.04297	.08794
		Asystasia gangetica	.042044*	.004255	<,001	.02850	.05559
		Corchorus confusus	.034206*	.005114	<,001	.01792	.05049
		Dicliptera clinopodia	.041667*	.005910	<,001	.02285	.06048
		Mentha aquatica	.020726*	.004314	<,001	.00699	.03446
		Plectranthus amboinicus	-.004071	.003926	.990	-.01657	.00843
		Portulaca oleracea	.065826*	.004378	<,001	.05189	.07976
		Spinacea oleracea	.010672	.004485	.341	-.00361	.02495
		Vigna unguilata	.023211*	.004652	<,001	.00840	.03802
	Spinacea oleracea	Amaranthus	.054781*	.00741	<,001	.03118	.07838

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		thunbergii		3		
		Asystasia gangetica	.031372*	.004815	<,001	.01604	.04670
		Corchorus confusus	.023534*	.005589	.001	.00574	.04133
		Dicliptera clinopodia	.030995*	.006325	<,001	.01086	.05113
		Mentha aquatica	.010054	.004867	.553	-.00544	.02555
		Plectranthus amboinicus	-.014743*	.004527	.040	-.02916	-.00033
		Portulaca oleracea	.055154*	.004924	<,001	.03948	.07083
		Portulacaria afra prostrata	-.010672	.004485	.341	-.02495	.00361
		Vigna unguilata	.012539	.005169	.314	-.00392	.02899
	Vigna unguilata	Amaranthus thunbergii	.042242*	.007516	<,001	.01831	.06617
		Asystasia gangetica	.018833*	.004971	.007	.00301	.03466
		Corchorus confusus	.010995	.005724	.655	-.00723	.02922
		Dicliptera clinopodia	.018456	.006445	.120	-.00206	.03897
		Mentha aquatica	-.002485	.005022	1.000	-.01847	.01350
		Plectranthus amboinicus	-.027281*	.004693	<,001	-.04222	-.01234
		Portulaca oleracea	.042615*	.005077	<,001	.02645	.05878
		Portulacaria afra prostrata	-.023211*	.004652	<,001	-.03802	-.00840
		Spinacea oleracea	-.012539	.005169	.314	-.02899	.00392

*. The mean difference is significant at the 0.05 level.

a. Study_site = Eco green wall

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Crop	N	Subset for alpha = 0.05				
		1	2	3	4	5
Portulaca oleracea	40	.76590				
Amaranthus thunbergii	11	.76627				
Asystasia gangetica	44		.78968			
Dicliptera clinopodia	17		.79006			
Corchorus confusus	25		.79752	.79752		
Vigna unguilata	33			.80852	.80852	
Mentha aquatica	42			.81100	.81100	
Spinacea oleracea	37				.82105	.82105
Portulacaria afra prostrata	62					.83173
Plectranthus amboinicus	59					.83580
Sig.		1.000	.936	.357	.465	.233

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall

b. Uses Harmonic Mean Sample Size = 28.435.

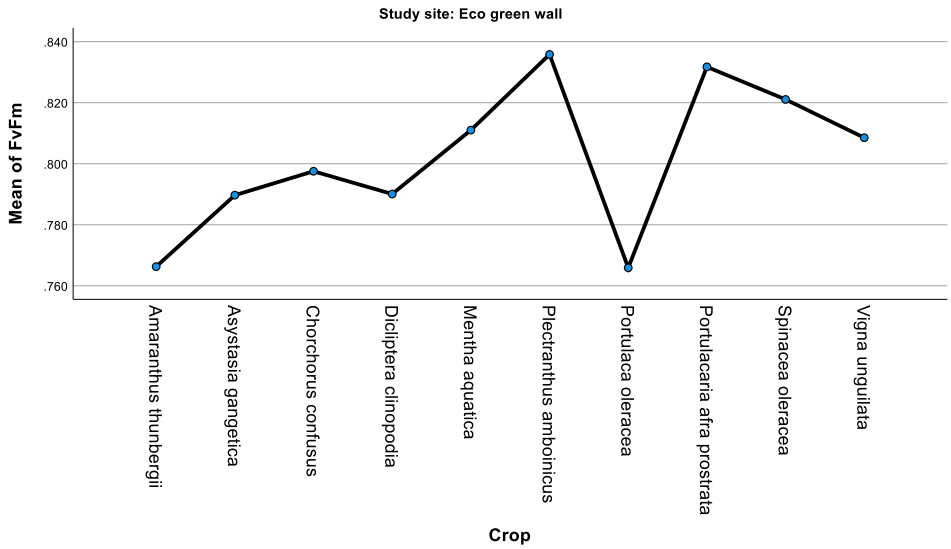
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Study_site[a]

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall

Means Plots



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Study site = Vicinity wall

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error
max_quantum_yield	Amaranthus thunbergii	16	.75956	.027122	.006780
	Asystasia gangetica	36	.80264	.015686	.002614
	Corchorus confusus	39	.80197	.021998	.003523
	Dicliptera clinopodia	27	.79252	.011657	.002243
	Mentha aquatica	41	.82134	.014001	.002187
	Plectranthus amboinicus	63	.83651	.015666	.001974
	Portulaca oleracea	42	.77783	.017974	.002773
	Portulacaria afra prostrata	58	.83936	.032241	.004233
	Spinacea oleracea	42	.82350	.020476	.003160
	Vigna unguilata	47	.81328	.017395	.002537
	Total	411	.81329	.029974	.001479
Study_site	Amaranthus thunbergii	16	2.00	.000	.000
	Asystasia gangetica	36	2.00	.000	.000
	Corchorus confusus	39	2.00	.000	.000
	Dicliptera clinopodia	27	2.00	.000	.000
	Mentha aquatica	41	2.00	.000	.000
	Plectranthus amboinicus	63	2.00	.000	.000
	Portulaca oleracea	42	2.00	.000	.000
	Portulacaria afra prostrata	58	2.00	.000	.000
	Spinacea oleracea	42	2.00	.000	.000
	Vigna unguilata	47	2.00	.000	.000
	Total	411	2.00	.000	.000

Descriptives[a]

		95% Confidence Interval for Mean		Minimum
		Lower Bound	Upper Bound	
max_quantum_yield	Amaranthus thunbergii	.74511	.77401	.711
	Asystasia gangetica	.79733	.80795	.773
	Corchorus confusus	.79484	.80911	.757
	Dicliptera clinopodia	.78791	.79713	.764
	Mentha aquatica	.81692	.82576	.775
	Plectranthus amboinicus	.83256	.84045	.787
	Portulaca oleracea	.77223	.78343	.740
	Portulacaria afra prostrata	.83088	.84784	.726
	Spinacea oleracea	.81712	.82988	.755
	Vigna unguilata	.80817	.81838	.760
	Total	.81038	.81619	.711
Study_site	Amaranthus thunbergii	2.00	2.00	2
	Asystasia gangetica	2.00	2.00	2
	Corchorus confusus	2.00	2.00	2
	Dicliptera clinopodia	2.00	2.00	2
	Mentha aquatica	2.00	2.00	2
	Plectranthus amboinicus	2.00	2.00	2
	Portulaca oleracea	2.00	2.00	2
	Portulacaria afra prostrata	2.00	2.00	2
	Spinacea oleracea	2.00	2.00	2
	Vigna unguilata	2.00	2.00	2
	Total	2.00	2.00	2

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Descriptives[a]

		Maximum
max_quantum_yield	Amaranthus thunbergii	.798
	Asystasia gangetica	.831
	Corchorus confusus	.838
	Dicliptera clinopodia	.809
	Mentha aquatica	.845
	Plectranthus amboinicus	.859
	Portulaca oleracea	.814
	Portulacaria afra prostrata	.880
	Spinacea oleracea	.853
	Vigna unguilata	.841
	Total	.880
Study_site	Amaranthus thunbergii	2
	Asystasia gangetica	2
	Corchorus confusus	2
	Dicliptera clinopodia	2
	Mentha aquatica	2
	Plectranthus amboinicus	2
	Portulaca oleracea	2
	Portulacaria afra prostrata	2
	Spinacea oleracea	2
	Vigna unguilata	2
	Total	2

a. Study_site = Vicinity wall

ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.200	9	.022	53.006
	Within Groups	.168	401	.000	
	Total	.368	410		
Study_site	Between Groups	.000	9	.000	.
	Within Groups	.000	401	.000	
	Total	.000	410		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
Study_site	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Vicinity wall

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ANOVA Effect Sizes[a,b]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.543	.472	.586
	Epsilon-squared	.533	.460	.577
	Omega-squared Fixed-effect	.532	.459	.576
	Omega-squared Random-effect	.112	.086	.131
Study_site	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Vicinity wall

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Crop	(J) Crop	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	Amaranthus thunbergii	Asystasia gangetica	-.043076*	.006154	<,001	-.06266	-.02350
		Corchorus confusus	-.042412*	.006081	<,001	-.06176	-.02306
		Dicliptera clinopodia	-.032956*	.006462	<,001	-.05352	-.01240
		Mentha aquatica	-.061779*	.006038	<,001	-.08099	-.04257
		Plectranthus amboinicus	-.076945*	.005734	<,001	-.09519	-.05870
		Portulaca oleracea	-.018271	.006017	.076	-.03742	.00087
		Portulacaria afra prostrata	-.079800*	.005784	<,001	-.09820	-.06140
		Spinacea oleracea	-.063938*	.006017	<,001	-.08308	-.04479
		Vigna unguilata	-.053714*	.005928	<,001	-.07258	-.03485
	Asystasia gangetica	Amaranthus thunbergii	.043076*	.006154	<,001	.02350	.06266
		Corchorus confusus	.000665	.004734	1.000	-.01440	.01573
		Dicliptera clinopodia	.010120	.005215	.641	-.00647	.02671
		Mentha aquatica	-.018703*	.004678	.003	-.03359	-.00382
		Plectranthus amboinicus	-.033869*	.004279	<,001	-.04748	-.02025
		Portulaca oleracea	.024806*	.004652	<,001	.01000	.03961

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		Portulacaria afra prostrata	-.036723*	.004346	<,001	-.05055	-.02290
		Spinacea oleracea	-.020861*	.004652	<,001	-.03566	-.00606
		Vigna unguilata	-.010638	.004536	.362	-.02507	.00380
	Corchorus confusus	Amaranthus thunbergii	.042412*	.006081	<,001	.02306	.06176
		Asystasia gangetica	-.000665	.004734	1.000	-.01573	.01440
		Dicliptera clinopodia	.009456	.005128	.707	-.00686	.02577
		Mentha aquatica	-.019367*	.004581	.001	-.03394	-.00479
		Plectranthus amboinicus	-.034534*	.004173	<,001	-.04781	-.02126
		Portulaca oleracea	.024141*	.004555	<,001	.00965	.03863
		Portulacaria afra prostrata	-.037388*	.004241	<,001	-.05088	-.02389
		Spinacea oleracea	-.021526*	.004555	<,001	-.03602	-.00703
		Vigna unguilata	-.011302	.004437	.247	-.02542	.00281
	Dicliptera clinopodia	Amaranthus thunbergii	.032956*	.006462	<,001	.01240	.05352
		Asystasia gangetica	-.010120	.005215	.641	-.02671	.00647
		Corchorus confusus	-.009456	.005128	.707	-.02577	.00686
		Mentha aquatica	-.028823*	.005076	<,001	-.04497	-.01267
		Plectranthus amboinicus	-.043989*	.004711	<,001	-.05898	-.02900
		Portulaca oleracea	.014685	.005052	.107	-.00139	.03076
		Portulacaria afra prostrata	-.046844*	.004772	<,001	-.06203	-.03166
		Spinacea oleracea	-.030981*	.005052	<,001	-.04706	-.01491
		Vigna unguilata	-.020758*	.004946	.001	-.03649	-.00502
	Mentha aquatica	Amaranthus thunbergii	.061779*	.006038	<,001	.04257	.08099
		Asystasia gangetica	.018703*	.004678	.003	.00382	.03359
		Corchorus confusus	.019367*	.004581	.001	.00479	.03394
		Dicliptera clinopodia	.028823*	.005076	<,001	.01267	.04497
		Plectranthus amboinicus	-.015166*	.004110	.010	-.02824	-.00209
		Portulaca oleracea	.043508*	.004497	<,001	.02920	.05782
		Portulacaria afra prostrata	-.018021*	.004179	<,001	-.03132	-.00472
		Spinacea oleracea	-.002159	.00449	1.000	-.01647	.01215

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			7			
	Vigna unguilata	.008065	.004377	.708	-.00586	.02199
Plectranthus amboinicus	Amaranthus thunbergii	.076945*	.005734	<,001	.05870	.09519
	Asystasia gangetica	.033869*	.004279	<,001	.02025	.04748
	Corchorus confusus	.034534*	.004173	<,001	.02126	.04781
	Dicliptera clinopodia	.043989*	.004711	<,001	.02900	.05898
	Mentha aquatica	.015166*	.004110	.010	.00209	.02824
	Portulaca oleracea	.058675*	.004080	<,001	.04569	.07166
	Portulacaria afra prostrata	-.002854	.003727	.999	-.01471	.00900
	Spinacea oleracea	.013008*	.004080	.049	.00003	.02599
	Vigna unguilata	.023231*	.003948	<,001	.01067	.03579
Portulaca oleracea	Amaranthus thunbergii	.018271	.006017	.076	-.00087	.03742
	Asystasia gangetica	-.024806*	.004652	<,001	-.03961	-.01000
	Corchorus confusus	-.024141*	.004555	<,001	-.03863	-.00965
	Dicliptera clinopodia	-.014685	.005052	.107	-.03076	.00139
	Mentha aquatica	-.043508*	.004497	<,001	-.05782	-.02920
	Plectranthus amboinicus	-.058675*	.004080	<,001	-.07166	-.04569
	Portulacaria afra prostrata	-.061529*	.004150	<,001	-.07473	-.04833
	Spinacea oleracea	-.045667*	.004470	<,001	-.05989	-.03145
	Vigna unguilata	-.035443*	.004349	<,001	-.04928	-.02161
Portulacaria afra prostrata	Amaranthus thunbergii	.079800*	.005784	<,001	.06140	.09820
	Asystasia gangetica	.036723*	.004346	<,001	.02290	.05055
	Corchorus confusus	.037388*	.004241	<,001	.02389	.05088
	Dicliptera clinopodia	.046844*	.004772	<,001	.03166	.06203
	Mentha aquatica	.018021*	.004179	<,001	.00472	.03132
	Plectranthus amboinicus	.002854	.003727	.999	-.00900	.01471
	Portulaca oleracea	.061529*	.004150	<,001	.04833	.07473
	Spinacea oleracea	.015862*	.004150	.006	.00266	.02907
	Vigna unguilata	.026085*	.004020	<,001	.01330	.03888
Spinacea oleracea	Amaranthus	.063938*	.00601	<,001	.04479	.08308

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		thunbergii		7		
		Asystasia gangetica	.020861*	.004652	<,001	.00606	.03566
		Corchorus confusus	.021526*	.004555	<,001	.00703	.03602
		Dicliptera clinopodia	.030981*	.005052	<,001	.01491	.04706
		Mentha aquatica	.002159	.004497	1.000	-.01215	.01647
		Plectranthus amboinicus	-.013008*	.004080	.049	-.02599	-.00003
		Portulaca oleracea	.045667*	.004470	<,001	.03145	.05989
		Portulacaria afra prostrata	-.015862*	.004150	.006	-.02907	-.00266
		Vigna unguilata	.010223	.004349	.359	-.00361	.02406
	Vigna unguilata	Amaranthus thunbergii	.053714*	.005928	<,001	.03485	.07258
		Asystasia gangetica	.010638	.004536	.362	-.00380	.02507
		Corchorus confusus	.011302	.004437	.247	-.00281	.02542
		Dicliptera clinopodia	.020758*	.004946	.001	.00502	.03649
		Mentha aquatica	-.008065	.004377	.708	-.02199	.00586
		Plectranthus amboinicus	-.023231*	.003948	<,001	-.03579	-.01067
		Portulaca oleracea	.035443*	.004349	<,001	.02161	.04928
		Portulacaria afra prostrata	-.026085*	.004020	<,001	-.03888	-.01330
		Spinacea oleracea	-.010223	.004349	.359	-.02406	.00361

*. The mean difference is significant at the 0.05 level.

a. Study_site = Vicinity wall

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Crop	N	Subset for alpha = 0.05				
		1	2	3	4	5
Amaranthus thunbergii	16	.75956				
Portulaca oleracea	42		.77783			
Dicliptera clinopodia	27		.79252	.79252		
Corchorus confusus	39			.80197	.80197	
Asystasia gangetica	36			.80264	.80264	
Vigna unguilata	47				.81328	.81328
Mentha aquatica	41					.82134
Spinacea oleracea	42					.82350
Plectranthus amboinicus	63					
Portulacaria afra prostrata	58					
Sig.		1.000	.076	.535	.369	.520

max_quantum_yield[a]

Tukey HSD[b,c]

Crop	Subset for alpha = 0.05	
	6	7
Amaranthus thunbergii		
Portulaca oleracea		
Dicliptera clinopodia		
Corchorus confusus		
Asystasia gangetica		
Vigna unguilata		
Mentha aquatica	.82134	
Spinacea oleracea	.82350	
Plectranthus amboinicus	.83651	.83651
Portulacaria afra prostrata		.83936
Sig.	.058	1.000

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall

b. Uses Harmonic Mean Sample Size = 35.797.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

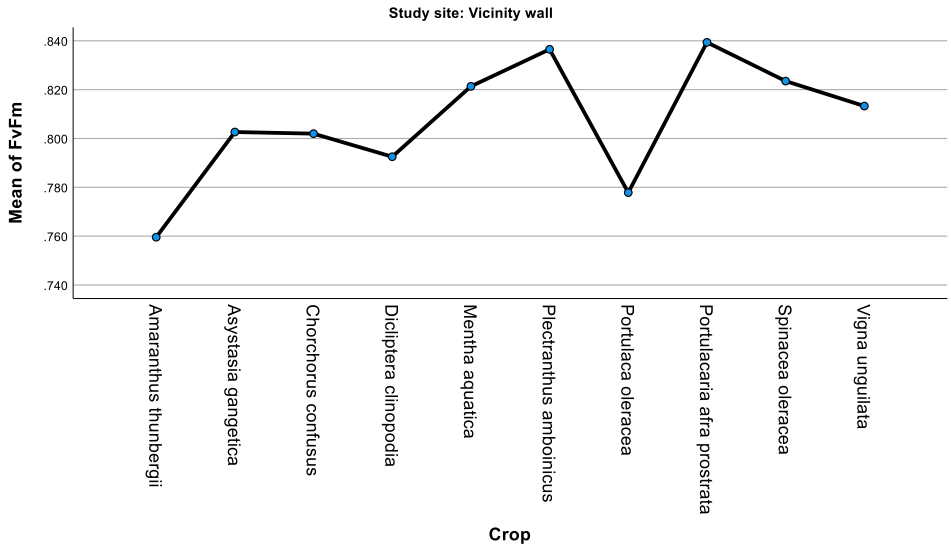
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Study_site[a]

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall

Means Plots



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Study site = Natural soil area

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error
max_quantum_yield	Amaranthus thunbergii	12	.77167	.013640	.003938
	Asystasia gangetica	51	.79431	.011704	.001639
	Corchorus confusus	43	.83079	.016454	.002509
	Dicliptera clinopodia	27	.78456	.012270	.002361
	Mentha aquatica	39	.82046	.009489	.001519
	Plectranthus amboinicus	54	.83774	.014864	.002023
	Portulaca oleracea	29	.77738	.024938	.004631
	Portulacaria afra prostrata	54	.83100	.022574	.003072
	Spinacea oleracea	39	.83254	.018164	.002909
	Vigna unguilata	42	.80590	.018665	.002880
	Total	390	.81448	.027303	.001383
Study_site	Amaranthus thunbergii	12	3.00	.000	.000
	Asystasia gangetica	51	3.00	.000	.000
	Corchorus confusus	43	3.00	.000	.000
	Dicliptera clinopodia	27	3.00	.000	.000
	Mentha aquatica	39	3.00	.000	.000
	Plectranthus amboinicus	54	3.00	.000	.000
	Portulaca oleracea	29	3.00	.000	.000
	Portulacaria afra prostrata	54	3.00	.000	.000
	Spinacea oleracea	39	3.00	.000	.000
	Vigna unguilata	42	3.00	.000	.000
	Total	390	3.00	.000	.000

Descriptives[a]

		95% Confidence Interval for Mean		Minimum
		Lower Bound	Upper Bound	
max_quantum_yield	Amaranthus thunbergii	.76300	.78033	.759
	Asystasia gangetica	.79102	.79761	.763
	Corchorus confusus	.82573	.83585	.779
	Dicliptera clinopodia	.77970	.78941	.757
	Mentha aquatica	.81739	.82354	.800
	Plectranthus amboinicus	.83368	.84180	.802
	Portulaca oleracea	.76789	.78687	.714
	Portulacaria afra prostrata	.82484	.83716	.771
	Spinacea oleracea	.82665	.83843	.801
	Vigna unguilata	.80009	.81172	.753
	Total	.81176	.81720	.714
Study_site	Amaranthus thunbergii	3.00	3.00	3
	Asystasia gangetica	3.00	3.00	3
	Corchorus confusus	3.00	3.00	3
	Dicliptera clinopodia	3.00	3.00	3
	Mentha aquatica	3.00	3.00	3
	Plectranthus amboinicus	3.00	3.00	3
	Portulaca oleracea	3.00	3.00	3
	Portulacaria afra prostrata	3.00	3.00	3
	Spinacea oleracea	3.00	3.00	3
	Vigna unguilata	3.00	3.00	3
	Total	3.00	3.00	3

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Descriptives[a]

		Maximum
max_quantum_yield	Amaranthus thunbergii	.802
	Asystasia gangetica	.815
	Corchorus confusus	.857
	Dicliptera clinopodia	.813
	Mentha aquatica	.842
	Plectranthus amboinicus	.859
	Portulaca oleracea	.817
	Portulacaria afra prostrata	.870
	Spinacea oleracea	.861
	Vigna unguilata	.834
	Total	.870
Study_site	Amaranthus thunbergii	3
	Asystasia gangetica	3
	Corchorus confusus	3
	Dicliptera clinopodia	3
	Mentha aquatica	3
	Plectranthus amboinicus	3
	Portulaca oleracea	3
	Portulacaria afra prostrata	3
	Spinacea oleracea	3
	Vigna unguilata	3
	Total	3

a. Study_site = Natural soil area

ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.179	9	.020	68.525
	Within Groups	.111	380	.000	
	Total	.290	389		
Study_site	Between Groups	.000	9	.000	.
	Within Groups	.000	380	.000	
	Total	.000	389		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
Study_site	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area

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ANOVA Effect Sizes[a,b]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.619	.554	.657
	Epsilon-squared	.610	.543	.649
	Omega-squared Fixed-effect	.609	.543	.648
	Omega-squared Random-effect	.148	.117	.170
Study_site	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Crop	(J) Crop	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	Amaranthus thunbergii	Asystasia gangetica	-.022647*	.005473	.002	-.04006	-.00523
		Corchorus confusus	-.059124*	.005569	<,001	-.07685	-.04140
		Dicliptera clinopodia	-.012889	.005918	.474	-.03172	.00595
		Mentha aquatica	-.048795*	.005631	<,001	-.06672	-.03087
		Plectranthus amboinicus	-.066074*	.005444	<,001	-.08340	-.04875
		Portulaca oleracea	-.005713	.005855	.993	-.02435	.01292
		Portulacaria afra prostrata	-.059333*	.005444	<,001	-.07666	-.04201
		Spinacea oleracea	-.060872*	.005631	<,001	-.07879	-.04295
		Vigna unguilata	-.034238*	.005583	<,001	-.05201	-.01647
	Asystasia gangetica	Amaranthus thunbergii	.022647*	.005473	.002	.00523	.04006
		Corchorus confusus	-.036477*	.003531	<,001	-.04772	-.02524
		Dicliptera clinopodia	.009758	.004060	.326	-.00316	.02268
		Mentha aquatica	-.026148*	.003628	<,001	-.03770	-.01460
		Plectranthus amboinicus	-.043427*	.003331	<,001	-.05403	-.03283
		Portulaca oleracea	.016934*	.003967	.001	.00431	.02956
		Portulacaria afra prostrata	-.036686*	.003331	<,001	-.04729	-.02609

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		Spinacea oleracea	-.038225*	.003628	<,001	-.04977	-.02668
		Vigna unguilata	-.011591*	.003554	.039	-.02290	-.00028
	Corchorus confusus	Amaranthus thunbergii	.059124*	.005569	<,001	.04140	.07685
		Asystasia gangetica	.036477*	.003531	<,001	.02524	.04772
		Dicliptera clinopodia	.046235*	.004188	<,001	.03291	.05956
		Mentha aquatica	.010329	.003772	.162	-.00167	.02233
		Plectranthus amboinicus	-.006950	.003486	.604	-.01805	.00415
		Portulaca oleracea	.053411*	.004099	<,001	.04037	.06646
		Portulacaria afra prostrata	-.000209	.003486	1.000	-.01130	.01089
		Spinacea oleracea	-.001748	.003772	1.000	-.01375	.01026
		Vigna unguilata	.024886*	.003700	<,001	.01311	.03666
	Dicliptera clinopodia	Amaranthus thunbergii	.012889	.005918	.474	-.00595	.03172
		Asystasia gangetica	-.009758	.004060	.326	-.02268	.00316
		Corchorus confusus	-.046235*	.004188	<,001	-.05956	-.03291
		Mentha aquatica	-.035906*	.004270	<,001	-.04950	-.02232
		Plectranthus amboinicus	-.053185*	.004020	<,001	-.06598	-.04039
		Portulaca oleracea	.007176	.004562	.860	-.00734	.02169
		Portulacaria afra prostrata	-.046444*	.004020	<,001	-.05924	-.03365
		Spinacea oleracea	-.047983*	.004270	<,001	-.06157	-.03439
		Vigna unguilata	-.021349*	.004207	<,001	-.03474	-.00796
	Mentha aquatica	Amaranthus thunbergii	.048795*	.005631	<,001	.03087	.06672
		Asystasia gangetica	.026148*	.003628	<,001	.01460	.03770
		Corchorus confusus	-.010329	.003772	.162	-.02233	.00167
		Dicliptera clinopodia	.035906*	.004270	<,001	.02232	.04950
		Plectranthus amboinicus	-.017279*	.003584	<,001	-.02869	-.00587
		Portulaca oleracea	.043082*	.004182	<,001	.02977	.05639
		Portulacaria afra prostrata	-.010538	.003584	.098	-.02195	.00087
		Spinacea oleracea	-.012077	.003863	.059	-.02437	.00022
		Vigna unguilata	.014557*	.00379	.006	.00248	.02663

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				3			
	Plectranthus amboinicus	Amaranthus thunbergii	.066074*	.00544 4	<,001	.04875	.08340
		Asystasia gangetica	.043427*	.00333 1	<,001	.03283	.05403
		Corchorus confusus	.006950	.00348 6	.604	-.00415	.01805
		Dicliptera clinopodia	.053185*	.00402 0	<,001	.04039	.06598
		Mentha aquatica	.017279*	.00358 4	<,001	.00587	.02869
		Portulaca oleracea	.060361*	.00392 7	<,001	.04786	.07286
		Portulacaria afra prostrata	.006741	.00328 3	.562	-.00371	.01719
		Spinacea oleracea	.005202	.00358 4	.910	-.00621	.01661
		Vigna unguilata	.031836*	.00350 9	<,001	.02067	.04300
	Portulaca oleracea	Amaranthus thunbergii	.005713	.00585 5	.993	-.01292	.02435
		Asystasia gangetica	-.016934*	.00396 7	.001	-.02956	-.00431
		Corchorus confusus	-.053411*	.00409 9	<,001	-.06646	-.04037
		Dicliptera clinopodia	-.007176	.00456 2	.860	-.02169	.00734
		Mentha aquatica	-.043082*	.00418 2	<,001	-.05639	-.02977
		Plectranthus amboinicus	-.060361*	.00392 7	<,001	-.07286	-.04786
		Portulacaria afra prostrata	-.053621*	.00392 7	<,001	-.06612	-.04112
		Spinacea oleracea	-.055159*	.00418 2	<,001	-.06847	-.04185
		Vigna unguilata	-.028525*	.004118	<,001	-.04163	-.01542
	Portulacaria afra prostrata	Amaranthus thunbergii	.059333*	.00544 4	<,001	.04201	.07666
		Asystasia gangetica	.036686*	.00333 1	<,001	.02609	.04729
		Corchorus confusus	.000209	.00348 6	1.000	-.01089	.01130
		Dicliptera clinopodia	.046444*	.00402 0	<,001	.03365	.05924
		Mentha aquatica	.010538	.00358 4	.098	-.00087	.02195
		Plectranthus amboinicus	-.006741	.00328 3	.562	-.01719	.00371
		Portulaca oleracea	.053621*	.00392 7	<,001	.04112	.06612
		Spinacea oleracea	-.001538	.00358 4	1.000	-.01295	.00987
		Vigna unguilata	.025095*	.00350 9	<,001	.01393	.03626
	Spinacea oleracea	Amaranthus thunbergii	.060872*	.00563 1	<,001	.04295	.07879
		Asystasia	.038225*	.00362	<,001	.02668	.04977

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	gangetica		8			
	Corchorus confusus	.001748	.003772	1.000	-.01026	.01375
	Dicliptera clinopodia	.047983*	.004270	<,001	.03439	.06157
	Mentha aquatica	.012077	.003863	.059	-.00022	.02437
	Plectranthus amboinicus	-.005202	.003584	.910	-.01661	.00621
	Portulaca oleracea	.055159*	.004182	<,001	.04185	.06847
	Portulacaria afra prostrata	.001538	.003584	1.000	-.00987	.01295
	Vigna unguilata	.026634*	.003793	<,001	.01456	.03871
Vigna unguilata	Amaranthus thunbergii	.034238*	.005583	<,001	.01647	.05201
	Asystasia gangetica	.011591*	.003554	.039	.00028	.02290
	Corchorus confusus	-.024886*	.003700	<,001	-.03666	-.01311
	Dicliptera clinopodia	.021349*	.004207	<,001	.00796	.03474
	Mentha aquatica	-.014557*	.003793	.006	-.02663	-.00248
	Plectranthus amboinicus	-.031836*	.003509	<,001	-.04300	-.02067
	Portulaca oleracea	.028525*	.004118	<,001	.01542	.04163
	Portulacaria afra prostrata	-.025095*	.003509	<,001	-.03626	-.01393
	Spinacea oleracea	-.026634*	.003793	<,001	-.03871	-.01456

*. The mean difference is significant at the 0.05 level.

a. Study_site = Natural soil area

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

		Subset for alpha = 0.05				
Crop	N	1	2	3	4	5
Amaranthus thunbergii	12	.77167				
Portulaca oleracea	29	.77738				
Dicliptera clinopodia	27	.78456	.78456			
Asystasia gangetica	51		.79431	.79431		
Vigna unguilata	42			.80590		
Mentha aquatica	39				.82046	
Corchorus confusus	43				.83079	.83079
Portulacaria afra prostrata	54				.83100	.83100
Spinacea oleracea	39				.83254	.83254
Plectranthus amboinicus	54					.83774
Sig.		.076	.393	.166	.126	.829

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Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area

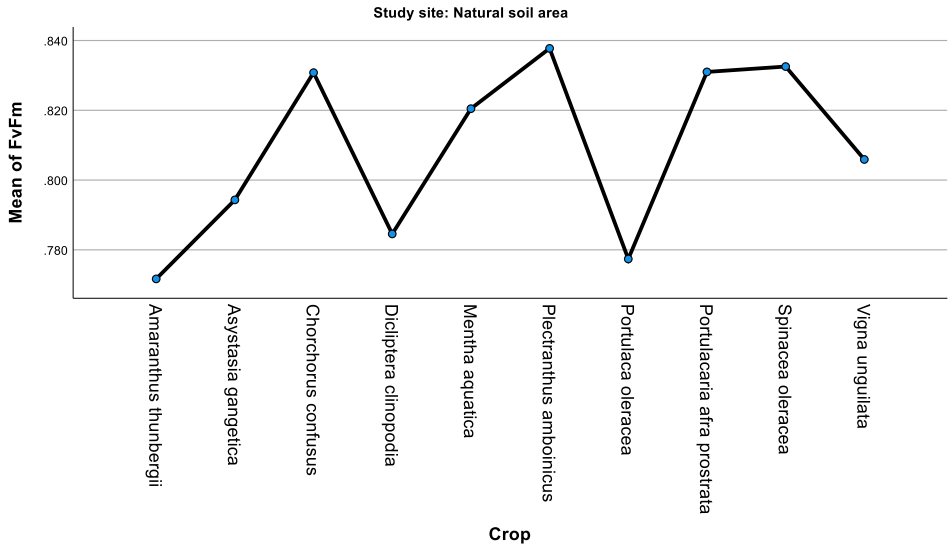
b. Uses Harmonic Mean Sample Size = 32.274.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

Study_site[a]

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area

Means Plots



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Appendix I: Statistical analysis results of the crops' F_vF_m and PI_{total} in the Eco Green Wall

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Oneway ANOVA
Eco Green Wall
Study site = Eco green wall, Crop = Amaranthus thunbergii

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	4	.77275	.016153	.008076	.74705
	DEC 2021	3	.75733	.037754	.021797	.66355
	FEB 2022	4	.76650	.010214	.005107	.75025
	Total	11	.76627	.020867	.006292	.75225
PI_total	NOV 2021	4	1.244675	.2181918	.1090959	.897483
	DEC 2021	3	1.518367	.9951018	.5745223	-.953603
	FEB 2022	4	.986100	.4343884	.2171942	.294891
	Total	11	1.225291	.5636834	.1699570	.846603
Crop	NOV 2021	4	1.00	.000	.000	1.00
	DEC 2021	3	1.00	.000	.000	1.00
	FEB 2022	4	1.00	.000	.000	1.00
	Total	11	1.00	.000	.000	1.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.79845	.751	.786
	DEC 2021	.85112	.716	.790
	FEB 2022	.78275	.752	.775
	Total	.78029	.716	.790
PI_total	NOV 2021	1.591867	1.0132	1.5338
	DEC 2021	3.990337	.7752	2.6489
	FEB 2022	1.677309	.6541	1.6155
	Total	1.603979	.6541	2.6489
Crop	NOV 2021	1.00	1	1
	DEC 2021	1.00	1	1
	FEB 2022	1.00	1	1
	Total	1.00	1	1

a. Study_site = Eco green wall, Crop = Amaranthus thunbergii

ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.000	2	.000	.413
	Within Groups	.004	8	.000	
	Total	.004	10		
PI_total	Between Groups	.488	2	.244	.726
	Within Groups	2.689	8	.336	
	Total	3.177	10		
Crop	Between Groups	.000	2	.000	.
	Within Groups	.000	8	.000	
	Total	.000	10		

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ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.675
	Within Groups	
	Total	
PI_total	Between Groups	.513
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall, Crop = Amaranthus thunbergii

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.094	.000	.371
	Epsilon-squared	-.133	-.250	.214
	Omega-squared Fixed-effect	-.119	-.222	.199
	Omega-squared Random-effect	-.056	-.100	.110
PI_total	Eta-squared	.154	.000	.442
	Epsilon-squared	-.058	-.250	.303
	Omega-squared Fixed-effect	-.052	-.222	.283
	Omega-squared Random-effect	-.026	-.100	.165
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Eco green wall, Crop = Amaranthus thunbergii
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound
max_quantum_yield	NOV 2021	DEC 2021	.015417	.016963	.650	-.03306
		FEB 2022	.006250	.015705	.917	-.03863
	DEC 2021	NOV 2021	-.015417	.016963	.650	-.06389
		FEB 2022	-.009167	.016963	.854	-.05764
	FEB 2022	NOV 2021	-.006250	.015705	.917	-.05113
		DEC 2021	.009167	.016963	.854	-.03931
PI_total	NOV 2021	DEC 2021	-.2736917	.4428307	.815	-1.539056
		FEB 2022	.2585750	.4099815	.808	-.912924
	DEC 2021	NOV 2021	.2736917	.4428307	.815	-.991672
		FEB 2022	.5322667	.4428307	.485	-.733097
	FEB 2022	NOV 2021	-.2585750	.4099815	.808	-1.430074
		DEC 2021	-.5322667	.4428307	.485	-1.797631

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Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.06389
		FEB 2022	.05113
	DEC 2021	NOV 2021	.03306
		FEB 2022	.03931
	FEB 2022	NOV 2021	.03863
		DEC 2021	.05764
PI_total	NOV 2021	DEC 2021	.991672
		FEB 2022	1.430074
	DEC 2021	NOV 2021	1.539056
		FEB 2022	1.797631
	FEB 2022	NOV 2021	.912924
		DEC 2021	.733097

a. Study_site = Eco green wall, Crop = Amaranthus thunbergii

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1
DEC 2021	3	.75733
FEB 2022	4	.76650
NOV 2021	4	.77275
Sig.		.637

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Amaranthus thunbergii

b. Uses Harmonic Mean Sample Size = 3.600.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1
FEB 2022	4	.986100
NOV 2021	4	1.244675
DEC 2021	3	1.518367
Sig.		.469

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Amaranthus thunbergii

b. Uses Harmonic Mean Sample Size = 3.600.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

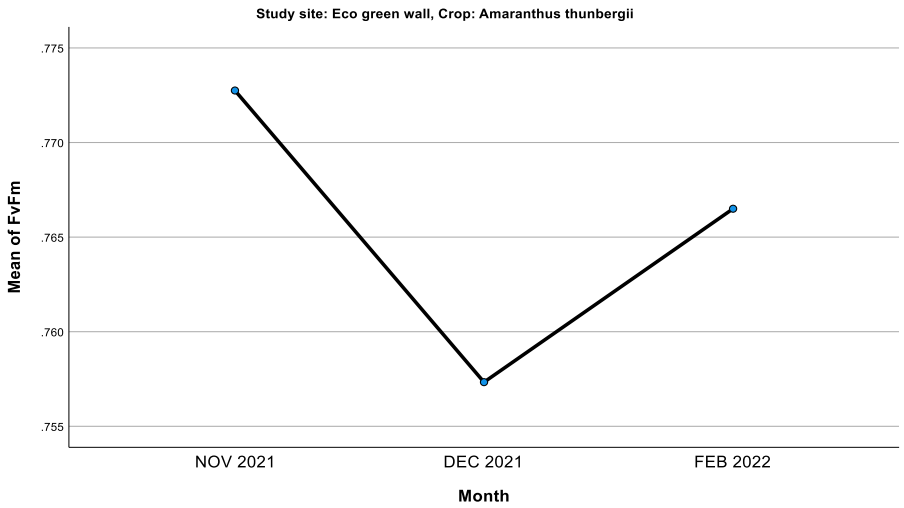
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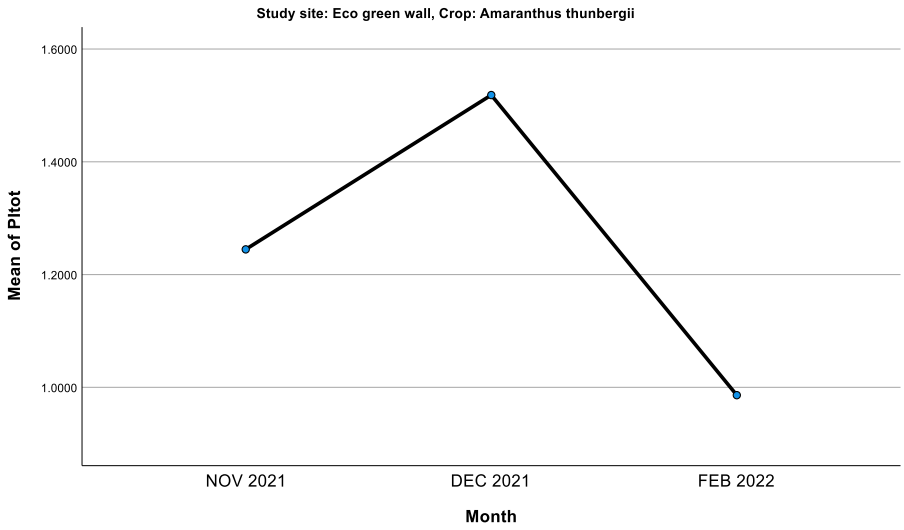
Crop[a]

Means for groups in homogeneous subsets are displayed.[a]

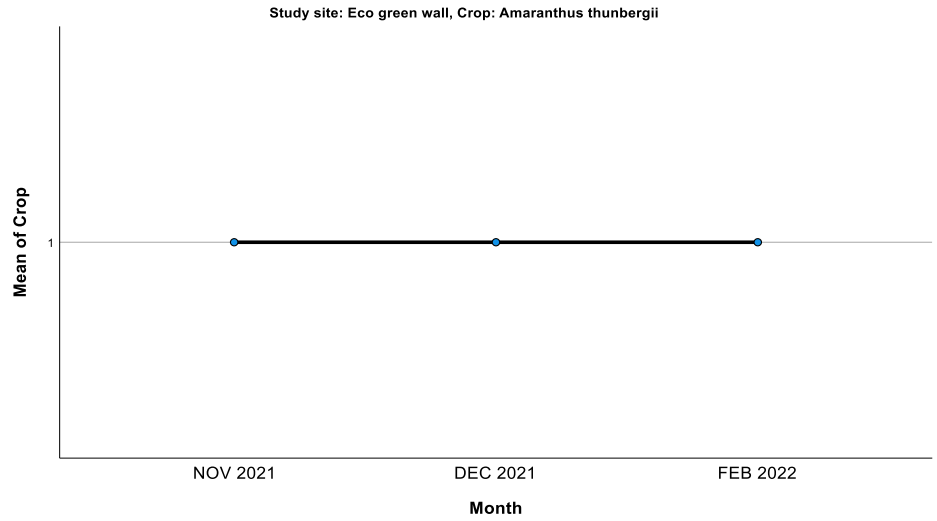
a. Study_site = Eco green wall, Crop = Amaranthus thunbergii

Means Plots





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Study site = Eco green wall, Crop = Asystasia gangetica

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.79089	.004936	.001645	.78709
	DEC 2021	8	.79463	.004274	.001511	.79105
	JAN 2022	5	.78500	.003240	.001449	.78098
	FEB 2022	7	.79486	.004375	.001654	.79081
	MAR 2022	6	.79117	.010088	.004118	.78058
	APR 2022	4	.79825	.007632	.003816	.78611
	Total	39	.79241	.006660	.001066	.79025
PI_total	NOV 2021	9	1.049622	.1860338	.0620113	.906624
	DEC 2021	8	1.031738	.1032534	.0365056	.945415
	JAN 2022	5	.705480	.0584033	.0261188	.632963
	FEB 2022	7	.865343	.2258836	.0853760	.656435
	MAR 2022	6	1.029850	.1415018	.0577679	.881353
	APR 2022	4	1.449300	.1122800	.0561400	1.270637
	Total	39	1.006708	.2412220	.0386264	.928513
Crop	NOV 2021	9	2.00	.000	.000	2.00
	DEC 2021	8	2.00	.000	.000	2.00
	JAN 2022	5	2.00	.000	.000	2.00
	FEB 2022	7	2.00	.000	.000	2.00
	MAR 2022	6	2.00	.000	.000	2.00
	APR 2022	4	2.00	.000	.000	2.00
	Total	39	2.00	.000	.000	2.00

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Descriptives[a]

		95% Confidence Interval for Mean		
		Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.79468	.784	.799
	DEC 2021	.79820	.788	.803
	JAN 2022	.78902	.780	.789
	FEB 2022	.79890	.788	.801
	MAR 2022	.80175	.773	.801
	APR 2022	.81039	.787	.804
	Total	.79457	.773	.804
PI_total	NOV 2021	1.192620	.7720	1.4048
	DEC 2021	1.118060	.8962	1.1962
	JAN 2022	.777997	.6182	.7601
	FEB 2022	1.074250	.5220	1.1819
	MAR 2022	1.178347	.8227	1.1771
	APR 2022	1.627963	1.3132	1.5531
	Total	1.084903	.5220	1.5531
Crop	NOV 2021	2.00	2	2
	DEC 2021	2.00	2	2
	JAN 2022	2.00	2	2
	FEB 2022	2.00	2	2
	MAR 2022	2.00	2	2
	APR 2022	2.00	2	2
	Total	2.00	2	2

a. Study_site = Eco green wall, Crop = Asystasia gangetica

ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.001	5	.000	2.963
	Within Groups	.001	33	.000	
	Total	.002	38		
PI_total	Between Groups	1.402	5	.280	11.434
	Within Groups	.809	33	.025	
	Total	2.211	38		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	33	.000	
	Total	.000	38		

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ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.026
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall, Crop = Asystasia gangetica

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.310	.000	.444
	Epsilon-squared	.205	-.152	.359
	Omega-squared Fixed-effect	.201	-.147	.353
	Omega-squared Random-effect	.048	-.026	.099
PI_total	Eta-squared	.634	.340	.719
	Epsilon-squared	.579	.240	.676
	Omega-squared Fixed-effect	.572	.235	.671
	Omega-squared Random-effect	.211	.058	.289
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Eco green wall, Crop = Asystasia gangetica

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.003736	.002885	.786	-.01246	.00499
		JAN 2022	.005889	.003312	.493	-.00412	.01590
		FEB 2022	-.003968	.002992	.769	-.01301	.00508
		MAR 2022	-.000278	.003129	1.000	-.00974	.00918
		APR 2022	-.007361	.003568	.331	-.01815	.00343
	DEC 2021	NOV 2021	.003736	.002885	.786	-.00499	.01246
		JAN 2022	.009625	.003385	.075	-.00061	.01986
		FEB 2022	-.000232	.003073	1.000	-.00952	.00906
		MAR 2022	.003458	.003206	.886	-.00624	.01315
		APR 2022	-.003625	.003636	.916	-.01462	.00737

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	JAN 2022	NOV 2021	-.005889	.003312	.493	-.01590	.00412
		DEC 2021	-.009625	.003385	.075	-.01986	.00061
		FEB 2022	-.009857	.003476	.076	-.02037	.00065
		MAR 2022	-.006167	.003595	.532	-.01704	.00470
		APR 2022	-.013250*	.003983	.024	-.02529	-.00121
	FEB 2022	NOV 2021	.003968	.002992	.769	-.00508	.01301
		DEC 2021	.000232	.003073	1.000	-.00906	.00952
		JAN 2022	.009857	.003476	.076	-.00065	.02037
		MAR 2022	.003690	.003303	.871	-.00630	.01368
		APR 2022	-.003393	.003721	.941	-.01464	.00786
	MAR 2022	NOV 2021	.000278	.003129	1.000	-.00918	.00974
		DEC 2021	-.003458	.003206	.886	-.01315	.00624
		JAN 2022	.006167	.003595	.532	-.00470	.01704
		FEB 2022	-.003690	.003303	.871	-.01368	.00630
		APR 2022	-.007083	.003832	.450	-.01867	.00450
	APR 2022	NOV 2021	.007361	.003568	.331	-.00343	.01815
		DEC 2021	.003625	.003636	.916	-.00737	.01462
		JAN 2022	.013250*	.003983	.024	.00121	.02529
		FEB 2022	.003393	.003721	.941	-.00786	.01464
		MAR 2022	.007083	.003832	.450	-.00450	.01867
PI_total	NOV 2021	DEC 2021	.0178847	.0760910	1.000	-.212179	.247948
		JAN 2022	.3441422*	.0873440	.005	.080055	.608229
		FEB 2022	.1842794	.0789160	.209	-.054326	.422884
		MAR 2022	.0197722	.0825323	1.000	-.229767	.269311
		APR 2022	-.3996778*	.0941013	.002	-.684196	-.115160
	DEC 2021	NOV 2021	-.0178847	.0760910	1.000	-.247948	.212179
		JAN 2022	.3262575*	.0892723	.011	.056340	.596175
		FEB 2022	.1663946	.0810451	.336	-.078648	.411437
		MAR 2022	.0018875	.0845705	1.000	-.253814	.257589
		APR 2022	-.4175625*	.0958939	.002	-.707501	-.127624
	JAN 2022	NOV 2021	-.3441422*	.0873440	.005	-.608229	-.080055
		DEC 2021	-.3262575*	.0892723	.011	-.596175	-.056340
		FEB 2022	-.1598629	.0916921	.514	-.437097	.117371
		MAR 2022	-.3243700*	.0948224	.019	-.611068	-.037672
		APR 2022	-.7438200*	.1050465	<,001	-1.061431	-.426209
	FEB 2022	NOV 2021	-.1842794	.0789160	.209	-.422884	.054326
		DEC 2021	-.1663946	.0810451	.336	-.411437	.078648
		JAN 2022	.1598629	.0916921	.514	-.117371	.437097
		MAR 2022	-.1645071	.0871209	.427	-.427920	.098906
		APR 2022	-.5839571*	.0981505	<,001	-.880718	-.287196
	MAR 2022	NOV 2021	-.0197722	.0825323	1.000	-.269311	.229767
		DEC 2021	-.0018875	.0845705	1.000	-.257589	.253814
		JAN 2022	.3243700*	.0948224	.019	.037672	.611068
		FEB 2022	.1645071	.0871209	.427	-.098906	.427920
		APR 2022	-.4194500*	.1010810	.003	-.725072	-.113828
	APR 2022	NOV 2021	.3996778*	.0941013	.002	.115160	.684196
		DEC 2021	.4175625*	.0958939	.002	.127624	.707501
		JAN 2022	.7438200*	.1050465	<,001	.426209	1.061431
		FEB 2022	.5839571*	.0981505	<,001	.287196	.880718
		MAR 2022	.4194500*	.1010810	.003	.113828	.725072

*. The mean difference is significant at the 0.05 level.

a. Study_site = Eco green wall, Crop = Asystasia gangetica

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
JAN 2022	5	.78500	
NOV 2021	9	.79089	.79089
MAR 2022	6	.79117	.79117
DEC 2021	8	.79463	.79463
FEB 2022	7	.79486	.79486
APR 2022	4		.79825
Sig.		.069	.287

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Asystasia gangetica

b. Uses Harmonic Mean Sample Size = 6.026.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05		
		1	2	3
JAN 2022	5	.705480		
FEB 2022	7	.865343	.865343	
MAR 2022	6		1.029850	
DEC 2021	8		1.031738	
NOV 2021	9		1.049622	
APR 2022	4			1.449300
Sig.		.497	.341	1.000

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Asystasia gangetica

b. Uses Harmonic Mean Sample Size = 6.026.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

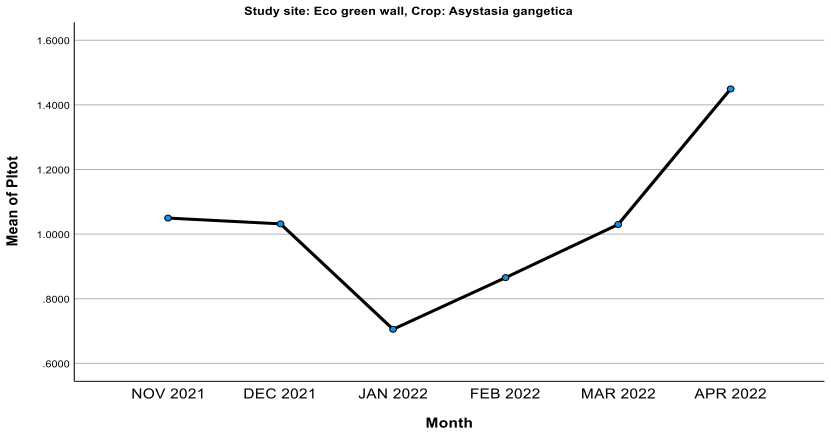
Crop[a]

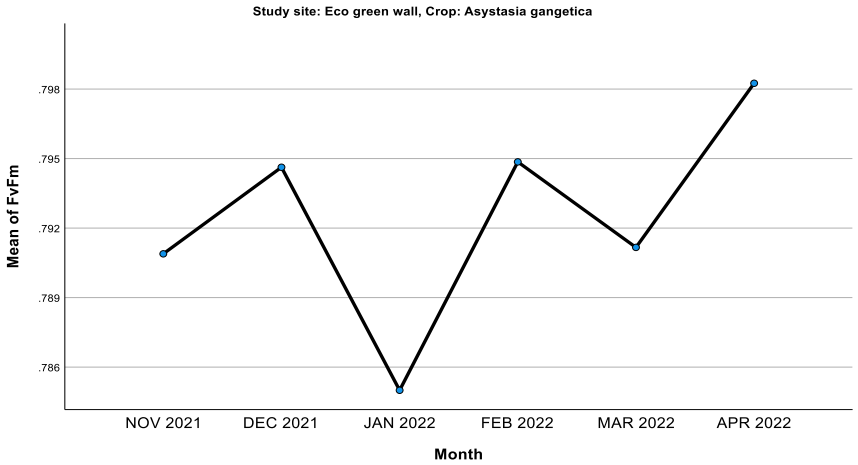
Means for groups in homogeneous subsets are displayed.[a]

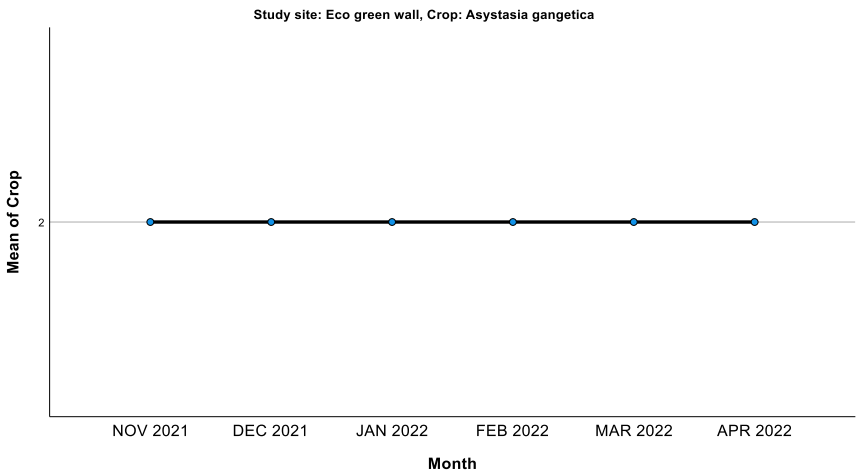
a. Study_site = Eco green wall, Crop = Asystasia gangetica

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Study site = Eco green wall, Crop = Corchorus confusus

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	DEC 2021	3	.80900	.021703	.012530	.75509
	JAN 2022	1	.80600	.	.	.
	FEB 2022	3	.80500	.019975	.011533	.75538
	MAR 2022	7	.79286	.011393	.004306	.78232
	APR 2022	7	.80129	.018607	.007033	.78408
	Total	21	.80033	.016304	.003558	.79291
PI_total	DEC 2021	3	1.912933	.6610736	.3816710	.270736
	JAN 2022	1	.148200	.	.	.
	FEB 2022	3	2.883333	1.4187639	.8191237	-.641072
	MAR 2022	7	3.050214	2.0413238	.7715479	1.162305
	APR 2022	7	1.181371	.9064030	.3425881	.343088
	Total	21	2.102767	1.6250217	.3546088	1.363066
Crop	DEC 2021	3	3.00	.000	.000	3.00
	JAN 2022	1	3.00	.	.	.
	FEB 2022	3	3.00	.000	.000	3.00
	MAR 2022	7	3.00	.000	.000	3.00
	APR 2022	7	3.00	.000	.000	3.00
	Total	21	3.00	.000	.000	3.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	DEC 2021	.86291	.784	.823
	JAN 2022	.	.806	.806
	FEB 2022	.85462	.788	.827
	MAR 2022	.80339	.769	.804
	APR 2022	.81849	.776	.821
	Total	.80776	.769	.827
PI_total	DEC 2021	3.555131	1.1562	2.3781
	JAN 2022	.	.1482	.1482
	FEB 2022	6.407738	1.9121	4.5115
	MAR 2022	4.938124	.2797	5.0420
	APR 2022	2.019654	.4222	2.8057
	Total	2.842468	.1482	5.0420
Crop	DEC 2021	3.00	3	3
	JAN 2022	.	3	3
	FEB 2022	3.00	3	3
	MAR 2022	3.00	3	3
	APR 2022	3.00	3	3
	Total	3.00	3	3

a. Study_site = Eco green wall, Crop = Corchorus confusus

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.001	4	.000	.627
	Within Groups	.005	16	.000	
	Total	.005	20		
PI_total	Between Groups	17.983	4	4.496	2.065
	Within Groups	34.831	16	2.177	
	Total	52.814	20		
Crop	Between Groups	.000	4	.000	.
	Within Groups	.000	16	.000	
	Total	.000	20		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.650
	Within Groups	
	Total	
PI_total	Between Groups	.133
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall, Crop = Corchorus confusus

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.135	.000	.286
	Epsilon-squared	-.081	-.250	.107
	Omega-squared Fixed-effect	-.076	-.235	.103
	Omega-squared Random-effect	-.018	-.050	.028
PI_total	Eta-squared	.340	.000	.507
	Epsilon-squared	.176	-.250	.383
	Omega-squared Fixed-effect	.169	-.235	.372
	Omega-squared Random-effect	.048	-.050	.129
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

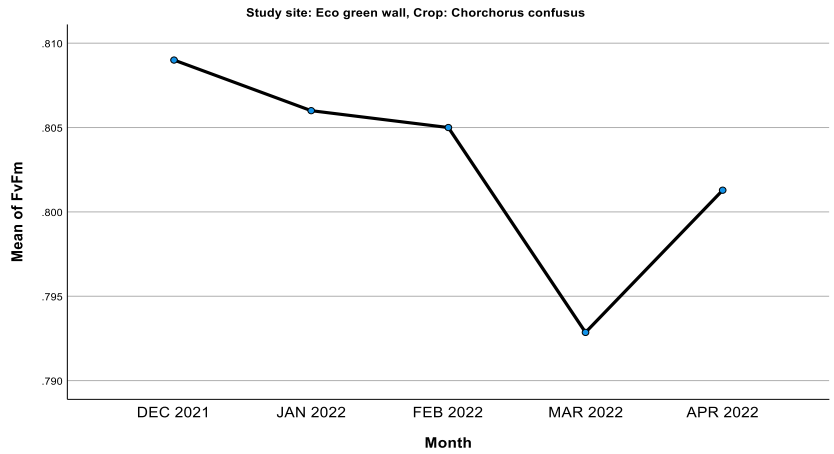
a. Study_site = Eco green wall, Crop = Corchorus confusus

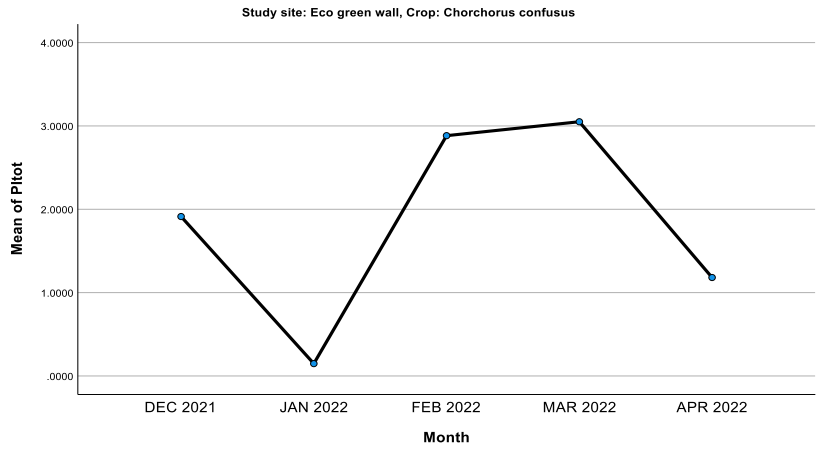
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

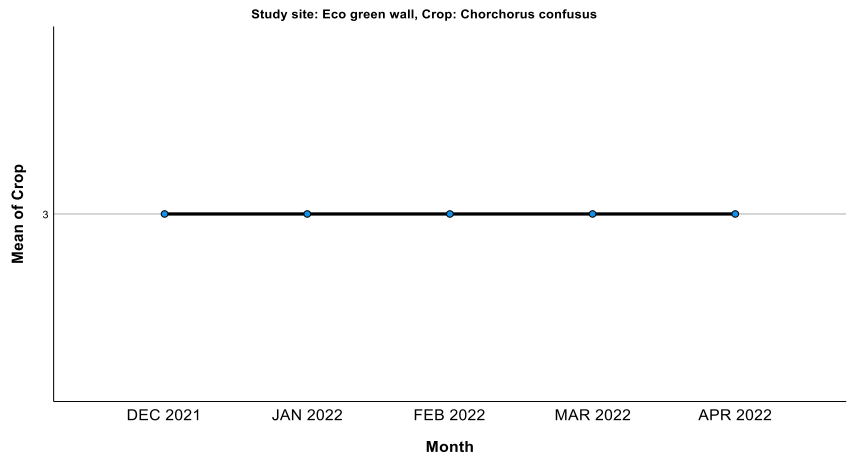
c. Negative but less biased estimates are retained, not rounded to zero.

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Study site = Eco green wall, Crop = Dicliptera clinopodia

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	3	.79833	.001155	.000667	.79546
	DEC 2021	4	.79425	.012066	.006033	.77505
	JAN 2022	2	.77850	.003536	.002500	.74673
	FEB 2022	4	.78125	.006898	.003449	.77027
	APR 2022	4	.79425	.005909	.002955	.78485
	Total	17	.79006	.010071	.002443	.78488
PI_total	NOV 2021	3	1.312400	.1251589	.0722605	1.001488
	DEC 2021	4	.750700	.1747008	.0873504	.472712
	JAN 2022	2	.531250	.0074246	.0052500	.464542
	FEB 2022	4	1.174150	.1580211	.0790105	.922703
	APR 2022	4	1.461900	.1117356	.0558678	1.284104
	Total	17	1.090982	.3579582	.0868176	.906937
Crop	NOV 2021	3	4.00	.000	.000	4.00
	DEC 2021	4	4.00	.000	.000	4.00
	JAN 2022	2	4.00	.000	.000	4.00
	FEB 2022	4	4.00	.000	.000	4.00
	APR 2022	4	4.00	.000	.000	4.00
	Total	17	4.00	.000	.000	4.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.80120	.797	.799
	DEC 2021	.81345	.778	.806
	JAN 2022	.81027	.776	.781
	FEB 2022	.79223	.774	.790
	APR 2022	.80365	.786	.800
	Total	.79524	.774	.806
PI_total	NOV 2021	1.623312	1.1739	1.4174
	DEC 2021	1.028688	.6233	1.0020
	JAN 2022	.597958	.5260	.5365
	FEB 2022	1.425597	1.0234	1.3735
	APR 2022	1.639696	1.3268	1.5571
	Total	1.275027	.5260	1.5571
Crop	NOV 2021	4.00	4	4
	DEC 2021	4.00	4	4
	JAN 2022	4.00	4	4
	FEB 2022	4.00	4	4
	APR 2022	4.00	4	4
	Total	4.00	4	4

a. Study_site = Eco green wall, Crop = Dicliptera clinopodia

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.001	4	.000	3.961
	Within Groups	.001	12	.000	
	Total	.002	16		
PI_total	Between Groups	1.815	4	.454	23.137
	Within Groups	.235	12	.020	
	Total	2.050	16		
Crop	Between Groups	.000	4	.000	.
	Within Groups	.000	12	.000	
	Total	.000	16		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.028
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall, Crop = Dicliptera clinopodia

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.569	.000	.691
	Epsilon-squared	.425	-.333	.589
	Omega-squared Fixed-effect	.411	-.308	.574
	Omega-squared Random-effect	.148	-.062	.252
PI_total	Eta-squared	.885	.599	.917
	Epsilon-squared	.847	.465	.890
	Omega-squared Fixed-effect	.839	.450	.884
	Omega-squared Random-effect	.566	.170	.655
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Eco green wall, Crop = Dicliptera clinopodia

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.004083	.005831	.953	-.01450	.02267
		JAN 2022	.019833	.006969	.089	-.00238	.04205
		FEB 2022	.017083	.005831	.077	-.00150	.03567
		APR 2022	.004083	.005831	.953	-.01450	.02267
	DEC 2021	NOV 2021	-.004083	.005831	.953	-.02267	.01450
		JAN 2022	.015750	.006612	.186	-.00532	.03682
		FEB 2022	.013000	.005398	.179	-.00421	.03021
		APR 2022	.000000	.005398	1.000	-.01721	.01721
	JAN 2022	NOV 2021	-.019833	.006969	.089	-.04205	.00238
		DEC 2021	-.015750	.006612	.186	-.03682	.00532
		FEB 2022	-.002750	.006612	.993	-.02382	.01832
		APR 2022	-.015750	.006612	.186	-.03682	.00532
	FEB 2022	NOV 2021	-.017083	.005831	.077	-.03567	.00150
		DEC 2021	-.013000	.005398	.179	-.03021	.00421
		JAN 2022	.002750	.006612	.993	-.01832	.02382
		APR 2022	-.013000	.005398	.179	-.03021	.00421
	APR 2022	NOV 2021	-.004083	.005831	.953	-.02267	.01450
		DEC 2021	.000000	.005398	1.000	-.01721	.01721
		JAN 2022	.015750	.006612	.186	-.00532	.03682
		FEB 2022	.013000	.005398	.179	-.00421	.03021
PI_total	NOV 2021	DEC 2021	.5617000*	.1069523	.002	.220797	.902603
		JAN 2022	.7811500*	.1278324	<,001	.373693	1.188607
		FEB 2022	.1382500	.1069523	.700	-.202653	.479153
		APR 2022	-.1495000	.1069523	.640	-.490403	.191403
	DEC 2021	NOV 2021	-.5617000*	.1069523	.002	-.902603	-.220797
		JAN 2022	.2194500	.1212725	.412	-.167098	.605998
		FEB 2022	-.4234500*	.0990185	.008	-.739065	-.107835
		APR 2022	-.7112000*	.0990185	<,001	-1.026815	-.395585
	JAN 2022	NOV 2021	-.7811500*	.1278324	<,001	-1.188607	-.373693
		DEC 2021	-.2194500	.1212725	.412	-.605998	.167098
		FEB 2022	-.6429000*	.1212725	.001	-1.029448	-.256352
		APR 2022	-.9306500*	.1212725	<,001	-1.317198	-.544102
	FEB 2022	NOV 2021	-.1382500	.1069523	.700	-.479153	.202653
		DEC 2021	.4234500*	.0990185	.008	.107835	.739065
		JAN 2022	.6429000*	.1212725	.001	.256352	1.029448
		APR 2022	-.2877500	.0990185	.080	-.603365	.027865
	APR 2022	NOV 2021	.1495000	.1069523	.640	-.191403	.490403
		DEC 2021	.7112000*	.0990185	<,001	.395585	1.026815
		JAN 2022	.9306500*	.1212725	<,001	.544102	1.317198
		FEB 2022	.2877500	.0990185	.080	-.027865	.603365

*. The mean difference is significant at the 0.05 level.

a. Study_site = Eco green wall, Crop = Dicliptera clinopodia

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
JAN 2022	2	.77850	
FEB 2022	4	.78125	.78125
DEC 2021	4	.79425	.79425
APR 2022	4	.79425	.79425
NOV 2021	3		.79833
Sig.		.134	.094

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Dicliptera clinopodia

b. Uses Harmonic Mean Sample Size = 3.158.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
JAN 2022	2	.531250	
DEC 2021	4	.750700	
FEB 2022	4		1.174150
NOV 2021	3		1.312400
APR 2022	4		1.461900
Sig.		.336	.136

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Dicliptera clinopodia

b. Uses Harmonic Mean Sample Size = 3.158.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

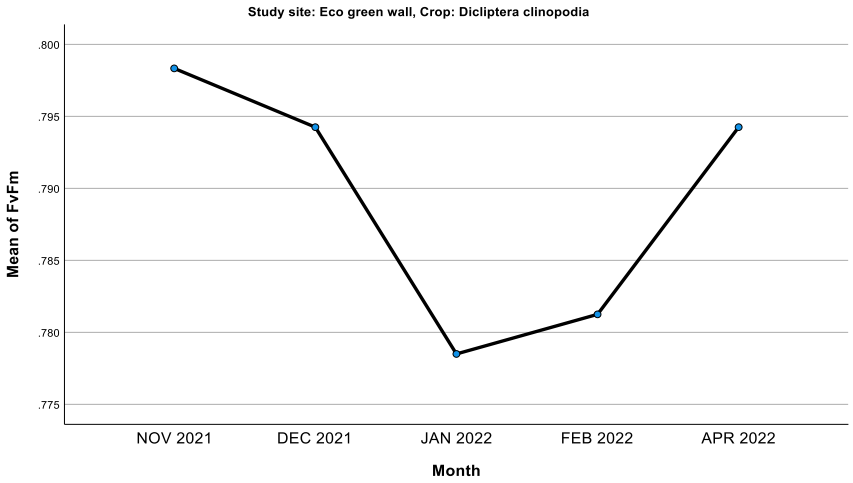
Crop[a]

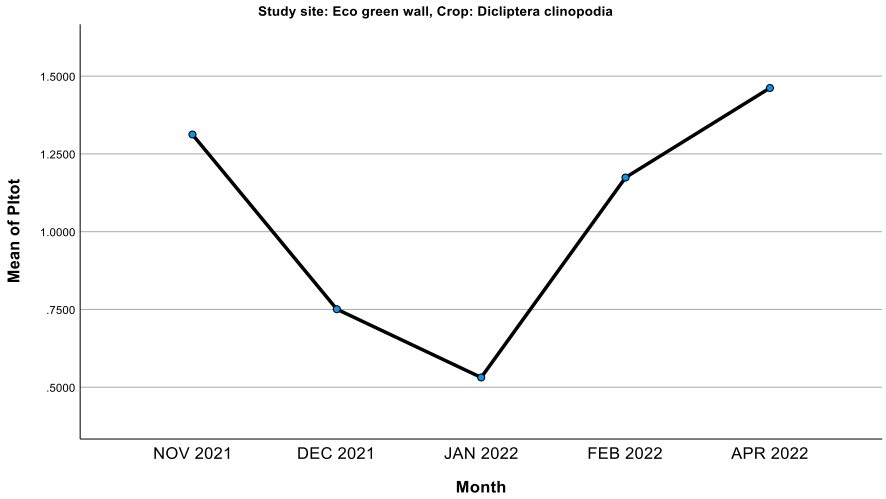
Means for groups in homogeneous subsets are displayed.[a]

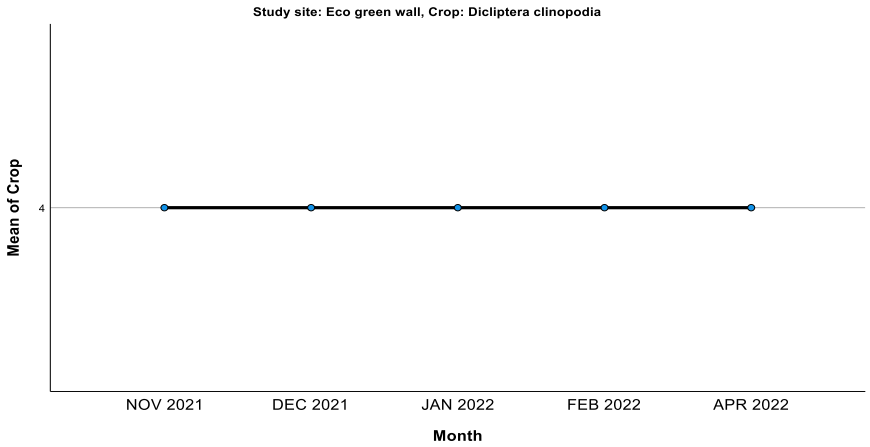
a. Study_site = Eco green wall, Crop = Dicliptera clinopodia

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Study site = Eco green wall, Crop = Mentha aquatica

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	1	.79400	.	.	.
	DEC 2021	8	.82700	.003295	.001165	.82425
	JAN 2022	9	.81378	.012775	.004258	.80396
	FEB 2022	3	.79267	.008505	.004910	.77154
	MAR 2022	5	.82060	.009397	.004202	.80893
	APR 2022	8	.81538	.011538	.004079	.80573
	Total	34	.81582	.013539	.002322	.81110
PI_total	NOV 2021	1	.860000	.	.	.
	DEC 2021	8	.731438	.1809140	.0639627	.580190
	JAN 2022	9	1.053222	.4408399	.1469466	.714363
	FEB 2022	3	.198300	.0285291	.0164713	.127430
	MAR 2022	5	.494640	.1016182	.0454451	.368464
	APR 2022	8	.877900	.2136953	.0755527	.699246
	Total	34	.772994	.3626846	.0621999	.646447
Crop	NOV 2021	1	5.00	.	.	.
	DEC 2021	8	5.00	.000	.000	5.00
	JAN 2022	9	5.00	.000	.000	5.00
	FEB 2022	3	5.00	.000	.000	5.00
	MAR 2022	5	5.00	.000	.000	5.00
	APR 2022	8	5.00	.000	.000	5.00
	Total	34	5.00	.000	.000	5.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.	.794	.794
	DEC 2021	.82975	.822	.831
	JAN 2022	.82360	.796	.832
	FEB 2022	.81379	.784	.801
	MAR 2022	.83227	.805	.828
	APR 2022	.82502	.799	.828
	Total	.82055	.784	.832
PI_total	NOV 2021	.	.8600	.8600
	DEC 2021	.882685	.4823	.9074
	JAN 2022	1.392082	.3643	1.8894
	FEB 2022	.269170	.1742	.2298
	MAR 2022	.620816	.4014	.6267
	APR 2022	1.056554	.5894	1.1959
	Total	.899541	.1742	1.8894
Crop	NOV 2021	.	5	5
	DEC 2021	5.00	5	5
	JAN 2022	5.00	5	5
	FEB 2022	5.00	5	5
	MAR 2022	5.00	5	5
	APR 2022	5.00	5	5
	Total	5.00	5	5

a. Study_site = Eco green wall, Crop = Mentha aquatica

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.003	5	.001	6.449
	Within Groups	.003	28	.000	
	Total	.006	33		
PI_total	Between Groups	2.194	5	.439	5.725
	Within Groups	2.146	28	.077	
	Total	4.341	33		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	28	.000	
	Total	.000	33		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall, Crop = Mentha aquatica

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.535	.168	.643
	Epsilon-squared	.452	.020	.579
	Omega-squared Fixed-effect	.445	.019	.572
	Omega-squared Random-effect	.138	.004	.211
PI_total	Eta-squared	.506	.134	.619
	Epsilon-squared	.417	-.021	.551
	Omega-squared Fixed-effect	.410	-.020	.543
	Omega-squared Random-effect	.122	-.004	.192
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

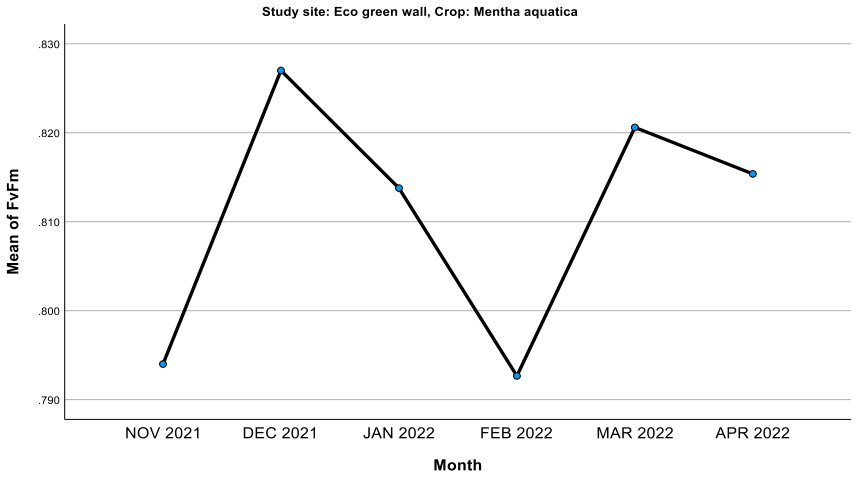
a. Study_site = Eco green wall, Crop = Mentha aquatica

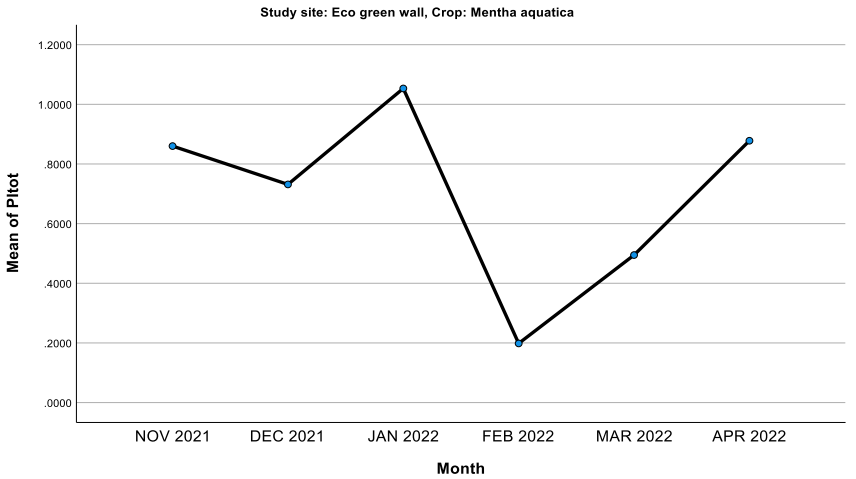
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

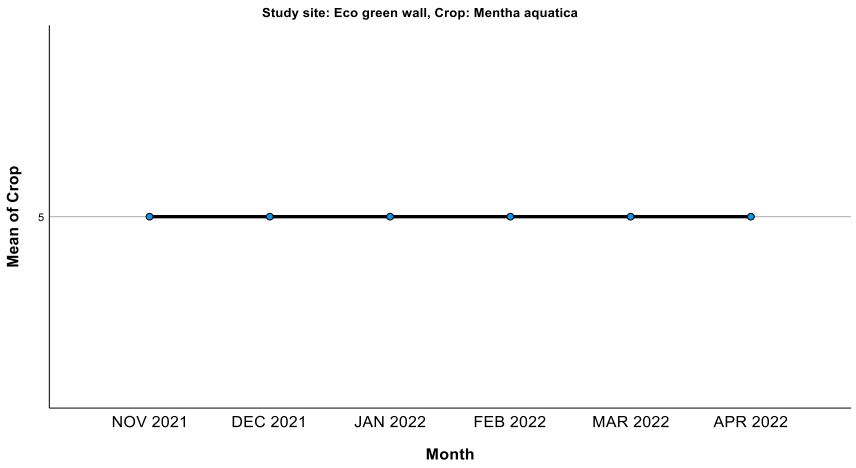
c. Negative but less biased estimates are retained, not rounded to zero.

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Study site = Eco green wall, Crop = Plectranthus amboinicus

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.84178	.005652	.001884	.83743
	DEC 2021	8	.85263	.015519	.005487	.83965
	JAN 2022	9	.83344	.008791	.002930	.82669
	FEB 2022	7	.83457	.028565	.010797	.80815
	MAR 2022	9	.82833	.010977	.003659	.81990
	APR 2022	8	.83125	.020141	.007121	.81441
	Total	50	.83690	.017210	.002434	.83201
PI_total	NOV 2021	9	2.576322	.4649367	.1549789	2.218940
	DEC 2021	8	3.238463	.8337007	.2947577	2.541471
	JAN 2022	9	1.537789	.2041524	.0680508	1.380863
	FEB 2022	7	2.356029	.9391870	.3549793	1.487426
	MAR 2022	9	1.374911	.5063053	.1687684	.985730
	APR 2022	8	2.087475	.8624990	.3049394	1.366408
	Total	50	2.170018	.8998968	.1272646	1.914270
Crop	NOV 2021	9	6.00	.000	.000	6.00
	DEC 2021	8	6.00	.000	.000	6.00
	JAN 2022	9	6.00	.000	.000	6.00
	FEB 2022	7	6.00	.000	.000	6.00
	MAR 2022	9	6.00	.000	.000	6.00
	APR 2022	8	6.00	.000	.000	6.00
	Total	50	6.00	.000	.000	6.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.84612	.834	.849
	DEC 2021	.86560	.822	.877
	JAN 2022	.84020	.817	.849
	FEB 2022	.86099	.770	.849
	MAR 2022	.83677	.803	.837
	APR 2022	.84809	.804	.860
	Total	.84179	.770	.877
PI_total	NOV 2021	2.933704	2.0520	3.3578
	DEC 2021	3.935454	2.3761	4.4008
	JAN 2022	1.694714	1.3153	1.8308
	FEB 2022	3.224632	.6693	3.4456
	MAR 2022	1.764092	.7053	2.1986
	APR 2022	2.808542	1.0512	3.2367
	Total	2.425766	.6693	4.4008
Crop	NOV 2021	6.00	6	6
	DEC 2021	6.00	6	6
	JAN 2022	6.00	6	6
	FEB 2022	6.00	6	6
	MAR 2022	6.00	6	6
	APR 2022	6.00	6	6
	Total	6.00	6	6

a. Study_site = Eco green wall, Crop = Plectranthus amboinicus

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.003	5	.001	2.543
	Within Groups	.011	44	.000	
	Total	.015	49		
PI_total	Between Groups	20.202	5	4.040	9.127
	Within Groups	19.479	44	.443	
	Total	39.681	49		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	44	.000	
	Total	.000	49		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.042
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall, Crop = Plectranthus amboinicus

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.224	.000	.350
	Epsilon-squared	.136	-.114	.276
	Omega-squared Fixed-effect	.134	-.111	.272
	Omega-squared Random-effect	.030	-.020	.070
PI_total	Eta-squared	.509	.233	.613
	Epsilon-squared	.453	.146	.569
	Omega-squared Fixed-effect	.448	.144	.564
	Omega-squared Random-effect	.140	.032	.206
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Eco green wall, Crop = Plectranthus amboinicus

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.010847	.007773	.729	-.03400	.01231
		JAN 2022	.008333	.007541	.877	-.01413	.03080
		FEB 2022	.007206	.008061	.946	-.01681	.03122
		MAR 2022	.013444	.007541	.487	-.00902	.03591
		APR 2022	.010528	.007773	.753	-.01263	.03368
	DEC 2021	NOV 2021	.010847	.007773	.729	-.01231	.03400
		JAN 2022	.019181	.007773	.156	-.00397	.04234
		FEB 2022	.018054	.008279	.267	-.00661	.04272
		MAR 2022	.024292*	.007773	.035	.00114	.04745
		APR 2022	.021375	.007998	.102	-.00245	.04520
	JAN 2022	NOV 2021	-.008333	.007541	.877	-.03080	.01413
		DEC 2021	-.019181	.007773	.156	-.04234	.00397
		FEB 2022	-.001127	.008061	1.000	-.02514	.02289
		MAR 2022	.005111	.007541	.984	-.01735	.02757
		APR 2022	.002194	.007773	1.000	-.02096	.02535
	FEB 2022	NOV 2021	-.007206	.008061	.946	-.03122	.01681
		DEC 2021	-.018054	.008279	.267	-.04272	.00661
		JAN 2022	.001127	.008061	1.000	-.02289	.02514
		MAR 2022	.006238	.008061	.971	-.01778	.03025
		APR 2022	.003321	.008279	.999	-.02134	.02798
	MAR 2022	NOV 2021	-.013444	.007541	.487	-.03591	.00902
		DEC 2021	-.024292*	.007773	.035	-.04745	-.00114
		JAN 2022	-.005111	.007541	.984	-.02757	.01735
		FEB 2022	-.006238	.008061	.971	-.03025	.01778
		APR 2022	-.002917	.007773	.999	-.02607	.02024
	APR 2022	NOV 2021	-.010528	.007773	.753	-.03368	.01263
		DEC 2021	-.021375	.007998	.102	-.04520	.00245
		JAN 2022	-.002194	.007773	1.000	-.02535	.02096
		FEB 2022	-.003321	.008279	.999	-.02798	.02134
		MAR 2022	.002917	.007773	.999	-.02024	.02607
PI_total	NOV 2021	DEC 2021	-.6621403	.3233044	.333	-1.625240	.300959
		JAN 2022	1.0385333*	.3136513	.022	.104190	1.972877
		FEB 2022	.2202937	.3353074	.986	-.778562	1.219149
		MAR 2022	1.2014111*	.3136513	.005	.267067	2.135755
		APR 2022	.4888472	.3233044	.659	-.474252	1.451947
	DEC 2021	NOV 2021	.6621403	.3233044	.333	-.300959	1.625240
		JAN 2022	1.7006736*	.3233044	<,001	.737574	2.663773
		FEB 2022	.8824339	.3443539	.129	-.143370	1.908238
		MAR 2022	1.8635514*	.3233044	<,001	.900452	2.826651
		APR 2022	1.1509875*	.3326775	.014	.159966	2.142009
	JAN 2022	NOV 2021	-1.0385333*	.3136513	.022	-1.972877	-.104190
		DEC 2021	-1.7006736*	.3233044	<,001	-2.663773	-.737574
		FEB 2022	-.8182397	.3353074	.165	-1.817095	.180616
		MAR 2022	.1628778	.3136513	.995	-.771466	1.097221
		APR 2022	-.5496861	.3233044	.539	-1.512785	.413413
	FEB 2022	NOV 2021	-.2202937	.3353074	.986	-1.219149	.778562
		DEC 2021	-.8824339	.3443539	.129	-1.908238	.143370
		JAN 2022	.8182397	.3353074	.165	-.180616	1.817095

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		MAR 2022	.9811175	.3353074	.057	-.017738	1.979973
		APR 2022	.2685536	.3443539	.970	-.757251	1.294358
	MAR 2022	NOV 2021	-1.2014111*	.3136513	.005	-2.135755	-.267067
		DEC 2021	-1.8635514*	.3233044	<,001	-2.826651	-.900452
		JAN 2022	-.1628778	.3136513	.995	-1.097221	.771466
		FEB 2022	-.9811175	.3353074	.057	-1.979973	.017738
		APR 2022	-.7125639	.3233044	.257	-1.675663	.250535
	APR 2022	NOV 2021	-.4888472	.3233044	.659	-1.451947	.474252
		DEC 2021	-1.1509875*	.3326775	.014	-2.142009	-.159966
		JAN 2022	.5496861	.3233044	.539	-.413413	1.512785
		FEB 2022	-.2685536	.3443539	.970	-1.294358	.757251
		MAR 2022	.7125639	.3233044	.257	-.250535	1.675663

*. The mean difference is significant at the 0.05 level.
a. Study_site = Eco green wall, Crop = Plectranthus amboinicus

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
MAR 2022	9	.82833	
APR 2022	8	.83125	.83125
JAN 2022	9	.83344	.83344
FEB 2022	7	.83457	.83457
NOV 2021	9	.84178	.84178
DEC 2021	8		.85263
Sig.		.534	.092

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Eco green wall, Crop = Plectranthus amboinicus
b. Uses Harmonic Mean Sample Size = 8.262.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05			
		1	2	3	4
MAR 2022	9	1.374911			
JAN 2022	9	1.537789	1.537789		
APR 2022	8	2.087475	2.087475	2.087475	
FEB 2022	7		2.356029	2.356029	2.356029
NOV 2021	9			2.576322	2.576322
DEC 2021	8				3.238463
Sig.		.269	.146	.670	.097

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Eco green wall, Crop = Plectranthus amboinicus

b. Uses Harmonic Mean Sample Size = 8.262.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

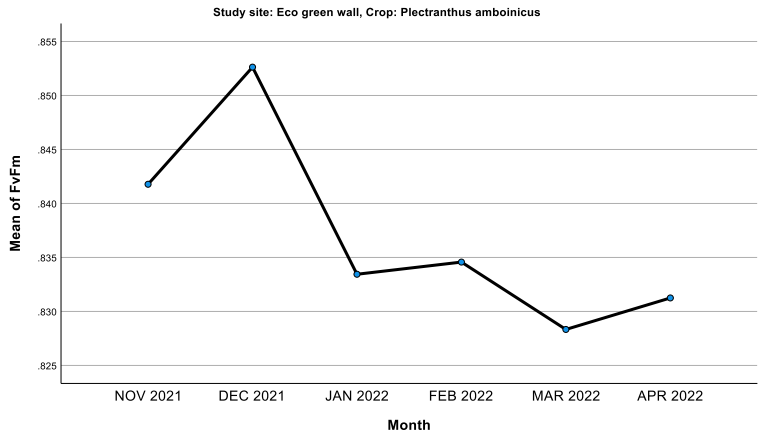
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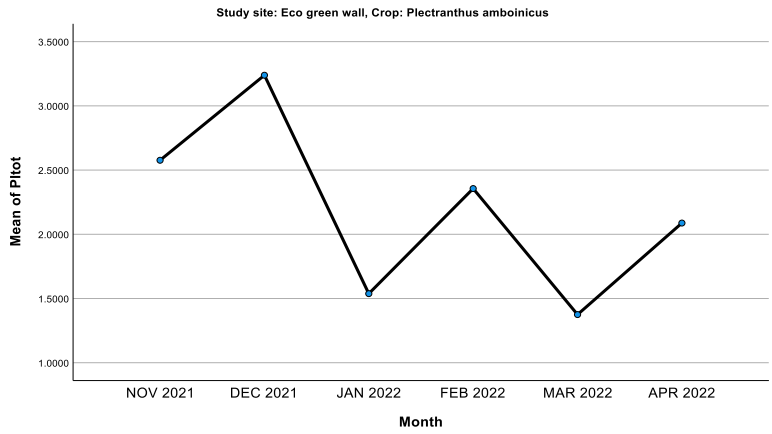
Crop[a]

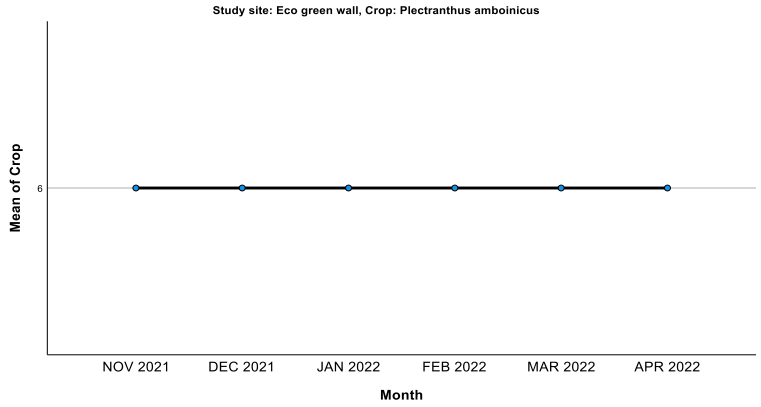
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Plectranthus amboinicus

Means Plots







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Study site = Eco green wall, Crop = Portulaca oleracea

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	4	.70375	.039677	.019838	.64062
	DEC 2021	8	.78988	.013851	.004897	.77830
	JAN 2022	7	.77629	.021360	.008073	.75653
	FEB 2022	6	.77033	.010309	.004208	.75952
	MAR 2022	3	.77433	.004163	.002404	.76399
	APR 2022	9	.75867	.023717	.007906	.74044
	Total	37	.76597	.031391	.005161	.75551
PI_total	NOV 2021	4	2.317850	1.2805574	.6402787	.280197
	DEC 2021	8	2.500275	.9031961	.3193280	1.745184
	JAN 2022	7	1.741657	.5936053	.2243617	1.192664
	FEB 2022	6	2.140883	.7884729	.3218927	1.313432
	MAR 2022	3	2.525433	1.0021825	.5786103	.035874
	APR 2022	9	3.721356	1.7284680	.5761560	2.392737
	Total	37	2.577811	1.2898905	.2120567	2.147740
Crop	NOV 2021	4	7.00	.000	.000	7.00
	DEC 2021	8	7.00	.000	.000	7.00
	JAN 2022	7	7.00	.000	.000	7.00
	FEB 2022	6	7.00	.000	.000	7.00
	MAR 2022	3	7.00	.000	.000	7.00
	APR 2022	9	7.00	.000	.000	7.00
	Total	37	7.00	.000	.000	7.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.76688	.657	.741
	DEC 2021	.80145	.771	.808
	JAN 2022	.79604	.739	.795
	FEB 2022	.78115	.759	.789
	MAR 2022	.78468	.771	.779
	APR 2022	.77690	.714	.792
	Total	.77644	.657	.808
PI_total	NOV 2021	4.355503	1.0896	3.9594
	DEC 2021	3.255366	1.5434	3.5404
	JAN 2022	2.290650	1.0689	2.5375
	FEB 2022	2.968335	1.0571	3.1677
	MAR 2022	5.014993	1.4556	3.4424
	APR 2022	5.049974	2.0508	5.9554
	Total	3.007882	1.0571	5.9554
Crop	NOV 2021	7.00	7	7
	DEC 2021	7.00	7	7
	JAN 2022	7.00	7	7
	FEB 2022	7.00	7	7
	MAR 2022	7.00	7	7
	APR 2022	7.00	7	7
	Total	7.00	7	7

a. Study_site = Eco green wall, Crop = Portulaca oleracea

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.022	5	.004	9.659
	Within Groups	.014	31	.000	
	Total	.035	36		
PI_total	Between Groups	18.135	5	3.627	2.692
	Within Groups	41.762	31	1.347	
	Total	59.897	36		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	31	.000	
	Total	.000	36		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
PI_total	Between Groups	.039
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall, Crop = Portulaca oleracea

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.609	.290	.700
	Epsilon-squared	.546	.175	.652
	Omega-squared Fixed-effect	.539	.171	.646
	Omega-squared Random-effect	.190	.040	.267
PI_total	Eta-squared	.303	.000	.438
	Epsilon-squared	.190	-.161	.348
	Omega-squared Fixed-effect	.186	-.156	.341
	Omega-squared Random-effect	.044	-.028	.094
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Eco green wall, Crop = Portulaca oleracea

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.086125*	.012953	<,001	-.12544	-.04681
		JAN 2022	-.072536*	.013257	<,001	-.11277	-.03230
		FEB 2022	-.066583*	.013653	<,001	-.10802	-.02514
		MAR 2022	-.070583*	.016155	.002	-.11962	-.02155
		APR 2022	-.054917*	.012711	.002	-.09350	-.01634
	DEC 2021	NOV 2021	.086125*	.012953	<,001	.04681	.12544
		JAN 2022	.013589	.010947	.813	-.01964	.04682
		FEB 2022	.019542	.011423	.535	-.01513	.05421
		MAR 2022	.015542	.014320	.883	-.02792	.05900
		APR 2022	.031208*	.010278	.050	.00001	.06240
	JAN 2022	NOV 2021	.072536*	.013257	<,001	.03230	.11277
		DEC 2021	-.013589	.010947	.813	-.04682	.01964
		FEB 2022	.005952	.011768	.996	-.02976	.04167
		MAR 2022	.001952	.014596	1.000	-.04235	.04625
		APR 2022	.017619	.010659	.571	-.01473	.04997
	FEB 2022	NOV 2021	.066583*	.013653	<,001	.02514	.10802
		DEC 2021	-.019542	.011423	.535	-.05421	.01513
		JAN 2022	-.005952	.011768	.996	-.04167	.02976
		MAR 2022	-.004000	.014956	1.000	-.04940	.04140
		APR 2022	.011667	.011148	.898	-.02217	.04550
	MAR 2022	NOV 2021	.070583*	.016155	.002	.02155	.11962
		DEC 2021	-.015542	.014320	.883	-.05900	.02792
		JAN 2022	-.001952	.014596	1.000	-.04625	.04235
		FEB 2022	.004000	.014956	1.000	-.04140	.04940
		APR 2022	.015667	.014101	.873	-.02713	.05847
	APR 2022	NOV 2021	.054917*	.012711	.002	.01634	.09350
		DEC 2021	-.031208*	.010278	.050	-.06240	-.00001
		JAN 2022	-.017619	.010659	.571	-.04997	.01473
		FEB 2022	-.011667	.011148	.898	-.04550	.02217
		MAR 2022	-.015667	.014101	.873	-.05847	.02713
PI_total	NOV 2021	DEC 2021	-.1824250	.7107643	1.000	-2.339715	1.974865
		JAN 2022	.5761929	.7274904	.967	-1.631864	2.784250
		FEB 2022	.1769667	.7492113	1.000	-2.097017	2.450950
		MAR 2022	-.2075833	.8864788	1.000	-2.898197	2.483031
		APR 2022	-1.4035056	.6974778	.359	-3.520469	.713458
	DEC 2021	NOV 2021	.1824250	.7107643	1.000	-1.974865	2.339715
		JAN 2022	.7586179	.6007054	.802	-1.064625	2.581861
		FEB 2022	.3593917	.6268352	.992	-1.543160	2.261943
		MAR 2022	-.0251583	.7857795	1.000	-2.410133	2.359816
		APR 2022	-1.2210806	.5639858	.282	-2.932873	.490712
	JAN 2022	NOV 2021	-.5761929	.7274904	.967	-2.784250	1.631864
		DEC 2021	-.7586179	.6007054	.802	-2.581861	1.064625
		FEB 2022	-.3992262	.6457389	.989	-2.359154	1.560701
		MAR 2022	-.7837762	.8009406	.921	-3.214767	1.647215
		APR 2022	-1.9796984*	.5849243	.022	-3.755043	-.204354
	FEB 2022	NOV 2021	-.1769667	.7492113	1.000	-2.450950	2.097017
		DEC 2021	-.3593917	.6268352	.992	-2.261943	1.543160
		JAN 2022	.3992262	.6457389	.989	-1.560701	2.359154
		MAR 2022	-.3845500	.8207199	.997	-2.875574	2.106474

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	APR 2022	-1.5804722	.6117285	.132	-3.437172	.276228
MAR 2022	NOV 2021	.2075833	.8864788	1.000	-2.483031	2.898197
	DEC 2021	.0251583	.7857795	1.000	-2.359816	2.410133
	JAN 2022	.7837762	.8009406	.921	-1.647215	3.214767
	FEB 2022	.3845500	.8207199	.997	-2.106474	2.875574
	APR 2022	-1.1959222	.7737821	.639	-3.544483	1.152638
APR 2022	NOV 2021	1.4035056	.6974778	.359	-.713458	3.520469
	DEC 2021	1.2210806	.5639858	.282	-.490712	2.932873
	JAN 2022	1.9796984*	.5849243	.022	.204354	3.755043
	FEB 2022	1.5804722	.6117285	.132	-.276228	3.437172
	MAR 2022	1.1959222	.7737821	.639	-1.152638	3.544483

*. The mean difference is significant at the 0.05 level.
a. Study_site = Eco green wall, Crop = Portulaca oleracea

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
NOV 2021	4	.70375	
APR 2022	9		.75867
FEB 2022	6		.77033
MAR 2022	3		.77433
JAN 2022	7		.77629
DEC 2021	8		.78988
Sig.		1.000	.186

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Eco green wall, Crop = Portulaca oleracea
b. Uses Harmonic Mean Sample Size = 5.315.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05
		1
JAN 2022	7	1.741657
FEB 2022	6	2.140883
NOV 2021	4	2.317850
DEC 2021	8	2.500275
MAR 2022	3	2.525433
APR 2022	9	3.721356
Sig.		.088

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Eco green wall, Crop = Portulaca oleracea
b. Uses Harmonic Mean Sample Size = 5.315.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

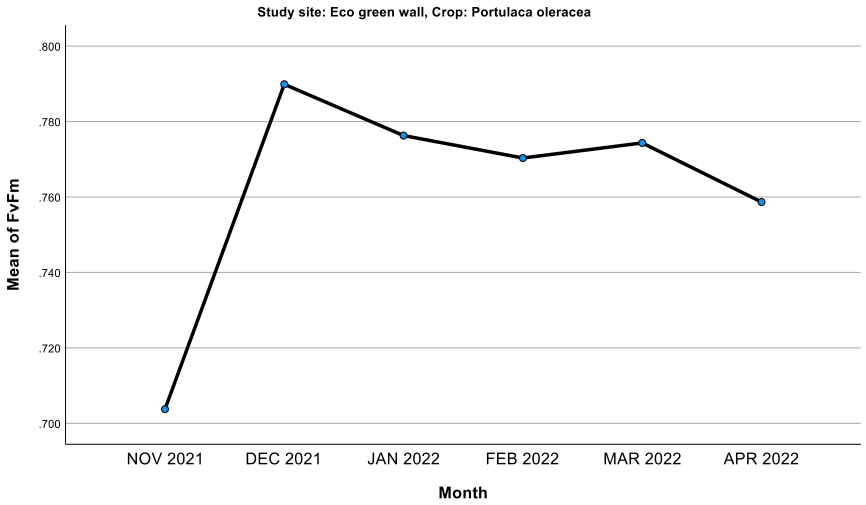
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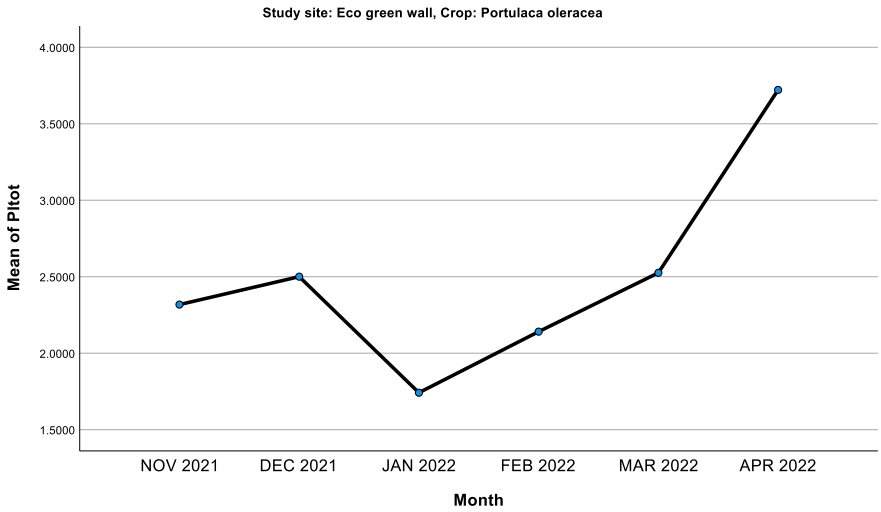
Crop[a]

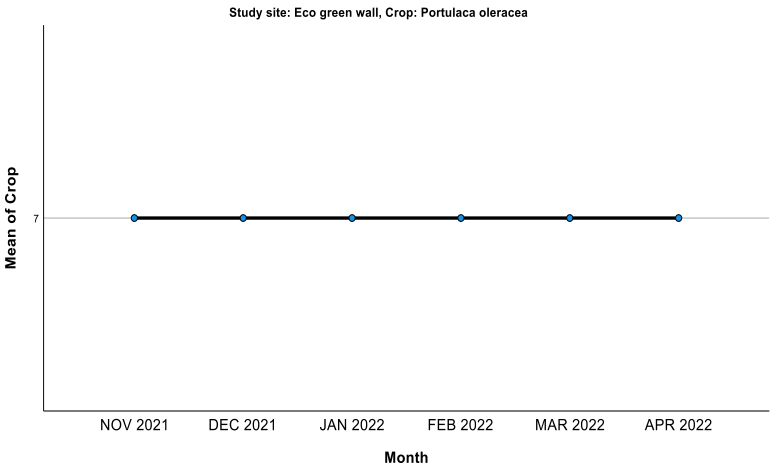
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Portulaca oleracea

Means Plots







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Study site = Eco green wall, Crop = Portulacaria afra prostrata

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.84611	.010179	.003393	.83829
	DEC 2021	9	.84611	.011141	.003714	.83755
	JAN 2022	9	.83833	.012971	.004324	.82836
	FEB 2022	9	.81211	.057250	.019083	.76810
	MAR 2022	9	.82511	.015169	.005056	.81345
	APR 2022	8	.84388	.011482	.004060	.83428
	Total	53	.83511	.027976	.003843	.82740
PI_total	NOV 2021	9	3.066733	.5749378	.1916459	2.624797
	DEC 2021	9	1.687667	.4630508	.1543503	1.331734
	JAN 2022	9	1.443056	.2397289	.0799096	1.258784
	FEB 2022	9	.993000	.2685200	.0895067	.786597
	MAR 2022	9	1.443500	.6238101	.2079367	.963997
	APR 2022	8	1.969638	.6356282	.2247285	1.438239
	Total	53	1.763447	.8110281	.1114033	1.539900
Crop	NOV 2021	9	8.00	.000	.000	8.00
	DEC 2021	9	8.00	.000	.000	8.00
	JAN 2022	9	8.00	.000	.000	8.00
	FEB 2022	9	8.00	.000	.000	8.00
	MAR 2022	9	8.00	.000	.000	8.00
	APR 2022	8	8.00	.000	.000	8.00
	Total	53	8.00	.000	.000	8.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.85394	.835	.862
	DEC 2021	.85467	.829	.865
	JAN 2022	.84830	.824	.864
	FEB 2022	.85612	.670	.855
	MAR 2022	.83677	.802	.850
	APR 2022	.85347	.825	.862
	Total	.84282	.670	.865
PI_total	NOV 2021	3.508670	2.4216	4.1313
	DEC 2021	2.043599	1.0390	2.3350
	JAN 2022	1.627327	1.1141	1.8052
	FEB 2022	1.199403	.4194	1.2666
	MAR 2022	1.923003	.5395	2.4875
	APR 2022	2.501036	1.3055	2.8392
	Total	1.986994	.4194	4.1313
Crop	NOV 2021	8.00	8	8
	DEC 2021	8.00	8	8
	JAN 2022	8.00	8	8
	FEB 2022	8.00	8	8
	MAR 2022	8.00	8	8
	APR 2022	8.00	8	8
	Total	8.00	8	8

a. Study_site = Eco green wall, Crop = Portulacaria afra prostrata

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.009	5	.002	2.499
	Within Groups	.032	47	.001	
	Total	.041	52		
PI_total	Between Groups	22.866	5	4.573	18.958
	Within Groups	11.338	47	.241	
	Total	34.204	52		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	47	.000	
	Total	.000	52		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.044
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall, Crop = Portulacaria afra prostrata

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.210	.000	.333
	Epsilon-squared	.126	-.106	.262
	Omega-squared Fixed-effect	.124	-.104	.259
	Omega-squared Random-effect	.028	-.019	.065
PI_total	Eta-squared	.669	.456	.741
	Epsilon-squared	.633	.398	.713
	Omega-squared Fixed-effect	.629	.394	.709
	Omega-squared Random-effect	.253	.115	.328
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Eco green wall, Crop = Portulacaria afra prostrata

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.000000	.012330	1.000	-.03662	.03662
		JAN 2022	.007778	.012330	.988	-.02885	.04440
		FEB 2022	.034000	.012330	.083	-.00262	.07062
		MAR 2022	.021000	.012330	.537	-.01562	.05762
		APR 2022	.002236	.012709	1.000	-.03552	.03999
	DEC 2021	NOV 2021	.000000	.012330	1.000	-.03662	.03662
		JAN 2022	.007778	.012330	.988	-.02885	.04440
		FEB 2022	.034000	.012330	.083	-.00262	.07062
		MAR 2022	.021000	.012330	.537	-.01562	.05762
		APR 2022	.002236	.012709	1.000	-.03552	.03999
	JAN 2022	NOV 2021	-.007778	.012330	.988	-.04440	.02885
		DEC 2021	-.007778	.012330	.988	-.04440	.02885
		FEB 2022	.026222	.012330	.292	-.01040	.06285
		MAR 2022	.013222	.012330	.890	-.02340	.04985
		APR 2022	-.005542	.012709	.998	-.04329	.03221
	FEB 2022	NOV 2021	-.034000	.012330	.083	-.07062	.00262
		DEC 2021	-.034000	.012330	.083	-.07062	.00262
		JAN 2022	-.026222	.012330	.292	-.06285	.01040
		MAR 2022	-.013000	.012330	.897	-.04962	.02362
		APR 2022	-.031764	.012709	.145	-.06952	.00599
	MAR 2022	NOV 2021	-.021000	.012330	.537	-.05762	.01562
		DEC 2021	-.021000	.012330	.537	-.05762	.01562
		JAN 2022	-.013222	.012330	.890	-.04985	.02340
		FEB 2022	.013000	.012330	.897	-.02362	.04962
		APR 2022	-.018764	.012709	.681	-.05652	.01899
	APR 2022	NOV 2021	-.002236	.012709	1.000	-.03999	.03552
		DEC 2021	-.002236	.012709	1.000	-.03999	.03552
		JAN 2022	.005542	.012709	.998	-.03221	.04329
		FEB 2022	.031764	.012709	.145	-.00599	.06952
		MAR 2022	.018764	.012709	.681	-.01899	.05652
PI_total	NOV 2021	DEC 2021	1.3790667*	.2315291	<,001	.691316	2.066817
		JAN 2022	1.6236778*	.2315291	<,001	.935927	2.311429
		FEB 2022	2.0737333*	.2315291	<,001	1.385983	2.761484
		MAR 2022	1.6232333*	.2315291	<,001	.935483	2.310984
		APR 2022	1.0970958*	.2386548	<,001	.388179	1.806013
	DEC 2021	NOV 2021	-1.3790667*	.2315291	<,001	-2.066817	-.691316
		JAN 2022	.2446111	.2315291	.896	-.443140	.932362
		FEB 2022	.6946667*	.2315291	.046	.006916	1.382417
		MAR 2022	.2441667	.2315291	.897	-.443584	.931917
		APR 2022	-.2819708	.2386548	.843	-.990888	.426946
	JAN 2022	NOV 2021	-1.6236778*	.2315291	<,001	-2.311429	-.935927
		DEC 2021	-.2446111	.2315291	.896	-.932362	.443140
		FEB 2022	.4500556	.2315291	.389	-.237695	1.137806
		MAR 2022	-.0004444	.2315291	1.000	-.688195	.687306
		APR 2022	-.5265819	.2386548	.254	-1.235499	.182335
	FEB 2022	NOV 2021	-2.0737333*	.2315291	<,001	-2.761484	-1.385983
		DEC 2021	-.6946667*	.2315291	.046	-1.382417	-.006916
		JAN 2022	-.4500556	.2315291	.389	-1.137806	.237695

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		MAR 2022	-.4505000	.2315291	.388	-1.138251	.237251
		APR 2022	-.9766375*	.2386548	.002	-1.685555	-.267720
	MAR 2022	NOV 2021	-1.6232333*	.2315291	<,001	-2.310984	-.935483
		DEC 2021	-.2441667	.2315291	.897	-.931917	.443584
		JAN 2022	.0004444	.2315291	1.000	-.687306	.688195
		FEB 2022	.4505000	.2315291	.388	-.237251	1.138251
		APR 2022	-.5261375	.2386548	.255	-1.235055	.182780
	APR 2022	NOV 2021	-1.0970958*	.2386548	<,001	-1.806013	-.388179
		DEC 2021	.2819708	.2386548	.843	-.426946	.990888
		JAN 2022	.5265819	.2386548	.254	-.182335	1.235499
		FEB 2022	.9766375*	.2386548	.002	.267720	1.685555
		MAR 2022	.5261375	.2386548	.255	-.182780	1.235055

*. The mean difference is significant at the 0.05 level.
a. Study_site = Eco green wall, Crop = Portulacaria afra prostrata

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1
FEB 2022	9	.81211
MAR 2022	9	.82511
JAN 2022	9	.83833
APR 2022	8	.84388
NOV 2021	9	.84611
DEC 2021	9	.84611
Sig.		.088

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Eco green wall, Crop = Portulacaria afra prostrata
b. Uses Harmonic Mean Sample Size = 8.816.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1	2	3
FEB 2022	9	.993000		
JAN 2022	9	1.443056	1.443056	
MAR 2022	9	1.443500	1.443500	
DEC 2021	9	1.687667	1.687667	
APR 2022	8		1.969638	
NOV 2021	9			3.066733
Sig.		.050	.235	1.000

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Eco green wall, Crop = Portulacaria afra prostrata
b. Uses Harmonic Mean Sample Size = 8.816.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

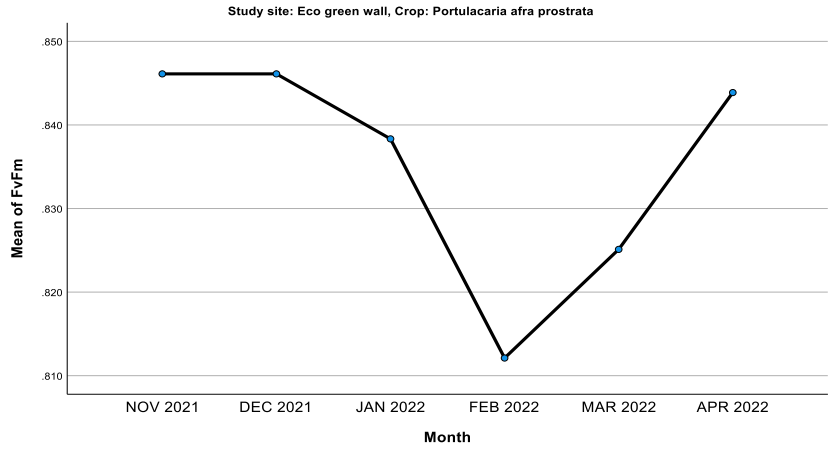
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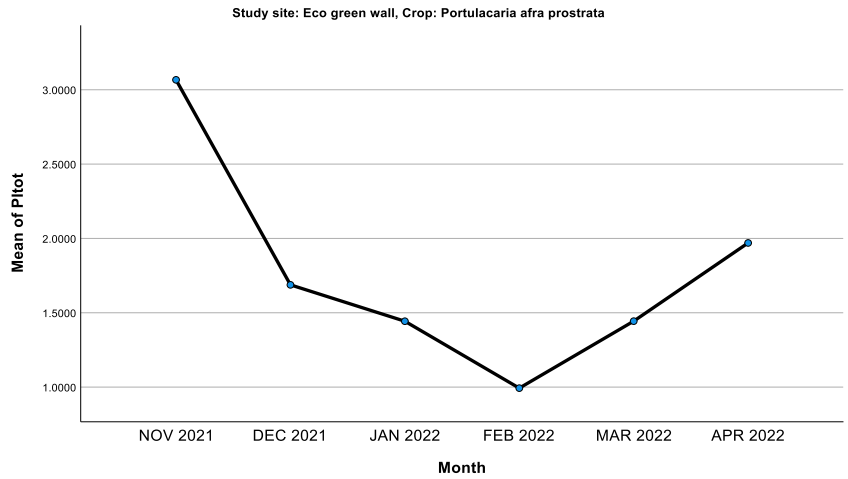
Crop[a]

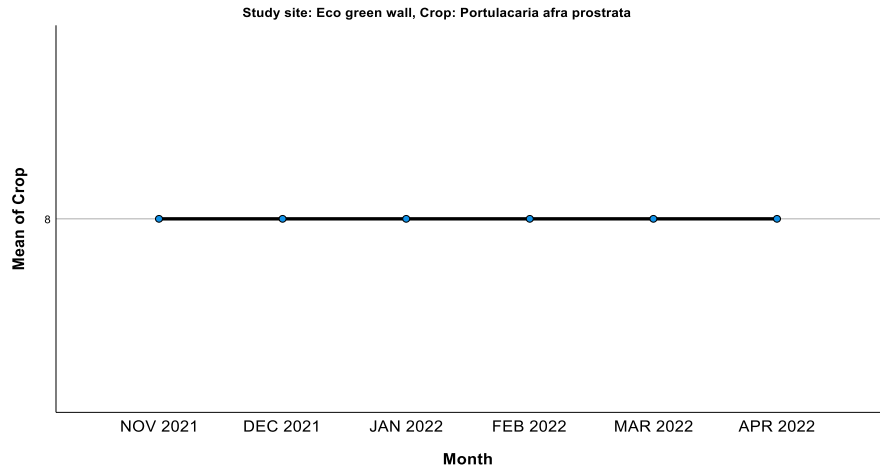
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Portulacaria afra prostrata

Means Plots







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Study site = Eco green wall, Crop = Spinacea oleracea

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	4	.79350	.020141	.010071	.76145
	DEC 2021	7	.83514	.011216	.004239	.82477
	FEB 2022	9	.82944	.009697	.003232	.82199
	MAR 2022	5	.80480	.010060	.004499	.79231
	APR 2022	6	.81500	.015849	.006470	.79837
	Total	31	.81932	.019055	.003422	.81233
PI_total	NOV 2021	4	.650725	.2371955	.1185978	.273294
	DEC 2021	7	.861129	.1748640	.0660924	.699406
	FEB 2022	9	1.022489	.4276390	.1425463	.693776
	MAR 2022	5	.749620	.2128631	.0951953	.485316
	APR 2022	6	1.008283	.2354691	.0961298	.761174
	Total	31	.891323	.3081650	.0553481	.778287
Crop	NOV 2021	4	9.00	.000	.000	9.00
	DEC 2021	7	9.00	.000	.000	9.00
	FEB 2022	9	9.00	.000	.000	9.00
	MAR 2022	5	9.00	.000	.000	9.00
	APR 2022	6	9.00	.000	.000	9.00
	Total	31	9.00	.000	.000	9.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.82555	.766	.810
	DEC 2021	.84552	.817	.854
	FEB 2022	.83690	.811	.844
	MAR 2022	.81729	.794	.819
	APR 2022	.83163	.790	.833
	Total	.82631	.766	.854
PI_total	NOV 2021	1.028156	.3199	.8538
	DEC 2021	1.022851	.6335	1.1028
	FEB 2022	1.351201	.5248	1.8618
	MAR 2022	1.013924	.5272	1.0376
	APR 2022	1.255393	.6468	1.2552
	Total	1.004358	.3199	1.8618
Crop	NOV 2021	9.00	9	9
	DEC 2021	9.00	9	9
	FEB 2022	9.00	9	9
	MAR 2022	9.00	9	9
	APR 2022	9.00	9	9
	Total	9.00	9	9

a. Study_site = Eco green wall, Crop = Spinacea oleracea

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ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
max_quantum_yield	Between Groups	.007	4	.002	9.647	<,001
	Within Groups	.004	26	.000		
	Total	.011	30			
PI_total	Between Groups	.575	4	.144	1.644	.193
	Within Groups	2.274	26	.087		
	Total	2.849	30			
Crop	Between Groups	.000	4	.000	.	.
	Within Groups	.000	26	.000		
	Total	.000	30			

a. Study_site = Eco green wall, Crop = Spinacea oleracea

ANOVA Effect Sizes[a,b,c]

		Point Estimate	95% Confidence Interval Lower	95% Confidence Interval Upper
max_quantum_yield	Eta-squared	.597	.251	.703
	Epsilon-squared	.536	.136	.657
	Omega-squared Fixed-effect	.527	.132	.650
	Omega-squared Random-effect	.218	.037	.317
PI_total	Eta-squared	.202	.000	.360
	Epsilon-squared	.079	-.154	.262
	Omega-squared Fixed-effect	.077	-.148	.255
	Omega-squared Random-effect	.020	-.033	.079
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Eco green wall, Crop = Spinacea oleracea

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.041643*	.008140	<,001	-.06548	-.01781
		FEB 2022	-.035944*	.007804	<,001	-.05880	-.01309
		MAR 2022	-.011300	.008712	.695	-.03681	.01421
		APR 2022	-.021500	.008383	.107	-.04605	.00305
	DEC 2021	NOV 2021	.041643*	.008140	<,001	.01781	.06548
		FEB 2022	.005698	.006545	.905	-.01347	.02486
		MAR 2022	.030343*	.007604	.004	.00807	.05261
		APR 2022	.020143	.007225	.068	-.00102	.04130
	FEB 2022	NOV 2021	.035944*	.007804	<,001	.01309	.05880
		DEC 2021	-.005698	.006545	.905	-.02486	.01347
		MAR 2022	.024644*	.007244	.017	.00343	.04586
		APR 2022	.014444	.006844	.246	-.00560	.03449
	MAR 2022	NOV 2021	.011300	.008712	.695	-.01421	.03681
		DEC 2021	-.030343*	.007604	.004	-.05261	-.00807
		FEB 2022	-.024644*	.007244	.017	-.04586	-.00343
		APR 2022	-.010200	.007864	.695	-.03323	.01283
	APR 2022	NOV 2021	.021500	.008383	.107	-.00305	.04605
		DEC 2021	-.020143	.007225	.068	-.04130	.00102
		FEB 2022	-.014444	.006844	.246	-.03449	.00560
		MAR 2022	.010200	.007864	.695	-.01283	.03323
PI_total	NOV 2021	DEC 2021	-.2104036	.1853529	.787	-.753200	.332393
		FEB 2022	-.3717639	.1777061	.254	-.892168	.148640
		MAR 2022	-.0988950	.1983756	.987	-.679828	.482038
		APR 2022	-.3575583	.1908870	.356	-.916562	.201445
	DEC 2021	NOV 2021	.2104036	.1853529	.787	-.332393	.753200
		FEB 2022	-.1613603	.1490293	.814	-.597785	.275065
		MAR 2022	.1115086	.1731564	.966	-.395572	.618589
		APR 2022	-.1471548	.1645239	.896	-.628955	.334645
	FEB 2022	NOV 2021	.3717639	.1777061	.254	-.148640	.892168
		DEC 2021	.1613603	.1490293	.814	-.275065	.597785
		MAR 2022	.2728689	.1649452	.478	-.210165	.755903
		APR 2022	.0142056	.1558586	1.000	-.442219	.470630
	MAR 2022	NOV 2021	.0988950	.1983756	.987	-.482038	.679828
		DEC 2021	-.1115086	.1731564	.966	-.618589	.395572
		FEB 2022	-.2728689	.1649452	.478	-.755903	.210165
		APR 2022	-.2586633	.1790679	.606	-.783055	.265728
	APR 2022	NOV 2021	.3575583	.1908870	.356	-.201445	.916562
		DEC 2021	.1471548	.1645239	.896	-.334645	.628955
		FEB 2022	-.0142056	.1558586	1.000	-.470630	.442219
		MAR 2022	.2586633	.1790679	.606	-.265728	.783055

*. The mean difference is significant at the 0.05 level.

a. Study_site = Eco green wall, Crop = Spinacea oleracea

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
NOV 2021	4	.79350	
MAR 2022	5	.80480	
APR 2022	6	.81500	.81500
FEB 2022	9		.82944
DEC 2021	7		.83514
Sig.		.065	.094

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Spinacea oleracea

b. Uses Harmonic Mean Sample Size = 5.743.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05
		1
NOV 2021	4	.650725
MAR 2022	5	.749620
DEC 2021	7	.861129
APR 2022	6	1.008283
FEB 2022	9	1.022489
Sig.		.238

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Spinacea oleracea

b. Uses Harmonic Mean Sample Size = 5.743.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

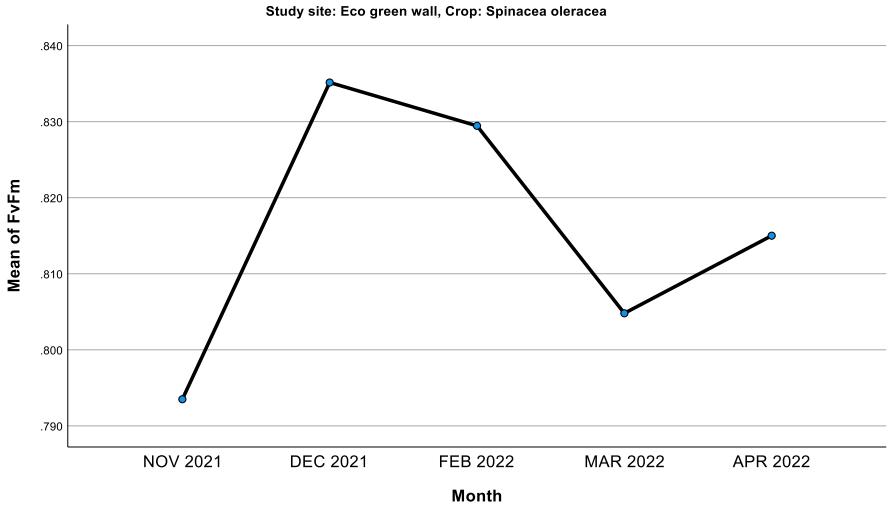
Crop[a]

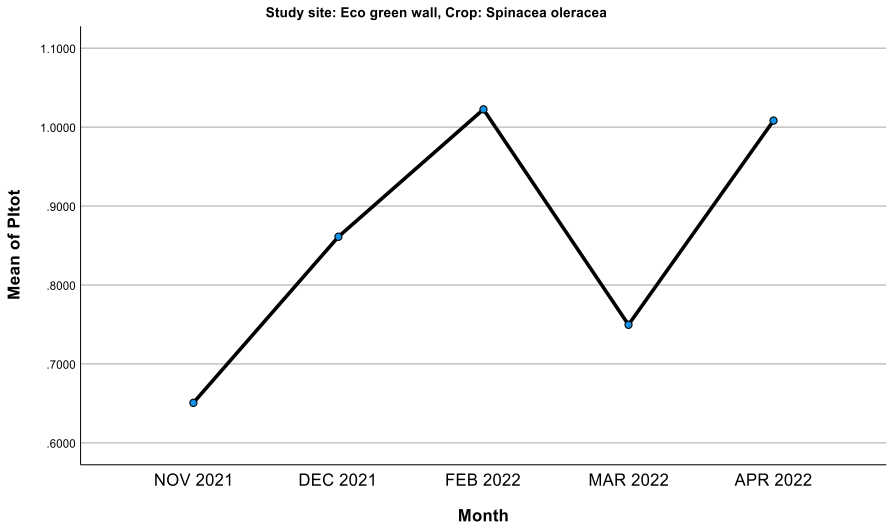
Means for groups in homogeneous subsets are displayed.[a]

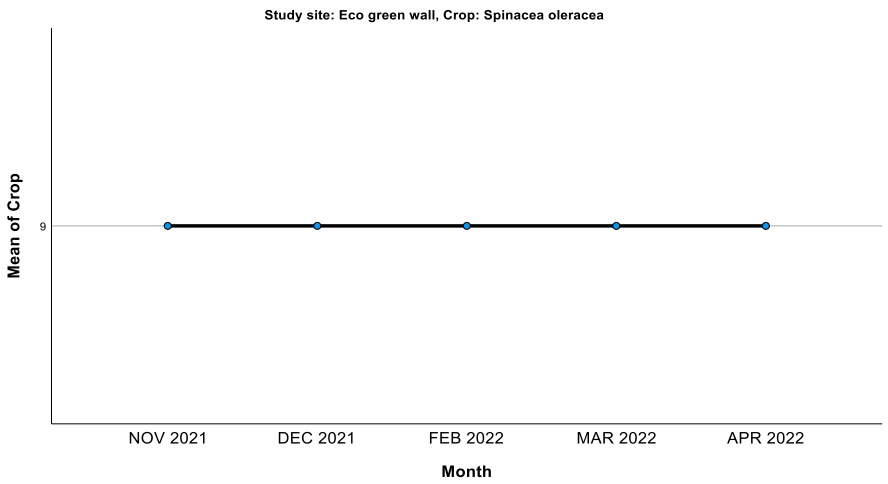
a. Study_site = Eco green wall, Crop = Spinacea oleracea

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Means Plots







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Study site = Eco green wall, Crop = Vigna unguilata

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	5	.78800	.032241	.014419	.74797
	DEC 2021	8	.83000	.024442	.008642	.80957
	JAN 2022	8	.81888	.013611	.004812	.80750
	MAR 2022	2	.76950	.013435	.009500	.64879
	APR 2022	9	.80033	.017371	.005790	.78698
	Total	32	.80853	.026961	.004766	.79881
PI_total	NOV 2021	5	1.380700	.9604170	.4295115	.188185
	DEC 2021	8	2.363525	1.1153726	.3943437	1.431050
	JAN 2022	8	2.452288	.5761623	.2037041	1.970604
	MAR 2022	2	1.842650	.1421992	.1005500	.565041
	APR 2022	9	1.747178	.5021885	.1673962	1.361162
	Total	32	2.026247	.8419184	.1488316	1.722703
Crop	NOV 2021	5	10.00	.000	.000	10.00
	DEC 2021	8	10.00	.000	.000	10.00
	JAN 2022	8	10.00	.000	.000	10.00
	MAR 2022	2	10.00	.000	.000	10.00
	APR 2022	9	10.00	.000	.000	10.00
	Total	32	10.00	.000	.000	10.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.82803	.738	.828
	DEC 2021	.85043	.791	.849
	JAN 2022	.83025	.794	.832
	MAR 2022	.89021	.760	.779
	APR 2022	.81369	.775	.823
	Total	.81825	.738	.849
PI_total	NOV 2021	2.573215	.2493	2.2894
	DEC 2021	3.296000	1.2929	3.9196
	JAN 2022	2.933971	1.5750	3.0534
	MAR 2022	3.120259	1.7421	1.9432
	APR 2022	2.133194	1.1663	2.5320
	Total	2.329791	.2493	3.9196
Crop	NOV 2021	10.00	10	10
	DEC 2021	10.00	10	10
	JAN 2022	10.00	10	10
	MAR 2022	10.00	10	10
	APR 2022	10.00	10	10
	Total	10.00	10	10

a. Study_site = Eco green wall, Crop = Vigna unguilata

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.010	4	.003	5.686
	Within Groups	.012	27	.000	
	Total	.023	31		
PI_total	Between Groups	5.214	4	1.304	2.100
	Within Groups	16.760	27	.621	
	Total	21.974	31		
Crop	Between Groups	.000	4	.000	.
	Within Groups	.000	27	.000	
	Total	.000	31		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.002
	Within Groups	
	Total	
PI_total	Between Groups	.109
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Eco green wall, Crop = Vigna unguilata

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.457	.098	.593
	Epsilon-squared	.377	-.036	.532
	Omega-squared Fixed-effect	.369	-.035	.524
	Omega-squared Random-effect	.128	-.009	.216
PI_total	Eta-squared	.237	.000	.396
	Epsilon-squared	.124	-.148	.307
	Omega-squared Fixed-effect	.121	-.143	.300
	Omega-squared Random-effect	.033	-.032	.097
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Eco green wall, Crop = Vigna unguilata

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.042000*	.012134	.014	-.07744	-.00656
		JAN 2022	-.030875	.012134	.110	-.06631	.00456
		MAR 2022	.018500	.017808	.835	-.03351	.07051
		APR 2022	-.012333	.011872	.835	-.04701	.02234
	DEC 2021	NOV 2021	.042000*	.012134	.014	.00656	.07744
		JAN 2022	.011125	.010642	.832	-.01996	.04221
		MAR 2022	.060500*	.016827	.010	.01135	.10965
		APR 2022	.029667	.010342	.056	-.00054	.05987
	JAN 2022	NOV 2021	.030875	.012134	.110	-.00456	.06631
		DEC 2021	-.011125	.010642	.832	-.04221	.01996
		MAR 2022	.049375*	.016827	.049	.00023	.09852
		APR 2022	.018542	.010342	.398	-.01166	.04875
	MAR 2022	NOV 2021	-.018500	.017808	.835	-.07051	.03351
		DEC 2021	-.060500*	.016827	.010	-.10965	-.01135
		JAN 2022	-.049375*	.016827	.049	-.09852	-.00023
		APR 2022	-.030833	.016639	.366	-.07943	.01776
	APR 2022	NOV 2021	.012333	.011872	.835	-.02234	.04701
		DEC 2021	-.029667	.010342	.056	-.05987	.00054
		JAN 2022	-.018542	.010342	.398	-.04875	.01166
		MAR 2022	.030833	.016639	.366	-.01776	.07943
PI_total	NOV 2021	DEC 2021	-.9828250	.4491489	.215	-2.294646	.328996
		JAN 2022	-1.0715875	.4491489	.150	-2.383409	.240234
		MAR 2022	-.4619500	.6591704	.955	-2.387177	1.463277
		APR 2022	-.3664778	.4394469	.918	-1.649963	.917007
	DEC 2021	NOV 2021	.9828250	.4491489	.215	-.328996	2.294646
		JAN 2022	-.0887625	.3939297	.999	-1.239306	1.061781
		MAR 2022	.5208750	.6228575	.917	-1.298294	2.340044
		APR 2022	.6163472	.3828308	.504	-.501780	1.734474
	JAN 2022	NOV 2021	1.0715875	.4491489	.150	-.240234	2.383409
		DEC 2021	.0887625	.3939297	.999	-1.061781	1.239306
		MAR 2022	.6096375	.6228575	.862	-1.209531	2.428806
		APR 2022	.7051097	.3828308	.372	-.413017	1.823237
	MAR 2022	NOV 2021	.4619500	.6591704	.955	-1.463277	2.387177
		DEC 2021	-.5208750	.6228575	.917	-2.340044	1.298294
		JAN 2022	-.6096375	.6228575	.862	-2.428806	1.209531
		APR 2022	.0954722	.6158980	1.000	-1.703370	1.894314
	APR 2022	NOV 2021	.3664778	.4394469	.918	-.917007	1.649963
		DEC 2021	-.6163472	.3828308	.504	-1.734474	.501780
		JAN 2022	-.7051097	.3828308	.372	-1.823237	.413017
		MAR 2022	-.0954722	.6158980	1.000	-1.894314	1.703370

*. The mean difference is significant at the 0.05 level.
a. Study_site = Eco green wall, Crop = Vigna unguilata

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05		
		1	2	3
MAR 2022	2	.76950		
NOV 2021	5	.78800	.78800	
APR 2022	9	.80033	.80033	.80033
JAN 2022	8		.81888	.81888
DEC 2021	8			.83000
Sig.		.202	.201	.233

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Vigna unguilata

b. Uses Harmonic Mean Sample Size = 4.712.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05
		1
NOV 2021	5	1.380700
APR 2022	9	1.747178
MAR 2022	2	1.842650
DEC 2021	8	2.363525
JAN 2022	8	2.452288
Sig.		.254

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Eco green wall, Crop = Vigna unguilata

b. Uses Harmonic Mean Sample Size = 4.712.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

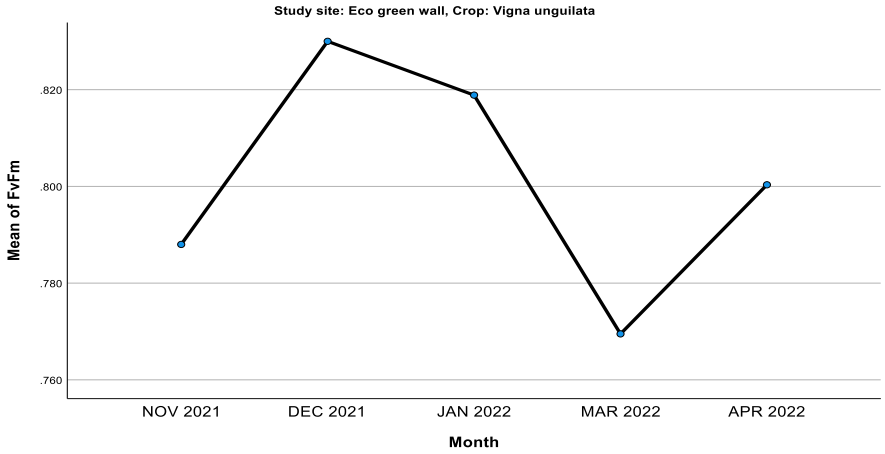
Crop[a]

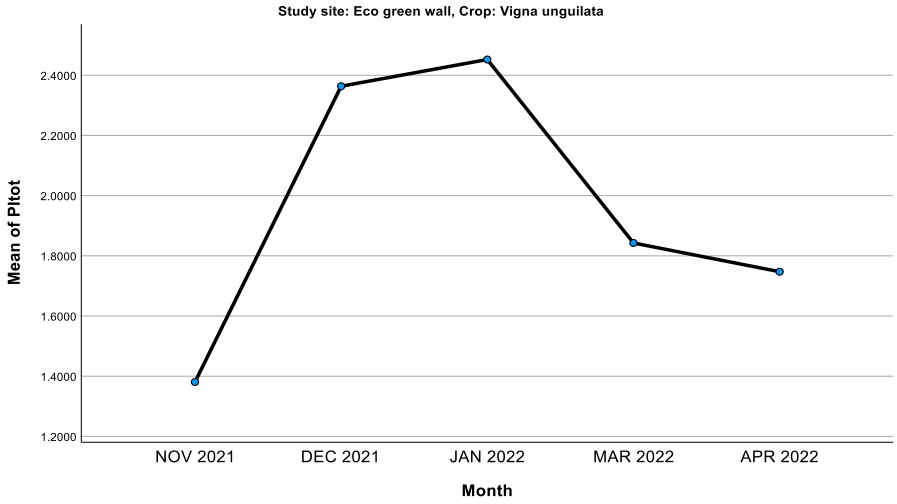
Means for groups in homogeneous subsets are displayed.[a]

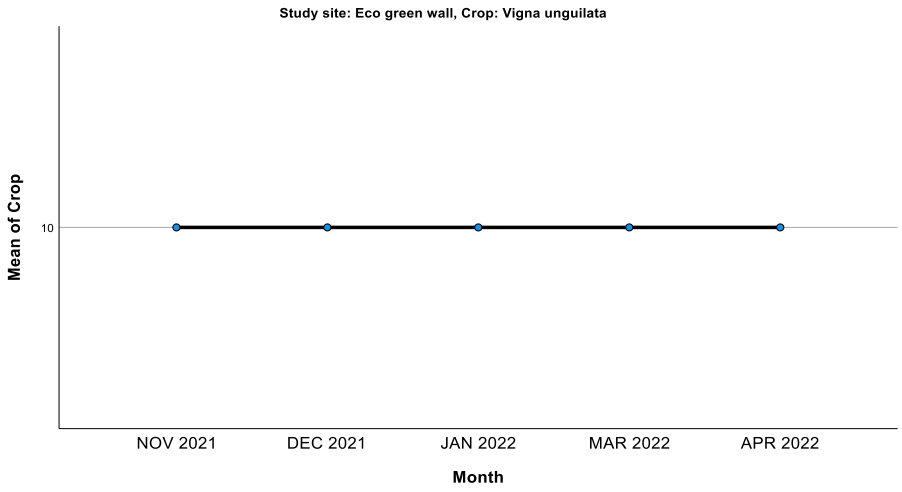
a. Study_site = Eco green wall, Crop = Vigna unguilata

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Appendix J: Statistical analysis results of the crops' F_vF_m and PI_{total} in the Vicinity Wall

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Oneway ANOVA
Vicinity wall

Descriptives[a]

a. Study_site = Vicinity wall, Crop = .

Study site = Vicinity wall, Crop = Amaranthus thunbergii

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	1	.71100	.	.	.
	DEC 2021	5	.78040	.013164	.005887	.76405
	FEB 2022	4	.77275	.005560	.002780	.76390
	MAR 2022	1	.71900	.	.	.
	APR 2022	3	.73133	.018930	.010929	.68431
	Total	14	.75836	.028747	.007683	.74176
PI_total	NOV 2021	1	2.993600	.	.	.
	DEC 2021	5	1.270640	.3672924	.1642581	.814586
	FEB 2022	4	1.169100	.2425617	.1212808	.783130
	MAR 2022	1	.560600	.	.	.
	APR 2022	3	2.491700	1.1327766	.6540089	-.322273
	Total	14	1.575636	.8756153	.2340180	1.070071
Crop	NOV 2021	1	1.00	.	.	.
	DEC 2021	5	1.00	.000	.000	1.00
	FEB 2022	4	1.00	.000	.000	1.00
	MAR 2022	1	1.00	.	.	.
	APR 2022	3	1.00	.000	.000	1.00
	Total	14	1.00	.000	.000	1.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.	.711	.711
	DEC 2021	.79675	.766	.798
	FEB 2022	.78160	.769	.781
	MAR 2022	.	.719	.719
	APR 2022	.77836	.718	.753
	Total	.77496	.711	.798
PI_total	NOV 2021	.	2.9936	2.9936
	DEC 2021	1.726694	.6898	1.6171
	FEB 2022	1.555070	.8175	1.3664
	MAR 2022	.	.5606	.5606
	APR 2022	5.305673	1.2160	3.3798
	Total	2.081201	.5606	3.3798
Crop	NOV 2021	.	1	1
	DEC 2021	1.00	1	1
	FEB 2022	1.00	1	1
	MAR 2022	.	1	1
	APR 2022	1.00	1	1
	Total	1.00	1	1

a. Study_site = Vicinity wall, Crop = Amaranthus thunbergii

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.009	4	.002	13.837
	Within Groups	.002	9	.000	
	Total	.011	13		
PI_total	Between Groups	6.685	4	1.671	4.582
	Within Groups	3.282	9	.365	
	Total	9.967	13		
Crop	Between Groups	.000	4	.000	.
	Within Groups	.000	9	.000	
	Total	.000	13		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
PI_total	Between Groups	.027
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

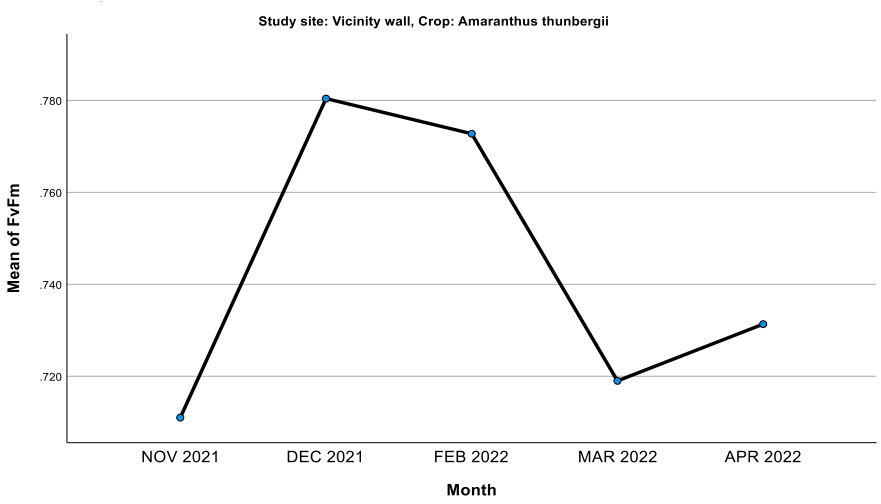
a. Study_site = Vicinity wall, Crop = Amaranthus thunbergii

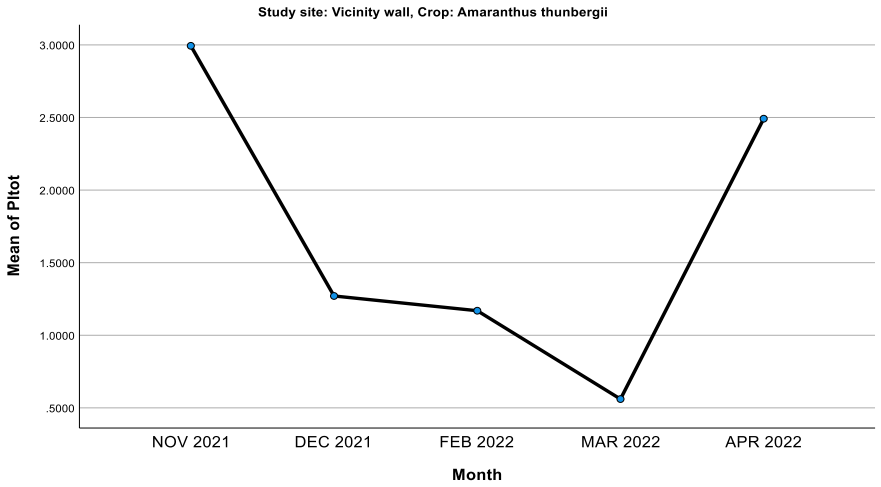
ANOVA Effect Sizes[a,b,c]

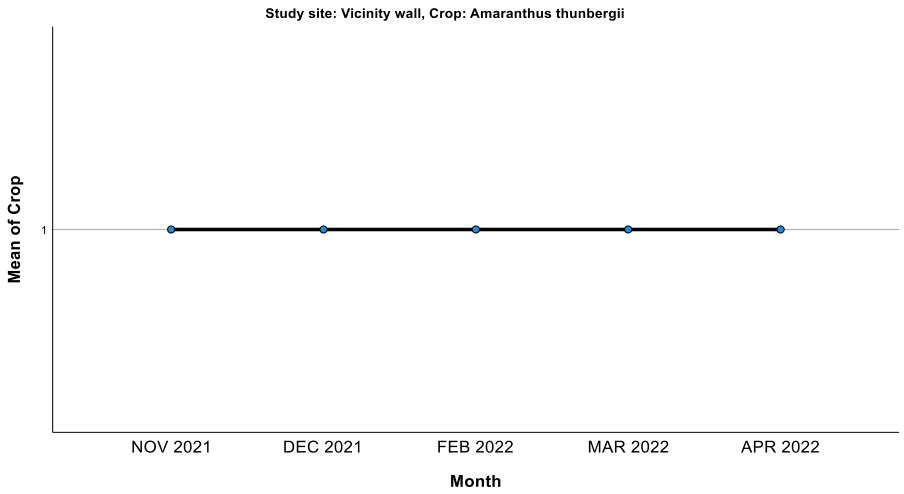
			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.860	.404	.899
	Epsilon-squared	.798	.139	.854
	Omega-squared Fixed-effect	.786	.130	.844
	Omega-squared Random-effect	.478	.036	.576
PI_total	Eta-squared	.671	.000	.764
	Epsilon-squared	.524	-.444	.660
	Omega-squared Fixed-effect	.506	-.400	.643
	Omega-squared Random-effect	.204	-.077	.310
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Vicinity wall, Crop = Amaranthus thunbergii
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Study site = Vicinity wall, Crop = Asystasia gangetica

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	3	.80333	.011590	.006692	.77454
	DEC 2021	5	.79660	.008562	.003829	.78597
	JAN 2022	4	.79650	.011387	.005694	.77838
	FEB 2022	5	.79540	.010114	.004523	.78284
	MAR 2022	3	.79533	.019348	.011170	.74727
	APR 2022	7	.79700	.018074	.006831	.78028
	Total	27	.79707	.012728	.002449	.79204
PI_total	NOV 2021	3	1.198167	.4704043	.2715880	.029618
	DEC 2021	5	.736600	.2566313	.1147690	.417950
	JAN 2022	4	.905125	.1242820	.0621410	.707365
	FEB 2022	5	.902420	.2154100	.0963343	.634953
	MAR 2022	3	.916800	.0195471	.0112855	.868242
	APR 2022	7	.970600	.2121683	.0801921	.774377
	Total	27	.924248	.2503078	.0481718	.825230
Crop	NOV 2021	3	2.00	.000	.000	2.00
	DEC 2021	5	2.00	.000	.000	2.00
	JAN 2022	4	2.00	.000	.000	2.00
	FEB 2022	5	2.00	.000	.000	2.00
	MAR 2022	3	2.00	.000	.000	2.00
	APR 2022	7	2.00	.000	.000	2.00
	Total	27	2.00	.000	.000	2.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.83213	.791	.814
	DEC 2021	.80723	.786	.808
	JAN 2022	.81462	.784	.810
	FEB 2022	.80796	.780	.807
	MAR 2022	.84340	.773	.807
	APR 2022	.81372	.773	.817
	Total	.80211	.773	.817
PI_total	NOV 2021	2.366716	.6592	1.5261
	DEC 2021	1.055250	.4914	1.0165
	JAN 2022	1.102885	.7203	.9831
	FEB 2022	1.169887	.6944	1.2133
	MAR 2022	.965358	.8953	.9335
	APR 2022	1.166823	.7355	1.2941
	Total	1.023267	.4914	1.5261
Crop	NOV 2021	2.00	2	2
	DEC 2021	2.00	2	2
	JAN 2022	2.00	2	2
	FEB 2022	2.00	2	2
	MAR 2022	2.00	2	2
	APR 2022	2.00	2	2
	Total	2.00	2	2

a. Study_site = Vicinity wall, Crop = Asystasia gangetica

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.000	5	.000	.148
	Within Groups	.004	21	.000	
	Total	.004	26		
PI_total	Between Groups	.420	5	.084	1.460
	Within Groups	1.209	21	.058	
	Total	1.629	26		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	21	.000	
	Total	.000	26		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.979
	Within Groups	
	Total	
PI_total	Between Groups	.245
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Vicinity wall, Crop = Asystasia gangetica

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.034	.000	.000
	Epsilon-squared	-.196	-.238	-.238
	Omega-squared Fixed-effect	-.187	-.227	-.227
	Omega-squared Random-effect	-.033	-.038	-.038
PI_total	Eta-squared	.258	.000	.398
	Epsilon-squared	.081	-.238	.255
	Omega-squared Fixed-effect	.078	-.227	.248
	Omega-squared Random-effect	.017	-.038	.062
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Vicinity wall, Crop = Asystasia gangetica
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.006733	.010165	.984	-.02507	.03854
		JAN 2022	.006833	.010631	.986	-.02643	.04009
		FEB 2022	.007933	.010165	.968	-.02387	.03974
		MAR 2022	.008000	.011365	.979	-.02756	.04356
		APR 2022	.006333	.009605	.985	-.02372	.03638
	DEC 2021	NOV 2021	-.006733	.010165	.984	-.03854	.02507
		JAN 2022	.000100	.009337	1.000	-.02911	.02931
		FEB 2022	.001200	.008803	1.000	-.02634	.02874
		MAR 2022	.001267	.010165	1.000	-.03054	.03307
		APR 2022	-.000400	.008150	1.000	-.02590	.02510
	JAN 2022	NOV 2021	-.006833	.010631	.986	-.04009	.02643
		DEC 2021	-.000100	.009337	1.000	-.02931	.02911
		FEB 2022	.001100	.009337	1.000	-.02811	.03031
		MAR 2022	.001167	.010631	1.000	-.03209	.03443
		APR 2022	-.000500	.008724	1.000	-.02779	.02679
	FEB 2022	NOV 2021	-.007933	.010165	.968	-.03974	.02387
		DEC 2021	-.001200	.008803	1.000	-.02874	.02634
		JAN 2022	-.001100	.009337	1.000	-.03031	.02811
		MAR 2022	.000067	.010165	1.000	-.03174	.03187
		APR 2022	-.001600	.008150	1.000	-.02710	.02390
	MAR 2022	NOV 2021	-.008000	.011365	.979	-.04356	.02756
		DEC 2021	-.001267	.010165	1.000	-.03307	.03054
		JAN 2022	-.001167	.010631	1.000	-.03443	.03209
		FEB 2022	-.000067	.010165	1.000	-.03187	.03174
		APR 2022	-.001667	.009605	1.000	-.03172	.02838
	APR 2022	NOV 2021	-.006333	.009605	.985	-.03638	.02372
		DEC 2021	.000400	.008150	1.000	-.02510	.02590
		JAN 2022	.000500	.008724	1.000	-.02679	.02779
		FEB 2022	.001600	.008150	1.000	-.02390	.02710
		MAR 2022	.001667	.009605	1.000	-.02838	.03172
PI_total	NOV 2021	DEC 2021	.4615667	.1752132	.132	-.086586	1.009719
		JAN 2022	.2930417	.1832424	.608	-.280230	.866314
		FEB 2022	.2957467	.1752132	.554	-.252406	.843899
		MAR 2022	.2813667	.1958943	.706	-.331487	.894220
		APR 2022	.2275667	.1655609	.741	-.290389	.745522
	DEC 2021	NOV 2021	-.4615667	.1752132	.132	-1.009719	.086586
		JAN 2022	-.1685250	.1609436	.896	-.672035	.334985
		FEB 2022	-.1658200	.1517391	.879	-.640534	.308894
		MAR 2022	-.1802000	.1752132	.903	-.728353	.367953
		APR 2022	-.2340000	.1404831	.567	-.673500	.205500
	JAN 2022	NOV 2021	-.2930417	.1832424	.608	-.866314	.280230
		DEC 2021	.1685250	.1609436	.896	-.334985	.672035
		FEB 2022	.0027050	.1609436	1.000	-.500805	.506215
		MAR 2022	-.0116750	.1832424	1.000	-.584947	.561597
		APR 2022	-.0654750	.1503782	.998	-.535932	.404982
	FEB 2022	NOV 2021	-.2957467	.1752132	.554	-.843899	.252406
		DEC 2021	.1658200	.1517391	.879	-.308894	.640534
		JAN 2022	-.0027050	.1609436	1.000	-.506215	.500805

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		MAR 2022	-.0143800	.1752132	1.000	-.562533	.533773
		APR 2022	-.0681800	.1404831	.996	-.507680	.371320
	MAR 2022	NOV 2021	-.2813667	.1958943	.706	-.894220	.331487
		DEC 2021	.1802000	.1752132	.903	-.367953	.728353
		JAN 2022	.0116750	.1832424	1.000	-.561597	.584947
		FEB 2022	.0143800	.1752132	1.000	-.533773	.562533
		APR 2022	-.0538000	.1655609	.999	-.571756	.464156
	APR 2022	NOV 2021	-.2275667	.1655609	.741	-.745522	.290389
		DEC 2021	.2340000	.1404831	.567	-.205500	.673500
		JAN 2022	.0654750	.1503782	.998	-.404982	.535932
		FEB 2022	.0681800	.1404831	.996	-.371320	.507680
		MAR 2022	.0538000	.1655609	.999	-.464156	.571756

a. Study_site = Vicinity wall, Crop = Asystasia gangetica

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1
MAR 2022	3	.79533
FEB 2022	5	.79540
JAN 2022	4	.79650
DEC 2021	5	.79660
APR 2022	7	.79700
NOV 2021	3	.80333
Sig.		.960

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Asystasia gangetica

b. Uses Harmonic Mean Sample Size = 4.111.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1
DEC 2021	5	.736600
FEB 2022	5	.902420
JAN 2022	4	.905125
MAR 2022	3	.916800
APR 2022	7	.970600
NOV 2021	3	1.198167
Sig.		.105

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Asystasia gangetica

b. Uses Harmonic Mean Sample Size = 4.111.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

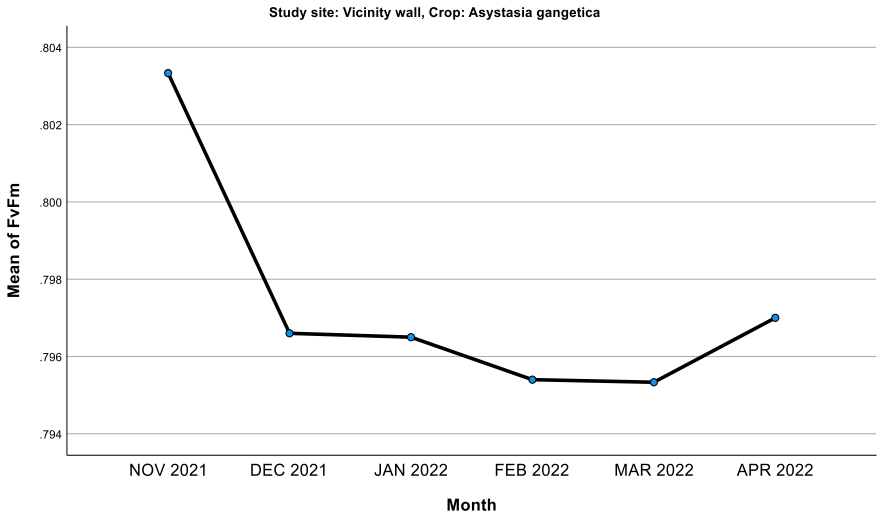
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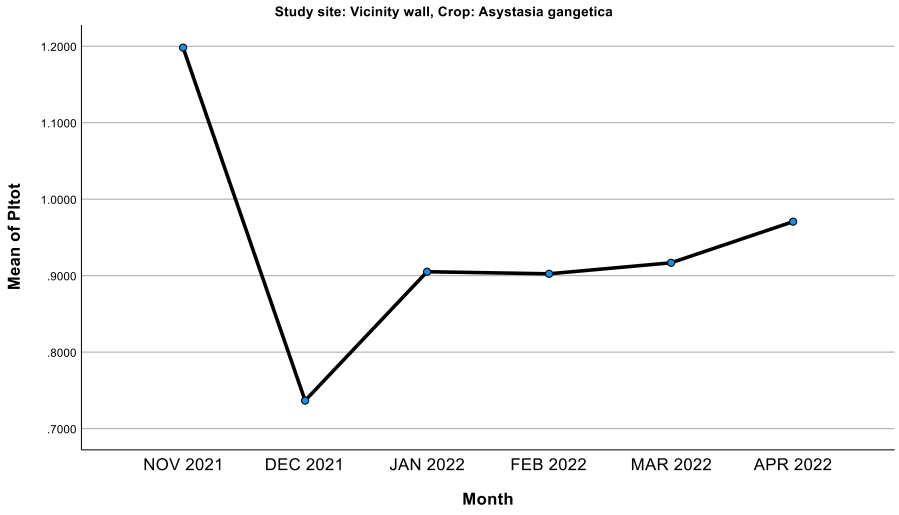
Crop[a]

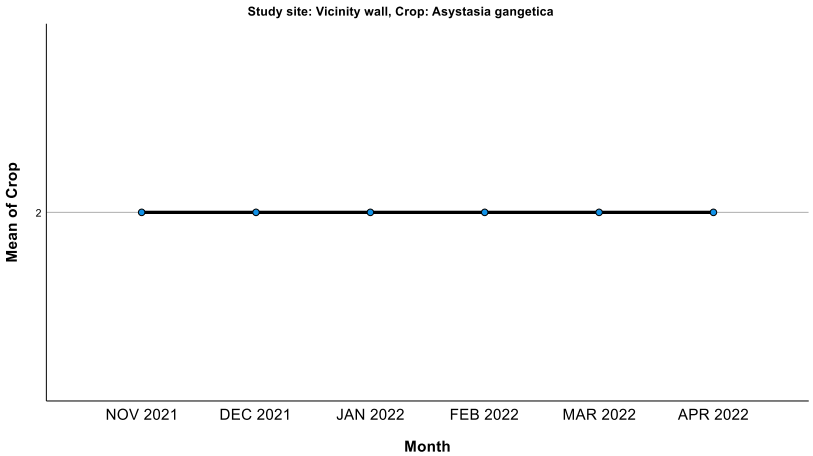
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Asystasia gangetica

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Study site = Vicinity wall, Crop = Corchorus confusus

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	6	.79417	.016618	.006784	.77673
	DEC 2021	9	.82211	.010191	.003397	.81428
	JAN 2022	9	.78289	.020065	.006688	.76747
	FEB 2022	9	.81689	.012781	.004260	.80706
	MAR 2022	1	.76800	.	.	.
	APR 2022	1	.77300	.	.	.
	Total	35	.80294	.023006	.003889	.79504
PI_total	NOV 2021	6	1.517500	.8019850	.3274090	.675868
	DEC 2021	9	1.818867	.6411953	.2137318	1.326000
	JAN 2022	9	.966678	.5420979	.1806993	.549984
	FEB 2022	9	1.385644	.2473688	.0824563	1.195500
	MAR 2022	1	1.193400	.	.	.
	APR 2022	1	.410200	.	.	.
	Total	35	1.378551	.6349011	.1073179	1.160455
Crop	NOV 2021	6	3.00	.000	.000	3.00
	DEC 2021	9	3.00	.000	.000	3.00
	JAN 2022	9	3.00	.000	.000	3.00
	FEB 2022	9	3.00	.000	.000	3.00
	MAR 2022	1	3.00	.	.	.
	APR 2022	1	3.00	.	.	.
	Total	35	3.00	.000	.000	3.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.81161	.782	.827
	DEC 2021	.82994	.801	.836
	JAN 2022	.79831	.757	.830
	FEB 2022	.82671	.805	.838
	MAR 2022	.	.768	.768
	APR 2022	.	.773	.773
	Total	.81085	.757	.838
PI_total	NOV 2021	2.359132	.8900	2.9750
	DEC 2021	2.311733	.5981	2.5053
	JAN 2022	1.383371	.3925	1.8127
	FEB 2022	1.575789	.9440	1.7465
	MAR 2022	.	1.1934	1.1934
	APR 2022	.	.4102	.4102
	Total	1.596648	.3925	2.9750
Crop	NOV 2021	3.00	3	3
	DEC 2021	3.00	3	3
	JAN 2022	3.00	3	3
	FEB 2022	3.00	3	3
	MAR 2022	.	3	3
	APR 2022	.	3	3
	Total	3.00	3	3

a. Study_site = Vicinity wall, Crop = Chorchorus confusus

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.011	5	.002	9.687
	Within Groups	.007	29	.000	
	Total	.018	34		
PI_total	Between Groups	4.360	5	.872	2.706
	Within Groups	9.345	29	.322	
	Total	13.705	34		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	29	.000	
	Total	.000	34		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
PI_total	Between Groups	.040
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Vicinity wall, Crop = Corchorus confusus

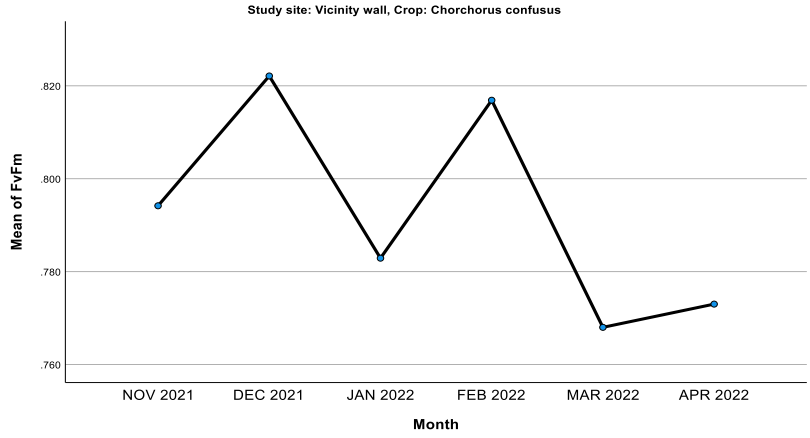
ANOVA Effect Sizes[a,b,c]

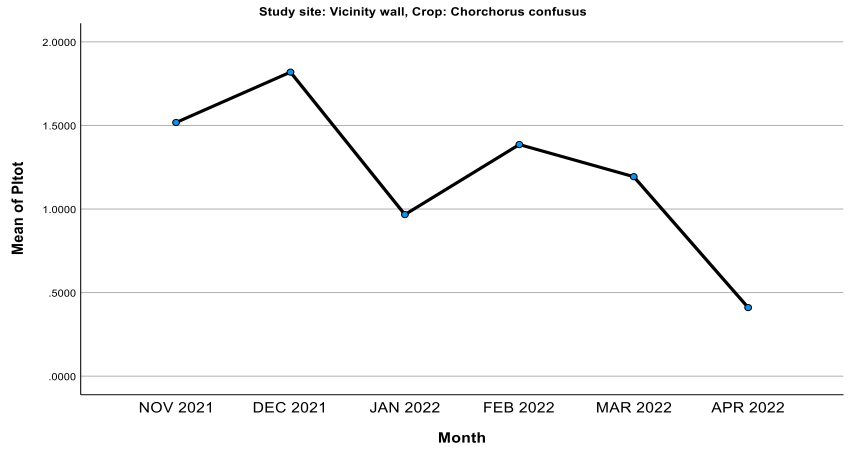
			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.625	.297	.714
	Epsilon-squared	.561	.176	.665
	Omega-squared Fixed-effect	.554	.172	.658
	Omega-squared Random-effect	.199	.040	.278
PI_total	Eta-squared	.318	.000	.454
	Epsilon-squared	.201	-.172	.360
	Omega-squared Fixed-effect	.196	-.167	.353
	Omega-squared Random-effect	.046	-.029	.099
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

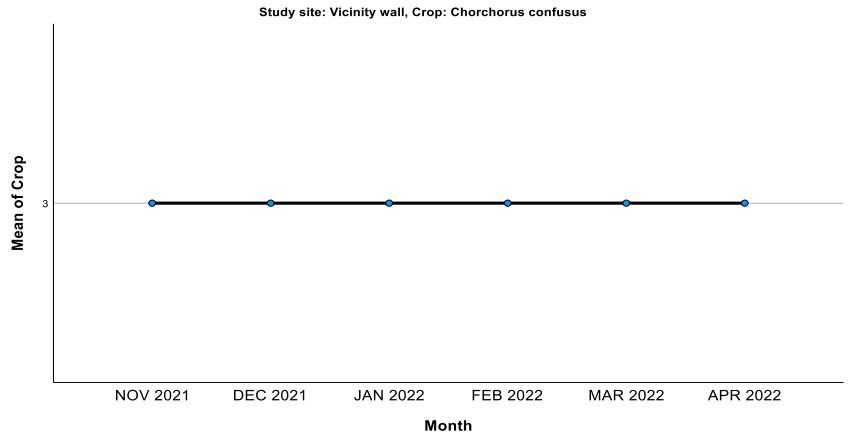
a. Study_site = Vicinity wall, Crop = Corchorus confusus
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Study site = Vicinity wall, Crop = Dicliptera clinopodia

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	8	.80000	.004567	.001615	.79618
	DEC 2021	6	.79667	.007891	.003221	.78839
	FEB 2022	3	.79567	.004163	.002404	.78532
	MAR 2022	1	.77000	.	.	.
	Total	18	.79650	.008726	.002057	.79216
PI_total	NOV 2021	8	.990975	.2943396	.1040648	.744901
	DEC 2021	6	.696317	.1204239	.0491628	.569940
	FEB 2022	3	.817467	.0350939	.0202615	.730289
	MAR 2022	1	.842900	.	.	.
	Total	18	.855611	.2406835	.0567296	.735922
Crop	NOV 2021	8	4.00	.000	.000	4.00
	DEC 2021	6	4.00	.000	.000	4.00
	FEB 2022	3	4.00	.000	.000	4.00
	MAR 2022	1	4.00	.	.	.
	Total	18	4.00	.000	.000	4.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.80382	.791	.804
	DEC 2021	.80495	.784	.808
	FEB 2022	.80601	.791	.799
	MAR 2022	.	.770	.770
	Total	.80084	.770	.808
PI_total	NOV 2021	1.237049	.6601	1.3970
	DEC 2021	.822694	.5818	.8495
	FEB 2022	.904645	.7788	.8473
	MAR 2022	.	.8429	.8429
	Total	.975300	.5818	1.3970
Crop	NOV 2021	4.00	4	4
	DEC 2021	4.00	4	4
	FEB 2022	4.00	4	4
	MAR 2022	.	4	4
	Total	4.00	4	4

a. Study_site = Vicinity wall, Crop = Dicliptera clinopodia

ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.001	3	.000	7.612
	Within Groups	.000	14	.000	
	Total	.001	17		
PI_total	Between Groups	.303	3	.101	2.078
	Within Groups	.681	14	.049	
	Total	.985	17		
Crop	Between Groups	.000	3	.000	.
	Within Groups	.000	14	.000	
	Total	.000	17		

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ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.003
	Within Groups	
	Total	
PI_total	Between Groups	.149
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Vicinity wall, Crop = Dicliptera clinopodia

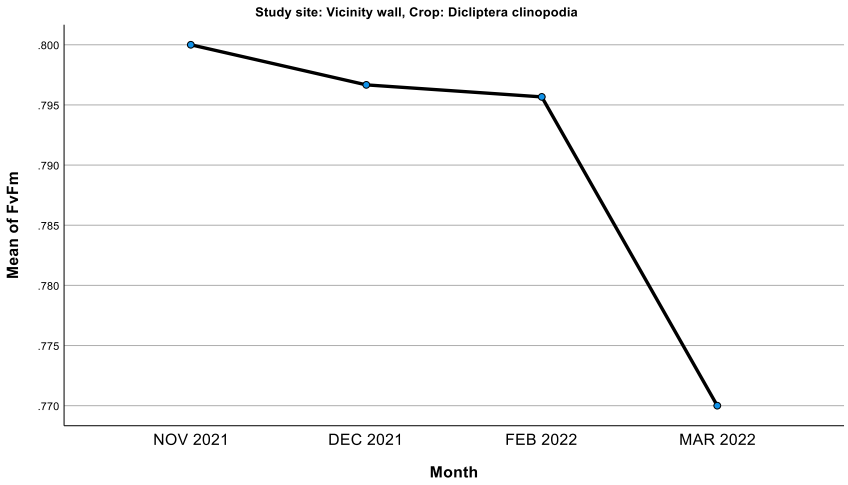
ANOVA Effect Sizes[a,b,c]

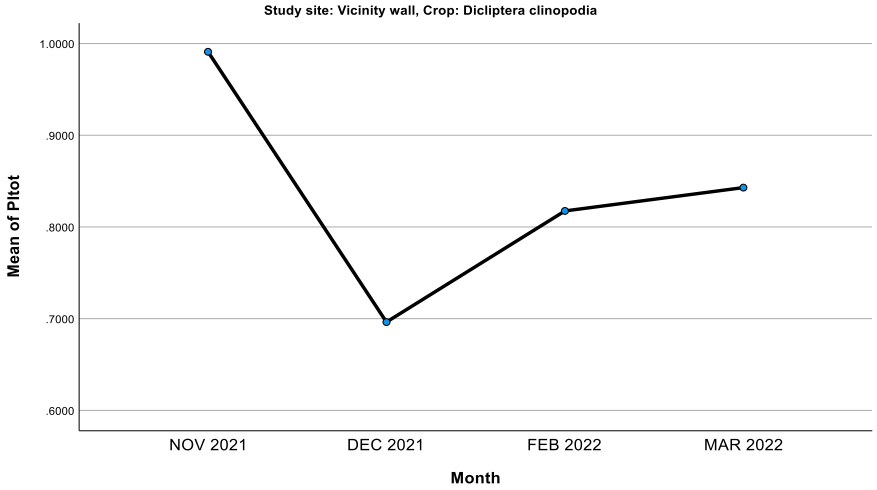
			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.620	.137	.743
	Epsilon-squared	.538	-.048	.687
	Omega-squared Fixed-effect	.524	-.045	.675
	Omega-squared Random-effect	.269	-.015	.409
PI_total	Eta-squared	.308	.000	.511
	Epsilon-squared	.160	-.214	.406
	Omega-squared Fixed-effect	.152	-.200	.392
	Omega-squared Random-effect	.056	-.059	.177
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

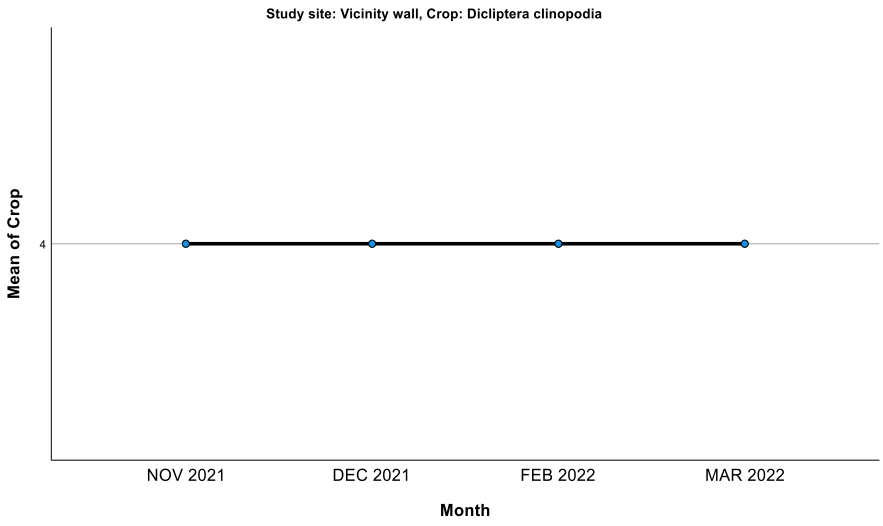
a. Study_site = Vicinity wall, Crop = Dicliptera clinopodia
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Study site = Vicinity wall, Crop = Mentha aquatica

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	6	.83350	.008597	.003510	.82448
	DEC 2021	9	.82889	.008551	.002850	.82232
	JAN 2022	4	.81325	.010935	.005468	.79585
	FEB 2022	6	.82200	.006841	.002793	.81482
	MAR 2022	6	.82183	.010304	.004206	.81102
	APR 2022	4	.81675	.018264	.009132	.78769
	Total	35	.82411	.011580	.001957	.82014
PI_total	NOV 2021	6	.629933	.1152144	.0470361	.509023
	DEC 2021	9	.630278	.2106366	.0702122	.468368
	JAN 2022	4	.382375	.0542069	.0271035	.296120
	FEB 2022	6	.613483	.0513789	.0209754	.559564
	MAR 2022	6	.674467	.0693430	.0283092	.601696
	APR 2022	4	.839900	.2070360	.1035180	.510459
	Total	35	.630540	.1741330	.0294338	.570723
Crop	NOV 2021	6	5.00	.000	.000	5.00
	DEC 2021	9	5.00	.000	.000	5.00
	JAN 2022	4	5.00	.000	.000	5.00
	FEB 2022	6	5.00	.000	.000	5.00
	MAR 2022	6	5.00	.000	.000	5.00
	APR 2022	4	5.00	.000	.000	5.00
	Total	35	5.00	.000	.000	5.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.84252	.820	.845
	DEC 2021	.83546	.815	.838
	JAN 2022	.83065	.804	.828
	FEB 2022	.82918	.812	.830
	MAR 2022	.83265	.810	.837
	APR 2022	.84581	.799	.833
	Total	.82809	.799	.845
PI_total	NOV 2021	.750843	.5298	.8037
	DEC 2021	.792187	.4569	.9629
	JAN 2022	.468630	.3182	.4462
	FEB 2022	.667402	.5373	.6871
	MAR 2022	.747238	.5818	.7483
	APR 2022	1.169341	.5296	.9496
	Total	.690357	.3182	.9629
Crop	NOV 2021	5.00	5	5
	DEC 2021	5.00	5	5
	JAN 2022	5.00	5	5
	FEB 2022	5.00	5	5
	MAR 2022	5.00	5	5
	APR 2022	5.00	5	5
	Total	5.00	5	5

a. Study_site = Vicinity wall, Crop = Mentha aquatica

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ANOVA[a]

		Sum of Squares	df	Mean Square	F	Sig.
max_quantum_yield	Between Groups	.001	5	.000	2.790	.036
	Within Groups	.003	29	.000		
	Total	.005	34			
PI_total	Between Groups	.435	5	.087	4.233	.005
	Within Groups	.596	29	.021		
	Total	1.031	34			
Crop	Between Groups	.000	5	.000	.	.
	Within Groups	.000	29	.000		
	Total	.000	34			

a. Study_site = Vicinity wall, Crop = Mentha aquatica

ANOVA Effect Sizes[a,b,c]

		Point Estimate	95% Confidence Interval Lower	Upper
max_quantum_yield	Eta-squared	.325	.000	.461
	Epsilon-squared	.208	-.172	.367
	Omega-squared Fixed-effect	.204	-.167	.361
	Omega-squared Random-effect	.049	-.029	.101
PI_total	Eta-squared	.422	.059	.548
	Epsilon-squared	.322	-.104	.470
	Omega-squared Fixed-effect	.316	-.100	.463
	Omega-squared Random-effect	.085	-.019	.147
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Vicinity wall, Crop = Mentha aquatica
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.004611	.005430	.955	-.01194	.02117
		JAN 2022	.020250	.006651	.050	-.00003	.04053
		FEB 2022	.011500	.005949	.403	-.00663	.02963
		MAR 2022	.011667	.005949	.388	-.00647	.02980
		APR 2022	.016750	.006651	.152	-.00353	.03703
	DEC 2021	NOV 2021	-.004611	.005430	.955	-.02117	.01194
		JAN 2022	.015639	.006192	.150	-.00324	.03451
		FEB 2022	.006889	.005430	.799	-.00967	.02344
		MAR 2022	.007056	.005430	.783	-.00950	.02361
		APR 2022	.012139	.006192	.388	-.00674	.03101
	JAN 2022	NOV 2021	-.020250	.006651	.050	-.04053	.00003
		DEC 2021	-.015639	.006192	.150	-.03451	.00324
		FEB 2022	-.008750	.006651	.774	-.02903	.01153
		MAR 2022	-.008583	.006651	.788	-.02886	.01169
		APR 2022	-.003500	.007286	.997	-.02571	.01871
	FEB 2022	NOV 2021	-.011500	.005949	.403	-.02963	.00663
		DEC 2021	-.006889	.005430	.799	-.02344	.00967
		JAN 2022	.008750	.006651	.774	-.01153	.02903
		MAR 2022	.000167	.005949	1.000	-.01797	.01830
		APR 2022	.005250	.006651	.967	-.01503	.02553
	MAR 2022	NOV 2021	-.011667	.005949	.388	-.02980	.00647
		DEC 2021	-.007056	.005430	.783	-.02361	.00950
		JAN 2022	.008583	.006651	.788	-.01169	.02886
		FEB 2022	-.000167	.005949	1.000	-.01830	.01797
		APR 2022	.005083	.006651	.971	-.01519	.02536
	APR 2022	NOV 2021	-.016750	.006651	.152	-.03703	.00353
		DEC 2021	-.012139	.006192	.388	-.03101	.00674
		JAN 2022	.003500	.007286	.997	-.01871	.02571
		FEB 2022	-.005250	.006651	.967	-.02553	.01503
		MAR 2022	-.005083	.006651	.971	-.02536	.01519
PI_total	NOV 2021	DEC 2021	-.0003444	.0755543	1.000	-.230670	.229981
		JAN 2022	.2475583	.0925347	.111	-.034532	.529649
		FEB 2022	.0164500	.0827656	1.000	-.235859	.268759
		MAR 2022	-.0445333	.0827656	.994	-.296842	.207776
		APR 2022	-.2099667	.0925347	.239	-.492057	.072124
	DEC 2021	NOV 2021	.0003444	.0755543	1.000	-.229981	.230670
		JAN 2022	.2479028	.0861451	.073	-.014709	.510514
		FEB 2022	.0167944	.0755543	1.000	-.213531	.247120
		MAR 2022	-.0441889	.0755543	.991	-.274515	.186137
		APR 2022	-.2096222	.0861451	.178	-.472234	.052989
	JAN 2022	NOV 2021	-.2475583	.0925347	.111	-.529649	.034532
		DEC 2021	-.2479028	.0861451	.073	-.510514	.014709
		FEB 2022	-.2311083	.0925347	.158	-.513199	.050982
		MAR 2022	-.2920917*	.0925347	.039	-.574182	-.010001
		APR 2022	-.4575250*	.1013667	.001	-.766539	-.148511
	FEB 2022	NOV 2021	-.0164500	.0827656	1.000	-.268759	.235859
		DEC 2021	-.0167944	.0755543	1.000	-.247120	.213531
		JAN 2022	.2311083	.0925347	.158	-.050982	.513199
		MAR 2022	-.0609833	.0827656	.976	-.313292	.191326

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	APR 2022	-.2264167	.0925347	.174	-.508507	.055674
MAR 2022	NOV 2021	.0445333	.0827656	.994	-.207776	.296842
	DEC 2021	.0441889	.0755543	.991	-.186137	.274515
	JAN 2022	.2920917*	.0925347	.039	.010001	.574182
	FEB 2022	.0609833	.0827656	.976	-.191326	.313292
	APR 2022	-.1654333	.0925347	.489	-.447524	.116657
APR 2022	NOV 2021	.2099667	.0925347	.239	-.072124	.492057
	DEC 2021	.2096222	.0861451	.178	-.052989	.472234
	JAN 2022	.4575250*	.1013667	.001	.148511	.766539
	FEB 2022	.2264167	.0925347	.174	-.055674	.508507
	MAR 2022	.1654333	.0925347	.489	-.116657	.447524

*. The mean difference is significant at the 0.05 level.

a. Study_site = Vicinity wall, Crop = Mentha aquatica

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

		Subset for alpha = 0.05	
Month	N	1	2
JAN 2022	4	.81325	
APR 2022	4	.81675	.81675
MAR 2022	6	.82183	.82183
FEB 2022	6	.82200	.82200
DEC 2021	9	.82889	.82889
NOV 2021	6		.83350
Sig.		.159	.112

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Mentha aquatica

b. Uses Harmonic Mean Sample Size = 5.400.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

		Subset for alpha = 0.05	
Month	N	1	2
JAN 2022	4	.382375	
FEB 2022	6	.613483	.613483
NOV 2021	6	.629933	.629933
DEC 2021	9	.630278	.630278
MAR 2022	6		.674467
APR 2022	4		.839900
Sig.		.079	.131

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Mentha aquatica

b. Uses Harmonic Mean Sample Size = 5.400.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

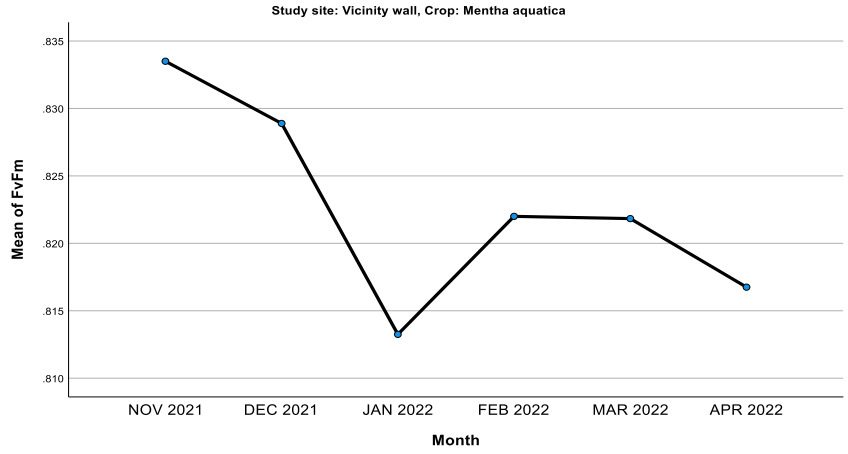
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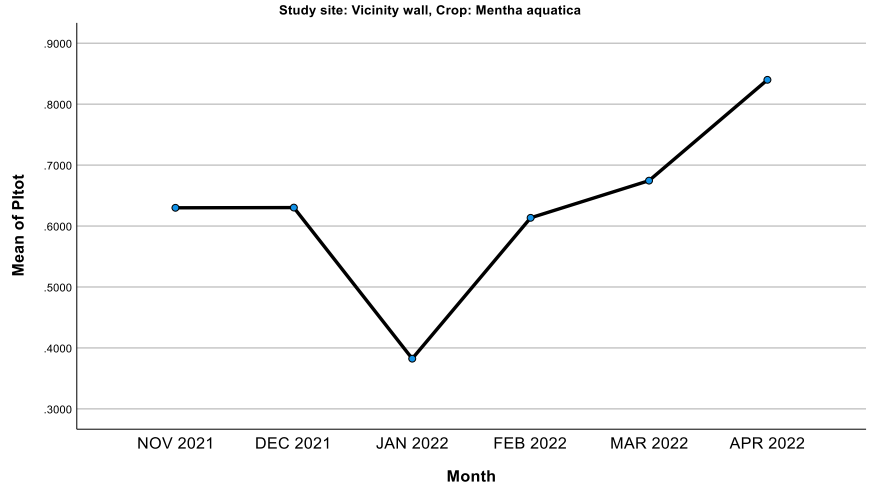
Crop[a]

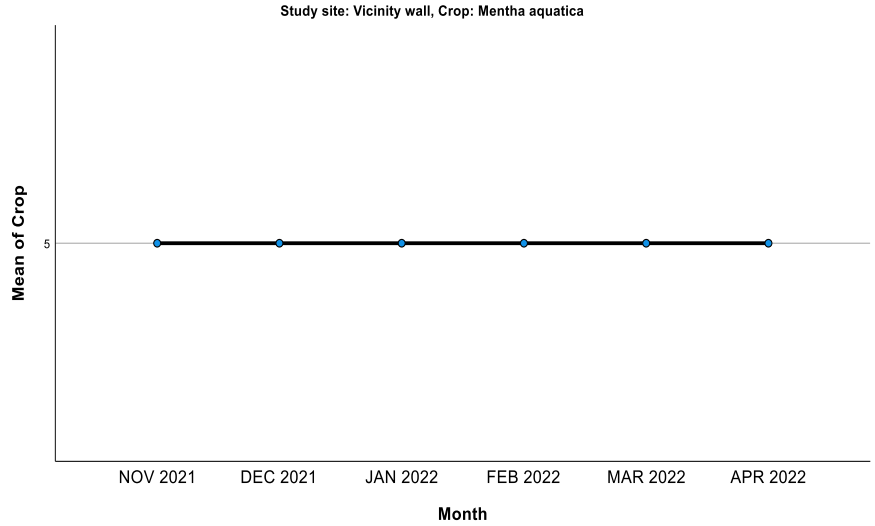
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Mentha aquatica

Means Plots







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Study site = Vicinity wall, Crop = Plectranthus amboinicus

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.83289	.015112	.005037	.82127
	DEC 2021	9	.82844	.023463	.007821	.81041
	JAN 2022	9	.83700	.006633	.002211	.83190
	FEB 2022	9	.85400	.004387	.001462	.85063
	MAR 2022	9	.82744	.016853	.005618	.81449
	APR 2022	9	.83822	.011366	.003789	.82949
	Total	54	.83633	.016406	.002233	.83186
PI_total	NOV 2021	9	1.683278	.3819416	.1273139	1.389691
	DEC 2021	9	1.292467	.6830589	.2276863	.767421
	JAN 2022	9	1.519633	.4921251	.1640417	1.141353
	FEB 2022	9	1.886456	.5714696	.1904899	1.447185
	MAR 2022	9	1.603222	.6438375	.2146125	1.108325
	APR 2022	9	2.186944	1.0080729	.3360243	1.412071
	Total	54	1.695333	.6897594	.0938644	1.507065
Crop	NOV 2021	9	6.00	.000	.000	6.00
	DEC 2021	9	6.00	.000	.000	6.00
	JAN 2022	9	6.00	.000	.000	6.00
	FEB 2022	9	6.00	.000	.000	6.00
	MAR 2022	9	6.00	.000	.000	6.00
	APR 2022	9	6.00	.000	.000	6.00
	Total	54	6.00	.000	.000	6.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.84450	.813	.854
	DEC 2021	.84648	.787	.851
	JAN 2022	.84210	.828	.851
	FEB 2022	.85737	.847	.859
	MAR 2022	.84040	.801	.846
	APR 2022	.84696	.819	.852
	Total	.84081	.787	.859
PI_total	NOV 2021	1.976864	1.2838	2.3874
	DEC 2021	1.817512	.5792	2.3899
	JAN 2022	1.897914	.8747	2.0069
	FEB 2022	2.325726	1.2216	3.0250
	MAR 2022	2.098120	.7851	2.4015
	APR 2022	2.961818	.7806	3.2132
	Total	1.883601	.5792	3.2132
Crop	NOV 2021	6.00	6	6
	DEC 2021	6.00	6	6
	JAN 2022	6.00	6	6
	FEB 2022	6.00	6	6
	MAR 2022	6.00	6	6
	APR 2022	6.00	6	6
	Total	6.00	6	6

a. Study_site = Vicinity wall, Crop = Plectranthus amboinicus

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.004	5	.001	4.037
	Within Groups	.010	48	.000	
	Total	.014	53		
PI_total	Between Groups	4.320	5	.864	1.985
	Within Groups	20.896	48	.435	
	Total	25.216	53		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	48	.000	
	Total	.000	53		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.004
	Within Groups	
	Total	
PI_total	Between Groups	.098
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Vicinity wall, Crop = Plectranthus amboinicus

ANOVA Effect Sizes[a,b,c]

		Point Estimate	95% Confidence Interval Lower	Upper
max_quantum_yield	Eta-squared	.296	.042	.421
	Epsilon-squared	.223	-.058	.360
	Omega-squared Fixed-effect	.219	-.056	.356
	Omega-squared Random-effect	.053	-.011	.100
PI_total	Eta-squared	.171	.000	.289
	Epsilon-squared	.085	-.104	.215
	Omega-squared Fixed-effect	.084	-.102	.212
	Omega-squared Random-effect	.018	-.019	.051
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Vicinity wall, Crop = Plectranthus amboinicus
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.004444	.006819	.986	-.01579	.02468
		JAN 2022	-.004111	.006819	.990	-.02435	.01613
		FEB 2022	-.021111*	.006819	.036	-.04135	-.00087
		MAR 2022	.005444	.006819	.966	-.01479	.02568
		APR 2022	-.005333	.006819	.969	-.02557	.01490
	DEC 2021	NOV 2021	-.004444	.006819	.986	-.02468	.01579
		JAN 2022	-.008556	.006819	.807	-.02879	.01168
		FEB 2022	-.025556*	.006819	.006	-.04579	-.00532
		MAR 2022	.001000	.006819	1.000	-.01924	.02124
		APR 2022	-.009778	.006819	.706	-.03002	.01046
	JAN 2022	NOV 2021	.004111	.006819	.990	-.01613	.02435
		DEC 2021	.008556	.006819	.807	-.01168	.02879
		FEB 2022	-.017000	.006819	.147	-.03724	.00324
		MAR 2022	.009556	.006819	.726	-.01068	.02979
		APR 2022	-.001222	.006819	1.000	-.02146	.01902
	FEB 2022	NOV 2021	.021111*	.006819	.036	.00087	.04135
		DEC 2021	.025556*	.006819	.006	.00532	.04579
		JAN 2022	.017000	.006819	.147	-.00324	.03724
		MAR 2022	.026556*	.006819	.004	.00632	.04679
		APR 2022	.015778	.006819	.209	-.00446	.03602
	MAR 2022	NOV 2021	-.005444	.006819	.966	-.02568	.01479
		DEC 2021	-.001000	.006819	1.000	-.02124	.01924
		JAN 2022	-.009556	.006819	.726	-.02979	.01068
		FEB 2022	-.026556*	.006819	.004	-.04679	-.00632
		APR 2022	-.010778	.006819	.615	-.03102	.00946
	APR 2022	NOV 2021	.005333	.006819	.969	-.01490	.02557
		DEC 2021	.009778	.006819	.706	-.01046	.03002
		JAN 2022	.001222	.006819	1.000	-.01902	.02146
		FEB 2022	-.015778	.006819	.209	-.03602	.00446
		MAR 2022	.010778	.006819	.615	-.00946	.03102
PI_total	NOV 2021	DEC 2021	.3908111	.3110288	.807	-.532290	1.313912
		JAN 2022	.1636444	.3110288	.995	-.759456	1.086745
		FEB 2022	-.2031778	.3110288	.986	-1.126279	.719923
		MAR 2022	.0800556	.3110288	1.000	-.843045	1.003156
		APR 2022	-.5036667	.3110288	.590	-1.426767	.419434
	DEC 2021	NOV 2021	-.3908111	.3110288	.807	-1.313912	.532290
		JAN 2022	-.2271667	.3110288	.977	-1.150267	.695934
		FEB 2022	-.5939889	.3110288	.409	-1.517090	.329112
		MAR 2022	-.3107556	.3110288	.916	-1.233856	.612345
		APR 2022	-.8944778	.3110288	.062	-1.817579	.028623
	JAN 2022	NOV 2021	-.1636444	.3110288	.995	-1.086745	.759456
		DEC 2021	.2271667	.3110288	.977	-.695934	1.150267
		FEB 2022	-.3668222	.3110288	.844	-1.289923	.556279
		MAR 2022	-.0835889	.3110288	1.000	-1.006690	.839512
		APR 2022	-.6673111	.3110288	.282	-1.590412	.255790
	FEB 2022	NOV 2021	.2031778	.3110288	.986	-.719923	1.126279
		DEC 2021	.5939889	.3110288	.409	-.329112	1.517090
		JAN 2022	.3668222	.3110288	.844	-.556279	1.289923

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		MAR 2022	.2832333	.3110288	.942	-.639867	1.206334
		APR 2022	-.3004889	.3110288	.926	-1.223590	.622612
	MAR 2022	NOV 2021	-.0800556	.3110288	1.000	-1.003156	.843045
		DEC 2021	.3107556	.3110288	.916	-.612345	1.233856
		JAN 2022	.0835889	.3110288	1.000	-.839512	1.006690
		FEB 2022	-.2832333	.3110288	.942	-1.206334	.639867
		APR 2022	-.5837222	.3110288	.429	-1.506823	.339379
	APR 2022	NOV 2021	.5036667	.3110288	.590	-.419434	1.426767
		DEC 2021	.8944778	.3110288	.062	-.028623	1.817579
		JAN 2022	.6673111	.3110288	.282	-.255790	1.590412
		FEB 2022	.3004889	.3110288	.926	-.622612	1.223590
		MAR 2022	.5837222	.3110288	.429	-.339379	1.506823

*. The mean difference is significant at the 0.05 level.

a. Study_site = Vicinity wall, Crop = Plectranthus amboinicus

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b]

Month	N	Subset for alpha = 0.05	
		1	2
MAR 2022	9	.82744	
DEC 2021	9	.82844	
NOV 2021	9	.83289	
JAN 2022	9	.83700	.83700
APR 2022	9	.83822	.83822
FEB 2022	9		.85400
Sig.		.615	.147

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Plectranthus amboinicus

b. Uses Harmonic Mean Sample Size = 9.000.

PI_total[a]

Tukey HSD[b]

Month	N	Subset for alpha = 0.05
		1
DEC 2021	9	1.292467
JAN 2022	9	1.519633
MAR 2022	9	1.603222
NOV 2021	9	1.683278
FEB 2022	9	1.886456
APR 2022	9	2.186944
Sig.		.062

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Plectranthus amboinicus

b. Uses Harmonic Mean Sample Size = 9.000.

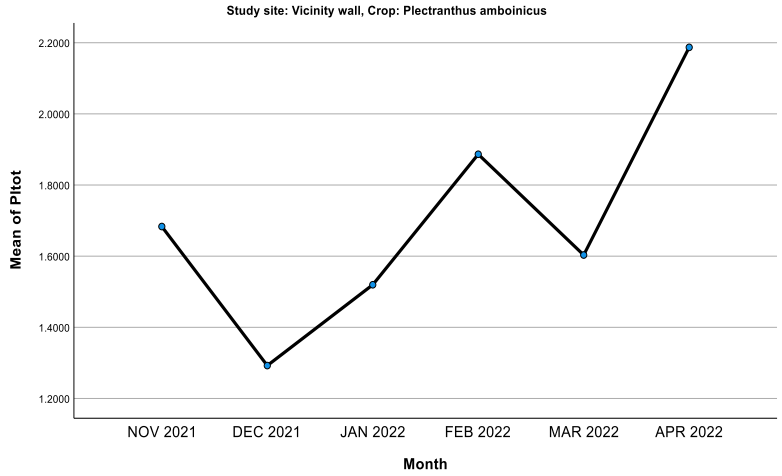
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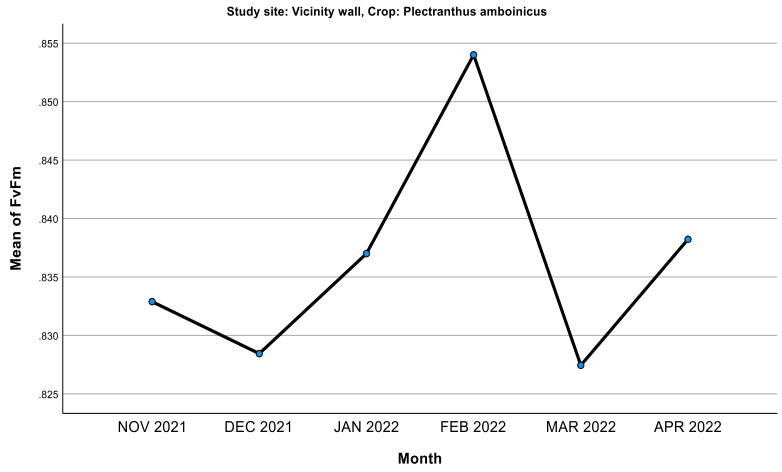
Crop[a]

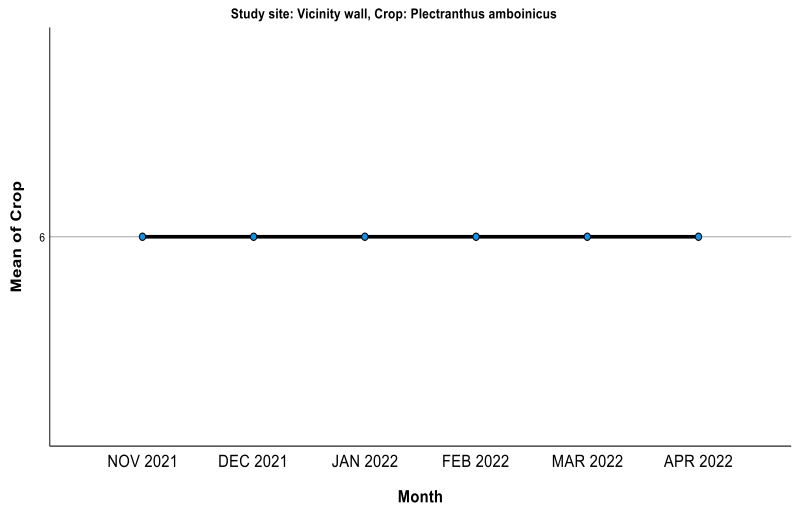
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Plectranthus amboinicus

Means Plots







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Study site = Vicinity wall, Crop = Portulaca oleracea

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.78867	.016763	.005588	.77578
	DEC 2021	8	.78513	.021807	.007710	.76689
	JAN 2022	6	.76717	.012844	.005244	.75369
	FEB 2022	7	.77186	.008214	.003105	.76426
	MAR 2022	4	.79225	.010905	.005452	.77490
	Total	34	.78100	.017467	.002996	.77491
PI_total	NOV 2021	9	2.367389	1.2015989	.4005330	1.443758
	DEC 2021	8	1.863750	1.0849068	.3835725	.956745
	JAN 2022	6	1.566250	.8833547	.3606280	.639226
	FEB 2022	7	1.697014	.5372651	.2030671	1.200127
	MAR 2022	4	1.522800	.2781330	.1390665	1.080228
	Total	34	1.870126	.9394965	.1611223	1.542321
Crop	NOV 2021	9	7.00	.000	.000	7.00
	DEC 2021	8	7.00	.000	.000	7.00
	JAN 2022	6	7.00	.000	.000	7.00
	FEB 2022	7	7.00	.000	.000	7.00
	MAR 2022	4	7.00	.000	.000	7.00
	Total	34	7.00	.000	.000	7.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.80155	.770	.811
	DEC 2021	.80336	.758	.814
	JAN 2022	.78065	.755	.789
	FEB 2022	.77945	.758	.783
	MAR 2022	.80960	.778	.804
	Total	.78709	.755	.814
PI_total	NOV 2021	3.291020	1.3078	4.6257
	DEC 2021	2.770755	.6380	3.5600
	JAN 2022	2.493274	.7407	2.6256
	FEB 2022	2.193902	1.0517	2.4141
	MAR 2022	1.965372	1.2707	1.9174
	Total	2.197932	.6380	4.6257
Crop	NOV 2021	7.00	7	7
	DEC 2021	7.00	7	7
	JAN 2022	7.00	7	7
	FEB 2022	7.00	7	7
	MAR 2022	7.00	7	7
	Total	7.00	7	7

a. Study_site = Vicinity wall, Crop = Portulaca oleracea

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.003	4	.001	2.940
	Within Groups	.007	29	.000	
	Total	.010	33		
PI_total	Between Groups	3.472	4	.868	.981
	Within Groups	25.655	29	.885	
	Total	29.128	33		
Crop	Between Groups	.000	4	.000	.
	Within Groups	.000	29	.000	
	Total	.000	33		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.037
	Within Groups	
	Total	
PI_total	Between Groups	.433
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Vicinity wall, Crop = Portulaca oleracea

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.289	.000	.444
	Epsilon-squared	.190	-.138	.367
	Omega-squared Fixed-effect	.186	-.133	.360
	Omega-squared Random-effect	.054	-.030	.124
PI_total	Eta-squared	.119	.000	.256
	Epsilon-squared	-.002	-.138	.153
	Omega-squared Fixed-effect	-.002	-.133	.149
	Omega-squared Random-effect	-.001	-.030	.042
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Vicinity wall, Crop = Portulaca oleracea
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.003542	.007637	.990	-.01866	.02574
		JAN 2022	.021500	.008283	.098	-.00258	.04558
		FEB 2022	.016810	.007920	.238	-.00621	.03983
		MAR 2022	-.003583	.009444	.995	-.03104	.02387
	DEC 2021	NOV 2021	-.003542	.007637	.990	-.02574	.01866
		JAN 2022	.017958	.008488	.241	-.00671	.04263
		FEB 2022	.013268	.008134	.490	-.01038	.03691
		MAR 2022	-.007125	.009624	.945	-.03510	.02085
	JAN 2022	NOV 2021	-.021500	.008283	.098	-.04558	.00258
		DEC 2021	-.017958	.008488	.241	-.04263	.00671
		FEB 2022	-.004690	.008744	.983	-.03011	.02073
		MAR 2022	-.025083	.010145	.125	-.05457	.00441
	FEB 2022	NOV 2021	-.016810	.007920	.238	-.03983	.00621
		DEC 2021	-.013268	.008134	.490	-.03691	.01038
		JAN 2022	.004690	.008744	.983	-.02073	.03011
		MAR 2022	-.020393	.009851	.260	-.04903	.00824
	MAR 2022	NOV 2021	.003583	.009444	.995	-.02387	.03104
		DEC 2021	.007125	.009624	.945	-.02085	.03510
		JAN 2022	.025083	.010145	.125	-.00441	.05457
		FEB 2022	.020393	.009851	.260	-.00824	.04903
PI_total	NOV 2021	DEC 2021	.5036389	.4570346	.804	-.824878	1.832156
		JAN 2022	.8011389	.4957236	.500	-.639840	2.242117
		FEB 2022	.6703746	.4740024	.624	-.707464	2.048214
		MAR 2022	.8445889	.5652119	.574	-.798379	2.487557
	DEC 2021	NOV 2021	-.5036389	.4570346	.804	-1.832156	.824878
		JAN 2022	.2975000	.5079655	.976	-1.179064	1.774064
		FEB 2022	.1667357	.4867909	.997	-1.248277	1.581749
		MAR 2022	.3409500	.5759788	.975	-1.333316	2.015216
	JAN 2022	NOV 2021	-.8011389	.4957236	.500	-2.242117	.639840
		DEC 2021	-.2975000	.5079655	.976	-1.774064	1.179064
		FEB 2022	-.1307643	.5232845	.999	-1.651857	1.390329
		MAR 2022	.0434500	.6071349	1.000	-1.721381	1.808281
	FEB 2022	NOV 2021	-.6703746	.4740024	.624	-2.048214	.707464
		DEC 2021	-.1667357	.4867909	.997	-1.581749	1.248277
		JAN 2022	.1307643	.5232845	.999	-1.390329	1.651857
		MAR 2022	.1742143	.5895331	.998	-1.539451	1.887880
	MAR 2022	NOV 2021	-.8445889	.5652119	.574	-2.487557	.798379
		DEC 2021	-.3409500	.5759788	.975	-2.015216	1.333316
		JAN 2022	-.0434500	.6071349	1.000	-1.808281	1.721381
		FEB 2022	-.1742143	.5895331	.998	-1.887880	1.539451

a. Study_site = Vicinity wall, Crop = Portulaca oleracea

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1
JAN 2022	6	.76717
FEB 2022	7	.77186
DEC 2021	8	.78513
NOV 2021	9	.78867
MAR 2022	4	.79225
Sig.		.059

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Vicinity wall, Crop = Portulaca oleracea
b. Uses Harmonic Mean Sample Size = 6.284.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1
MAR 2022	4	1.522800
JAN 2022	6	1.566250
FEB 2022	7	1.697014
DEC 2021	8	1.863750
NOV 2021	9	2.367389
Sig.		.514

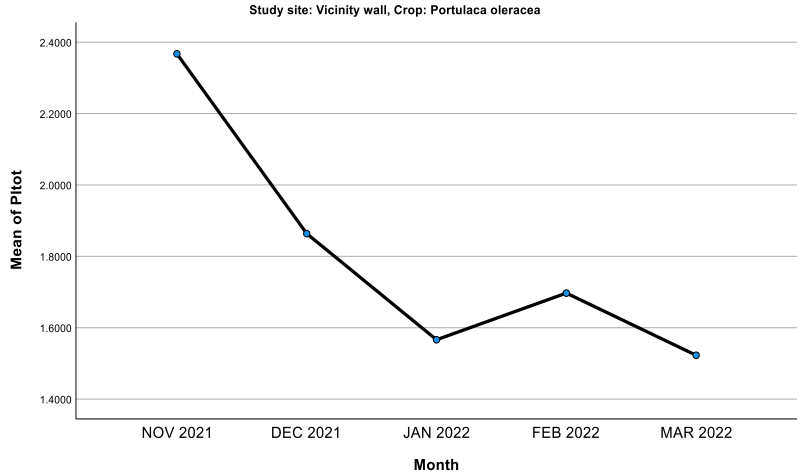
Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Vicinity wall, Crop = Portulaca oleracea
b. Uses Harmonic Mean Sample Size = 6.284.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

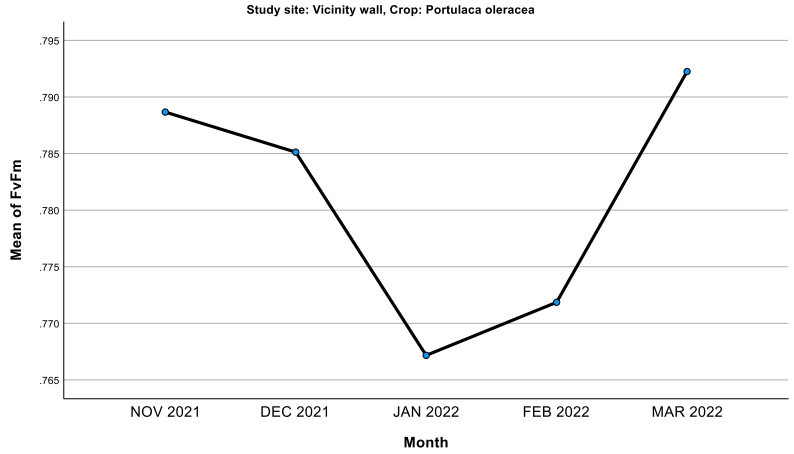
Crop[a]

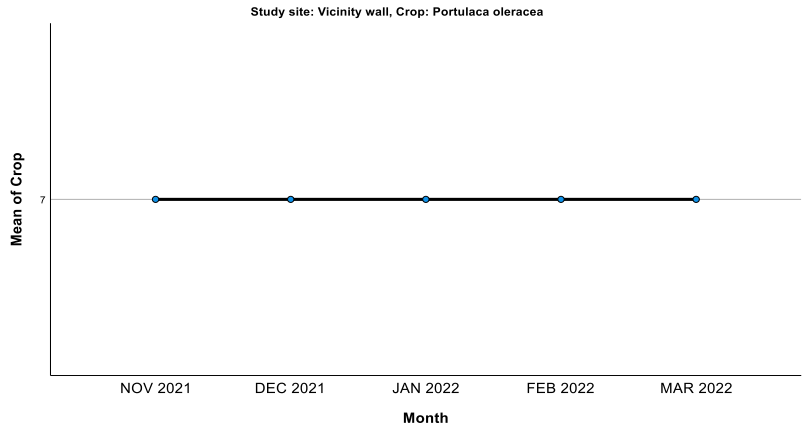
Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Vicinity wall, Crop = Portulaca oleracea

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Means Plots







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Study site = Vicinity wall, Crop = Portulacaria afra prostrata

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.85244	.012749	.004250	.84264
	DEC 2021	9	.86667	.008062	.002687	.86047
	JAN 2022	9	.84800	.011303	.003768	.83931
	FEB 2022	9	.84689	.016519	.005506	.83419
	MAR 2022	9	.83233	.023200	.007733	.81450
	APR 2022	5	.79800	.055417	.024783	.72919
	Total	50	.84414	.028177	.003985	.83613
PI_total	NOV 2021	9	2.482478	.5418916	.1806305	2.065943
	DEC 2021	9	2.293667	.8425261	.2808420	1.646044
	JAN 2022	9	1.855700	.8146781	.2715594	1.229483
	FEB 2022	9	1.281511	.3815765	.1271922	.988205
	MAR 2022	9	1.285067	.3814811	.1271604	.991834
	APR 2022	5	.756520	.2371404	.1060524	.462071
	Total	50	1.731368	.8121455	.1148547	1.500559
Crop	NOV 2021	9	8.00	.000	.000	8.00
	DEC 2021	9	8.00	.000	.000	8.00
	JAN 2022	9	8.00	.000	.000	8.00
	FEB 2022	9	8.00	.000	.000	8.00
	MAR 2022	9	8.00	.000	.000	8.00
	APR 2022	5	8.00	.000	.000	8.00
	Total	50	8.00	.000	.000	8.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.86224	.834	.874
	DEC 2021	.87286	.854	.880
	JAN 2022	.85669	.832	.866
	FEB 2022	.85959	.814	.869
	MAR 2022	.85017	.795	.862
	APR 2022	.86681	.726	.861
	Total	.85215	.726	.880
PI_total	NOV 2021	2.899013	1.7159	3.1998
	DEC 2021	2.941290	.6128	3.3463
	JAN 2022	2.481917	1.0379	3.1374
	FEB 2022	1.574817	.7194	1.7803
	MAR 2022	1.578299	.7995	1.9756
	APR 2022	1.050969	.4018	1.0510
	Total	1.962177	.4018	3.3463
Crop	NOV 2021	8.00	8	8
	DEC 2021	8.00	8	8
	JAN 2022	8.00	8	8
	FEB 2022	8.00	8	8
	MAR 2022	8.00	8	8
	APR 2022	8.00	8	8
	Total	8.00	8	8

a. Study_site = Vicinity wall, Crop = Portulacaria afra prostrata

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.017	5	.003	7.039
	Within Groups	.022	44	.000	
	Total	.039	49		
PI_total	Between Groups	16.428	5	3.286	9.097
	Within Groups	15.892	44	.361	
	Total	32.319	49		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	44	.000	
	Total	.000	49		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Vicinity wall, Crop = Portulacaria afra prostrata

ANOVA Effect Sizes[a,b]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.444	.161	.558
	Epsilon-squared	.381	.065	.508
	Omega-squared Fixed-effect	.377	.064	.503
	Omega-squared Random-effect	.108	.014	.168
PI_total	Eta-squared	.508	.232	.612
	Epsilon-squared	.452	.145	.568
	Omega-squared Fixed-effect	.447	.143	.563
	Omega-squared Random-effect	.139	.032	.205
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Vicinity wall, Crop = Portulacaria afra prostrata

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.014222	.010448	.749	-.04535	.01690
		JAN 2022	.004444	.010448	.998	-.02668	.03557
		FEB 2022	.005556	.010448	.995	-.02557	.03668
		MAR 2022	.020111	.010448	.401	-.01101	.05124
		APR 2022	.054444*	.012363	<,001	.01762	.09127
	DEC 2021	NOV 2021	.014222	.010448	.749	-.01690	.04535
		JAN 2022	.018667	.010448	.485	-.01246	.04979
		FEB 2022	.019778	.010448	.420	-.01135	.05090
		MAR 2022	.034333*	.010448	.023	.00321	.06546
		APR 2022	.068667*	.012363	<,001	.03184	.10549
	JAN 2022	NOV 2021	-.004444	.010448	.998	-.03557	.02668
		DEC 2021	-.018667	.010448	.485	-.04979	.01246
		FEB 2022	.001111	.010448	1.000	-.03001	.03224
		MAR 2022	.015667	.010448	.666	-.01546	.04679
		APR 2022	.050000*	.012363	.003	.01317	.08683
	FEB 2022	NOV 2021	-.005556	.010448	.995	-.03668	.02557
		DEC 2021	-.019778	.010448	.420	-.05090	.01135
		JAN 2022	-.001111	.010448	1.000	-.03224	.03001
		MAR 2022	.014556	.010448	.731	-.01657	.04568
		APR 2022	.048889*	.012363	.004	.01206	.08572
	MAR 2022	NOV 2021	-.020111	.010448	.401	-.05124	.01101
		DEC 2021	-.034333*	.010448	.023	-.06546	-.00321
		JAN 2022	-.015667	.010448	.666	-.04679	.01546
		FEB 2022	-.014556	.010448	.731	-.04568	.01657
		APR 2022	.034333	.012363	.080	-.00249	.07116
	APR 2022	NOV 2021	-.054444*	.012363	<,001	-.09127	-.01762
		DEC 2021	-.068667*	.012363	<,001	-.10549	-.03184
		JAN 2022	-.050000*	.012363	.003	-.08683	-.01317
		FEB 2022	-.048889*	.012363	.004	-.08572	-.01206
		MAR 2022	-.034333	.012363	.080	-.07116	.00249
PI_total	NOV 2021	DEC 2021	.1888111	.2833026	.985	-.655126	1.032748
		JAN 2022	.6267778	.2833026	.253	-.217159	1.470715
		FEB 2022	1.2009667*	.2833026	.001	.357030	2.044904
		MAR 2022	1.1974111*	.2833026	.002	.353474	2.041348
		APR 2022	1.7259578*	.3352081	<,001	.727398	2.724517
	DEC 2021	NOV 2021	-.1888111	.2833026	.985	-1.032748	.655126
		JAN 2022	.4379667	.2833026	.637	-.405970	1.281904
		FEB 2022	1.0121556*	.2833026	.011	.168219	1.856092
		MAR 2022	1.0086000*	.2833026	.011	.164663	1.852537
		APR 2022	1.5371467*	.3352081	<,001	.538587	2.535706
	JAN 2022	NOV 2021	-.6267778	.2833026	.253	-1.470715	.217159
		DEC 2021	-.4379667	.2833026	.637	-1.281904	.405970
		FEB 2022	.5741889	.2833026	.344	-.269748	1.418126
		MAR 2022	.5706333	.2833026	.351	-.273304	1.414570
		APR 2022	1.0991800*	.3352081	.023	.100620	2.097740
	FEB 2022	NOV 2021	-1.2009667*	.2833026	.001	-2.044904	-.357030
		DEC 2021	-1.0121556*	.2833026	.011	-1.856092	-.168219
		JAN 2022	-.5741889	.2833026	.344	-1.418126	.269748

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		MAR 2022	-.0035556	.2833026	1.000	-.847492	.840381
		APR 2022	.5249911	.3352081	.624	-.473569	1.523551
	MAR 2022	NOV 2021	-1.1974111*	.2833026	.002	-2.041348	-.353474
		DEC 2021	-1.0086000*	.2833026	.011	-1.852537	-.164663
		JAN 2022	-.5706333	.2833026	.351	-1.414570	.273304
		FEB 2022	.0035556	.2833026	1.000	-.840381	.847492
		APR 2022	.5285467	.3352081	.618	-.470013	1.527106
	APR 2022	NOV 2021	-1.7259578*	.3352081	<,001	-2.724517	-.727398
		DEC 2021	-1.5371467*	.3352081	<,001	-2.535706	-.538587
		JAN 2022	-1.0991800*	.3352081	.023	-2.097740	-.100620
		FEB 2022	-.5249911	.3352081	.624	-1.523551	.473569
		MAR 2022	-.5285467	.3352081	.618	-1.527106	.470013

*. The mean difference is significant at the 0.05 level.
a. Study_site = Vicinity wall, Crop = Portulacaria afra prostrata

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05		
		1	2	3
APR 2022	5	.79800		
MAR 2022	9		.83233	
FEB 2022	9		.84689	.84689
JAN 2022	9		.84800	.84800
NOV 2021	9		.85244	.85244
DEC 2021	9			.86667
Sig.		1.000	.471	.490

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Vicinity wall, Crop = Portulacaria afra prostrata
b. Uses Harmonic Mean Sample Size = 7.941.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05		
		1	2	3
APR 2022	5	.756520		
FEB 2022	9	1.281511	1.281511	
MAR 2022	9	1.285067	1.285067	
JAN 2022	9		1.855700	1.855700
DEC 2021	9			2.293667
NOV 2021	9			2.482478
Sig.		.506	.414	.317

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Vicinity wall, Crop = Portulacaria afra prostrata
b. Uses Harmonic Mean Sample Size = 7.941.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

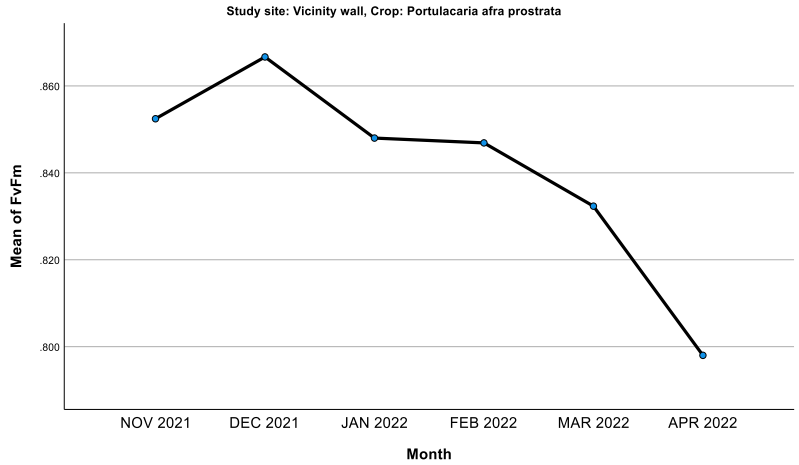
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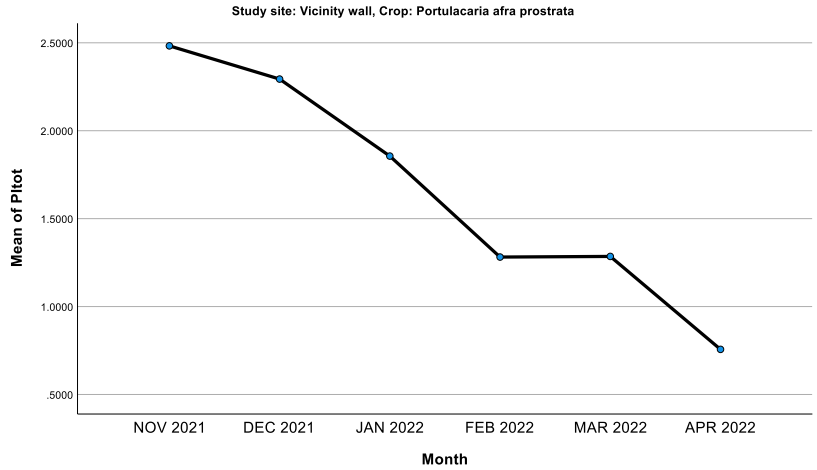
Crop[a]

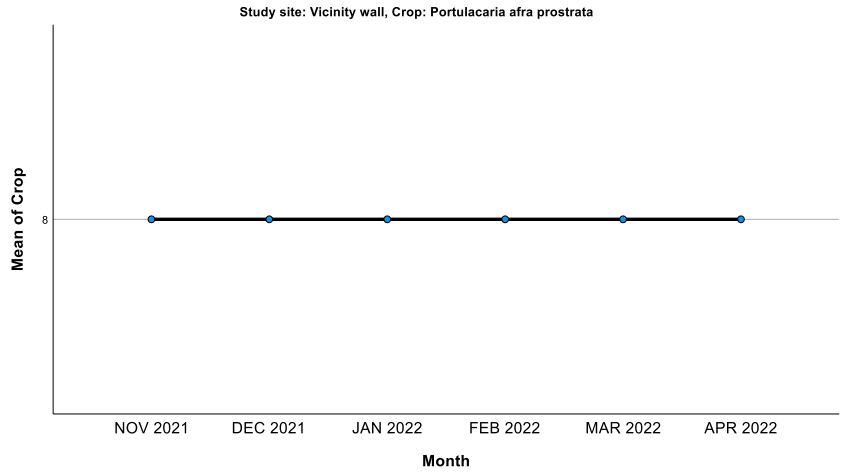
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Portulacaria afra prostrata

Means Plots







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Study site = Vicinity wall, Crop = Spinacea oleracea

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	3	.84333	.002887	.001667	.83616
	DEC 2021	6	.82633	.021602	.008819	.80366
	JAN 2022	7	.81529	.013111	.004956	.80316
	FEB 2022	9	.83111	.015504	.005168	.81919
	MAR 2022	8	.80900	.012083	.004272	.79890
	APR 2022	9	.82667	.029304	.009768	.80414
	Total	42	.82350	.020476	.003160	.81712
PI_total	NOV 2021	3	1.569900	.0800650	.0462256	1.371007
	DEC 2021	6	.987033	.4820973	.1968154	.481103
	JAN 2022	7	.510586	.1833430	.0692971	.341022
	FEB 2022	9	1.198522	.5953336	.1984445	.740908
	MAR 2022	8	.831375	.3007876	.1063445	.579910
	APR 2022	9	1.057500	.3752938	.1250979	.769024
	Total	42	.980029	.4741946	.0731698	.832259
Crop	NOV 2021	3	9.00	.000	.000	9.00
	DEC 2021	6	9.00	.000	.000	9.00
	JAN 2022	7	9.00	.000	.000	9.00
	FEB 2022	9	9.00	.000	.000	9.00
	MAR 2022	8	9.00	.000	.000	9.00
	APR 2022	9	9.00	.000	.000	9.00
	Total	42	9.00	.000	.000	9.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.85050	.840	.845
	DEC 2021	.84900	.788	.845
	JAN 2022	.82741	.788	.827
	FEB 2022	.84303	.813	.853
	MAR 2022	.81910	.790	.827
	APR 2022	.84919	.755	.847
	Total	.82988	.755	.853
PI_total	NOV 2021	1.768793	1.4779	1.6238
	DEC 2021	1.492963	.4755	1.7322
	JAN 2022	.680150	.1795	.6557
	FEB 2022	1.656136	.5564	2.1239
	MAR 2022	1.082840	.4149	1.2100
	APR 2022	1.345976	.5717	1.5944
	Total	1.127798	.1795	2.1239
Crop	NOV 2021	9.00	9	9
	DEC 2021	9.00	9	9
	JAN 2022	9.00	9	9
	FEB 2022	9.00	9	9
	MAR 2022	9.00	9	9
	APR 2022	9.00	9	9
	Total	9.00	9	9

a. Study_site = Vicinity wall, Crop = Spinacea oleracea

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.004	5	.001	2.179
	Within Groups	.013	36	.000	
	Total	.017	41		
PI_total	Between Groups	3.247	5	.649	3.915
	Within Groups	5.972	36	.166	
	Total	9.219	41		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	36	.000	
	Total	.000	41		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.078
	Within Groups	
	Total	
PI_total	Between Groups	.006
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Vicinity wall, Crop = Spinacea oleracea

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.232	.000	.364
	Epsilon-squared	.126	-.139	.275
	Omega-squared Fixed-effect	.123	-.135	.271
	Omega-squared Random-effect	.027	-.024	.069
PI_total	Eta-squared	.352	.042	.481
	Epsilon-squared	.262	-.092	.409
	Omega-squared Fixed-effect	.258	-.089	.404
	Omega-squared Random-effect	.065	-.017	.119
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Vicinity wall, Crop = Spinacea oleracea
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.017000	.013538	.806	-.02373	.05773
		JAN 2022	.028048	.013212	.299	-.01170	.06780
		FEB 2022	.012222	.012764	.928	-.02618	.05062
		MAR 2022	.034333	.012962	.111	-.00466	.07333
		APR 2022	.016667	.012764	.780	-.02173	.05507
	DEC 2021	NOV 2021	-.017000	.013538	.806	-.05773	.02373
		JAN 2022	.011048	.010652	.902	-.02100	.04309
		FEB 2022	-.004778	.010091	.997	-.03514	.02558
		MAR 2022	.017333	.010340	.556	-.01378	.04844
		APR 2022	-.000333	.010091	1.000	-.03069	.03003
	JAN 2022	NOV 2021	-.028048	.013212	.299	-.06780	.01170
		DEC 2021	-.011048	.010652	.902	-.04309	.02100
		FEB 2022	-.015825	.009649	.578	-.04485	.01320
		MAR 2022	.006286	.009909	.988	-.02353	.03610
		APR 2022	-.011381	.009649	.844	-.04041	.01765
	FEB 2022	NOV 2021	-.012222	.012764	.928	-.05062	.02618
		DEC 2021	.004778	.010091	.997	-.02558	.03514
		JAN 2022	.015825	.009649	.578	-.01320	.04485
		MAR 2022	.022111	.009303	.192	-.00588	.05010
		APR 2022	.004444	.009025	.996	-.02271	.03160
	MAR 2022	NOV 2021	-.034333	.012962	.111	-.07333	.00466
		DEC 2021	-.017333	.010340	.556	-.04844	.01378
		JAN 2022	-.006286	.009909	.988	-.03610	.02353
		FEB 2022	-.022111	.009303	.192	-.05010	.00588
		APR 2022	-.017667	.009303	.419	-.04566	.01032
	APR 2022	NOV 2021	-.016667	.012764	.780	-.05507	.02173
		DEC 2021	.000333	.010091	1.000	-.03003	.03069
		JAN 2022	.011381	.009649	.844	-.01765	.04041
		FEB 2022	-.004444	.009025	.996	-.03160	.02271
		MAR 2022	.017667	.009303	.419	-.01032	.04566
PI_total	NOV 2021	DEC 2021	.5828667	.2880020	.349	-.283609	1.449342
		JAN 2022	1.0593143*	.2810612	.007	.213721	1.904908
		FEB 2022	.3713778	.2715309	.745	-.445543	1.188299
		MAR 2022	.7385250	.2757409	.105	-.091062	1.568112
		APR 2022	.5124000	.2715309	.426	-.304521	1.329321
	DEC 2021	NOV 2021	-.5828667	.2880020	.349	-1.449342	.283609
		JAN 2022	.4764476	.2265988	.309	-.205292	1.158187
		FEB 2022	-.2114889	.2146640	.920	-.857322	.434344
		MAR 2022	.1556583	.2199652	.980	-.506123	.817440
		APR 2022	-.0704667	.2146640	.999	-.716299	.575366
	JAN 2022	NOV 2021	-1.0593143*	.2810612	.007	-1.904908	-.213721
		DEC 2021	-.4764476	.2265988	.309	-1.158187	.205292
		FEB 2022	-.6879365*	.2052581	.022	-1.305471	-.070402
		MAR 2022	-.3207893	.2107959	.653	-.954984	.313406
		APR 2022	-.5469143	.2052581	.108	-1.164448	.070620
	FEB 2022	NOV 2021	-.3713778	.2715309	.745	-1.188299	.445543
		DEC 2021	.2114889	.2146640	.920	-.434344	.857322
		JAN 2022	.6879365*	.2052581	.022	.070402	1.305471
		MAR 2022	.3671472	.1979104	.445	-.228281	.962576

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	APR 2022	.1410222	.1920013	.976	-.436628	.718673
MAR 2022	NOV 2021	-.7385250	.2757409	.105	-1.568112	.091062
	DEC 2021	-.1556583	.2199652	.980	-.817440	.506123
	JAN 2022	.3207893	.2107959	.653	-.313406	.954984
	FEB 2022	-.3671472	.1979104	.445	-.962576	.228281
	APR 2022	-.2261250	.1979104	.860	-.821553	.369303
APR 2022	NOV 2021	-.5124000	.2715309	.426	-1.329321	.304521
	DEC 2021	.0704667	.2146640	.999	-.575366	.716299
	JAN 2022	.5469143	.2052581	.108	-.070620	1.164448
	FEB 2022	-.1410222	.1920013	.976	-.718673	.436628
	MAR 2022	.2261250	.1979104	.860	-.369303	.821553

*. The mean difference is significant at the 0.05 level.
a. Study_site = Vicinity wall, Crop = Spinacea oleracea

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1	2
MAR 2022	8	.80900	
JAN 2022	7	.81529	.81529
DEC 2021	6	.82633	.82633
APR 2022	9	.82667	.82667
FEB 2022	9	.83111	.83111
NOV 2021	3		.84333
Sig.		.357	.137

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Vicinity wall, Crop = Spinacea oleracea
b. Uses Harmonic Mean Sample Size = 6.060.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1	2
JAN 2022	7	.510586	
MAR 2022	8	.831375	
DEC 2021	6	.987033	.987033
APR 2022	9	1.057500	1.057500
FEB 2022	9	1.198522	1.198522
NOV 2021	3		1.569900
Sig.		.059	.154

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Vicinity wall, Crop = Spinacea oleracea
b. Uses Harmonic Mean Sample Size = 6.060.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

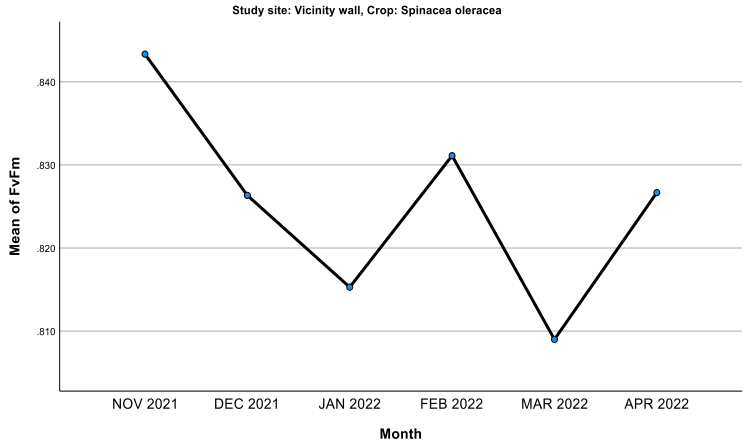
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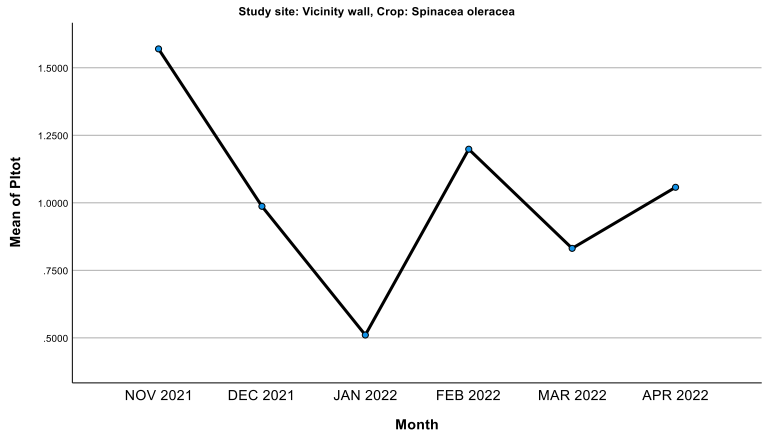
Crop[a]

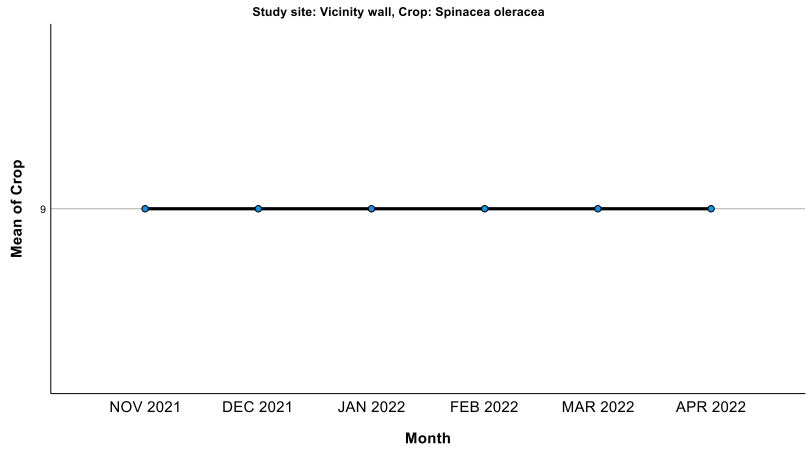
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Spinacea oleracea

Means Plots







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Study site = Vicinity wall, Crop = Vigna unguilata

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.81367	.018588	.006196	.79938
	DEC 2021	8	.82600	.013459	.004758	.81475
	JAN 2022	8	.81300	.004071	.001439	.80960
	FEB 2022	9	.81133	.008367	.002789	.80490
	MAR 2022	5	.78300	.018262	.008167	.76032
	APR 2022	6	.82517	.012123	.004949	.81244
	Total	45	.81340	.017541	.002615	.80813
PI_total	NOV 2021	9	1.523167	.5388543	.1796181	1.108967
	DEC 2021	8	2.482300	1.3050904	.4614191	1.391217
	JAN 2022	8	1.304988	.7426193	.2625556	.684142
	FEB 2022	9	1.224533	.2912403	.0970801	1.000666
	MAR 2022	5	1.697960	.8288864	.3706892	.668762
	APR 2022	6	3.069717	2.0068064	.8192753	.963702
	Total	45	1.820793	1.1748278	.1751330	1.467836
Crop	NOV 2021	9	10.00	.000	.000	10.00
	DEC 2021	8	10.00	.000	.000	10.00
	JAN 2022	8	10.00	.000	.000	10.00
	FEB 2022	9	10.00	.000	.000	10.00
	MAR 2022	5	10.00	.000	.000	10.00
	APR 2022	6	10.00	.000	.000	10.00
	Total	45	10.00	.000	.000	10.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.82795	.787	.840
	DEC 2021	.83725	.805	.841
	JAN 2022	.81640	.809	.821
	FEB 2022	.81776	.798	.822
	MAR 2022	.80568	.760	.800
	APR 2022	.83789	.810	.838
	Total	.81867	.760	.841
PI_total	NOV 2021	1.937367	1.0220	2.5285
	DEC 2021	3.573383	1.3564	4.8047
	JAN 2022	1.925833	.5420	2.3483
	FEB 2022	1.448400	.8756	1.7260
	MAR 2022	2.727158	.5833	2.6743
	APR 2022	5.175731	.7675	5.1674
	Total	2.173751	.5420	5.1674
Crop	NOV 2021	10.00	10	10
	DEC 2021	10.00	10	10
	JAN 2022	10.00	10	10
	FEB 2022	10.00	10	10
	MAR 2022	10.00	10	10
	APR 2022	10.00	10	10
	Total	10.00	10	10

a. Study_site = Vicinity wall, Crop = Vigna unguilata

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.007	5	.001	7.783
	Within Groups	.007	39	.000	
	Total	.014	44		
PI_total	Between Groups	19.060	5	3.812	3.568
	Within Groups	41.669	39	1.068	
	Total	60.730	44		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	39	.000	
	Total	.000	44		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
PI_total	Between Groups	.009
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Vicinity wall, Crop = Vigna unguilata

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.499	.199	.608
	Epsilon-squared	.435	.096	.557
	Omega-squared Fixed-effect	.430	.094	.552
	Omega-squared Random-effect	.131	.020	.197
PI_total	Eta-squared	.314	.026	.444
	Epsilon-squared	.226	-.099	.372
	Omega-squared Fixed-effect	.222	-.096	.367
	Omega-squared Random-effect	.054	-.018	.104
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Vicinity wall, Crop = Vigna unguilata
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.012333	.006405	.403	-.03152	.00686
		JAN 2022	.000667	.006405	1.000	-.01852	.01986
		FEB 2022	.002333	.006214	.999	-.01628	.02095
		MAR 2022	.030667*	.007353	.002	.00864	.05269
		APR 2022	-.011500	.006948	.568	-.03231	.00931
	DEC 2021	NOV 2021	.012333	.006405	.403	-.00686	.03152
		JAN 2022	.013000	.006591	.376	-.00675	.03275
		FEB 2022	.014667	.006405	.223	-.00452	.03386
		MAR 2022	.043000*	.007515	<,001	.02049	.06551
		APR 2022	.000833	.007119	1.000	-.02050	.02216
	JAN 2022	NOV 2021	-.000667	.006405	1.000	-.01986	.01852
		DEC 2021	-.013000	.006591	.376	-.03275	.00675
		FEB 2022	.001667	.006405	1.000	-.01752	.02086
		MAR 2022	.030000*	.007515	.004	.00749	.05251
		APR 2022	-.012167	.007119	.534	-.03350	.00916
	FEB 2022	NOV 2021	-.002333	.006214	.999	-.02095	.01628
		DEC 2021	-.014667	.006405	.223	-.03386	.00452
		JAN 2022	-.001667	.006405	1.000	-.02086	.01752
		MAR 2022	.028333*	.007353	.005	.00631	.05036
		APR 2022	-.013833	.006948	.366	-.03465	.00698
	MAR 2022	NOV 2021	-.030667*	.007353	.002	-.05269	-.00864
		DEC 2021	-.043000*	.007515	<,001	-.06551	-.02049
		JAN 2022	-.030000*	.007515	.004	-.05251	-.00749
		FEB 2022	-.028333*	.007353	.005	-.05036	-.00631
		APR 2022	-.042167*	.007982	<,001	-.06608	-.01825
	APR 2022	NOV 2021	.011500	.006948	.568	-.00931	.03231
		DEC 2021	-.000833	.007119	1.000	-.02216	.02050
		JAN 2022	.012167	.007119	.534	-.00916	.03350
		FEB 2022	.013833	.006948	.366	-.00698	.03465
		MAR 2022	.042167*	.007982	<,001	.01825	.06608
PI_total	NOV 2021	DEC 2021	-.9591333	.5022660	.412	-2.463916	.545650
		JAN 2022	.2181792	.5022660	.998	-1.286604	1.722962
		FEB 2022	.2986333	.4872696	.989	-1.161221	1.758487
		MAR 2022	-.1747933	.5765452	1.000	-1.902116	1.552529
		APR 2022	-1.5465500	.5447840	.072	-3.178716	.085616
	DEC 2021	NOV 2021	.9591333	.5022660	.412	-.545650	2.463916
		JAN 2022	1.1773125	.5168275	.227	-.371096	2.725721
		FEB 2022	1.2577667	.5022660	.148	-.247016	2.762550
		MAR 2022	.7843400	.5892740	.766	-.981118	2.549798
		APR 2022	-.5874167	.5582375	.897	-2.259889	1.085056
	JAN 2022	NOV 2021	-.2181792	.5022660	.998	-1.722962	1.286604
		DEC 2021	-1.1773125	.5168275	.227	-2.725721	.371096
		FEB 2022	.0804542	.5022660	1.000	-1.424329	1.585237
		MAR 2022	-.3929725	.5892740	.985	-2.158430	1.372485
		APR 2022	-1.7647292*	.5582375	.033	-3.437202	-.092256
	FEB 2022	NOV 2021	-.2986333	.4872696	.989	-1.758487	1.161221
		DEC 2021	-1.2577667	.5022660	.148	-2.762550	.247016
		JAN 2022	-.0804542	.5022660	1.000	-1.585237	1.424329
		MAR 2022	-.4734267	.5765452	.962	-2.200749	1.253896

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	APR 2022	-1.8451833*	.5447840	.019	-3.477350	-.213017
MAR 2022	NOV 2021	.1747933	.5765452	1.000	-1.552529	1.902116
	DEC 2021	-.7843400	.5892740	.766	-2.549798	.981118
	JAN 2022	.3929725	.5892740	.985	-1.372485	2.158430
	FEB 2022	.4734267	.5765452	.962	-1.253896	2.200749
	APR 2022	-1.3717567	.6259092	.265	-3.246973	.503460
APR 2022	NOV 2021	1.5465500	.5447840	.072	-.085616	3.178716
	DEC 2021	.5874167	.5582375	.897	-1.085056	2.259889
	JAN 2022	1.7647292*	.5582375	.033	.092256	3.437202
	FEB 2022	1.8451833*	.5447840	.019	.213017	3.477350
	MAR 2022	1.3717567	.6259092	.265	-.503460	3.246973

*. The mean difference is significant at the 0.05 level.
a. Study_site = Vicinity wall, Crop = Vigna unguilata

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

		Subset for alpha = 0.05	
Month	N	1	2
MAR 2022	5	.78300	
FEB 2022	9		.81133
JAN 2022	8		.81300
NOV 2021	9		.81367
APR 2022	6		.82517
DEC 2021	8		.82600
Sig.		1.000	.306

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Vicinity wall, Crop = Vigna unguilata
b. Uses Harmonic Mean Sample Size = 7.152.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

		Subset for alpha = 0.05	
Month	N	1	2
FEB 2022	9	1.224533	
JAN 2022	8	1.304988	
NOV 2021	9	1.523167	1.523167
MAR 2022	5	1.697960	1.697960
DEC 2021	8	2.482300	2.482300
APR 2022	6		3.069717
Sig.		.218	.074

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Vicinity wall, Crop = Vigna unguilata
b. Uses Harmonic Mean Sample Size = 7.152.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

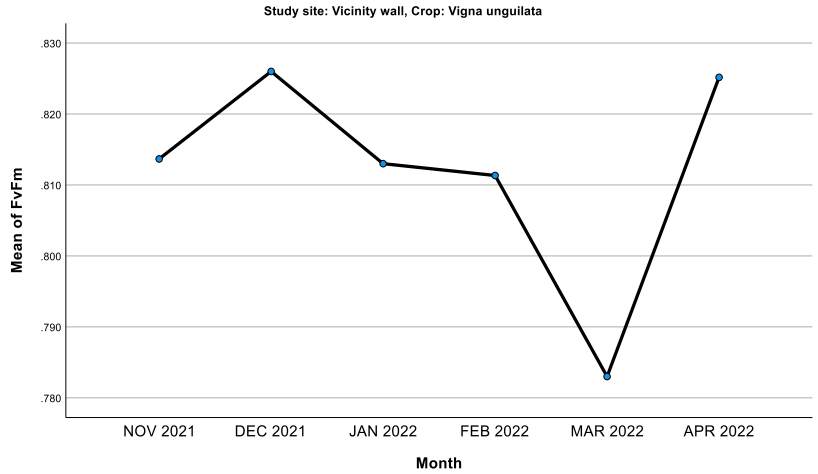
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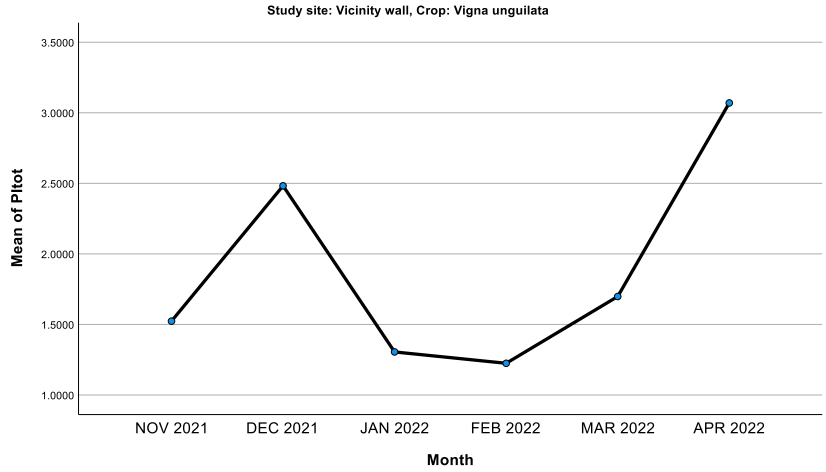
Crop[a]

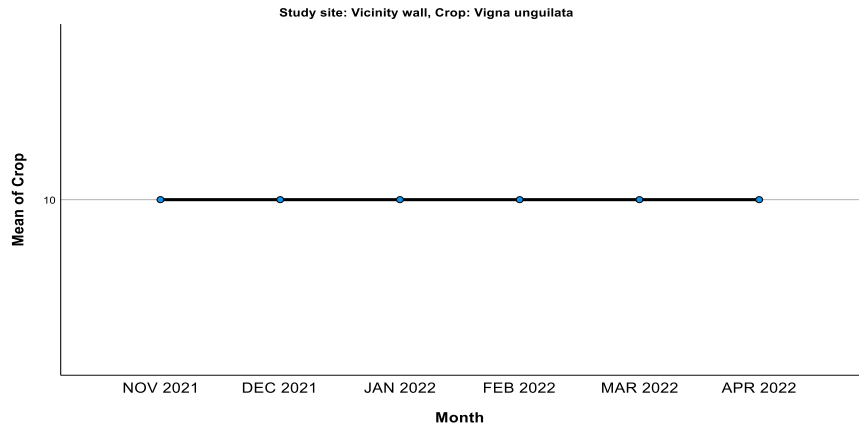
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Vicinity wall, Crop = Vigna unguilata

Means Plots







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Appendix K: Statistical analysis results of the crops' F_vF_m and PI_{total} in the natural soil area

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Oneway ANOVA
Natural soil area
Study site = Natural soil area, Crop = Amaranthus thunbergii

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	4	.77475	.014728	.007364	.75131
	DEC 2021	4	.77300	.019613	.009806	.74179
	FEB 2022	4	.76725	.006292	.003146	.75724
	Total	12	.77167	.013640	.003938	.76300
PI_total	NOV 2021	4	.946925	.1969920	.0984960	.633467
	DEC 2021	4	1.773100	.6684056	.3342028	.709518
	FEB 2022	4	2.370000	.2781363	.1390681	1.927423
	Total	12	1.696675	.7245139	.2091492	1.236341
Crop	NOV 2021	4	1.00	.000	.000	1.00
	DEC 2021	4	1.00	.000	.000	1.00
	FEB 2022	4	1.00	.000	.000	1.00
	Total	12	1.00	.000	.000	1.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.79819	.762	.795
	DEC 2021	.80421	.759	.802
	FEB 2022	.77726	.760	.773
	Total	.78033	.759	.802
PI_total	NOV 2021	1.260383	.7484	1.2176
	DEC 2021	2.836682	1.1331	2.7081
	FEB 2022	2.812577	2.0697	2.7393
	Total	2.157009	.7484	2.7393
Crop	NOV 2021	1.00	1	1
	DEC 2021	1.00	1	1
	FEB 2022	1.00	1	1
	Total	1.00	1	1

a. Study_site = Natural soil area, Crop = Amaranthus thunbergii

ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.000	2	.000	.288
	Within Groups	.002	9	.000	
	Total	.002	11		
PI_total	Between Groups	4.085	2	2.043	10.886
	Within Groups	1.689	9	.188	
	Total	5.774	11		
Crop	Between Groups	.000	2	.000	.
	Within Groups	.000	9	.000	
	Total	.000	11		

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ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.756
	Within Groups	
	Total	
PI_total	Between Groups	.004
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Amaranthus thunbergii

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.060	.000	.310
	Epsilon-squared	-.149	-.222	.156
	Omega-squared Fixed-effect	-.135	-.200	.145
	Omega-squared Random-effect	-.063	-.091	.078
PI_total	Eta-squared	.708	.154	.821
	Epsilon-squared	.643	-.034	.781
	Omega-squared Fixed-effect	.622	-.031	.766
	Omega-squared Random-effect	.452	-.015	.621
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area, Crop = Amaranthus thunbergii
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound
max_quantum_yield	NOV 2021	DEC 2021	.001750	.010337	.984	-.02711
		FEB 2022	.007500	.010337	.755	-.02136
	DEC 2021	NOV 2021	-.001750	.010337	.984	-.03061
		FEB 2022	.005750	.010337	.846	-.02311
	FEB 2022	NOV 2021	-.007500	.010337	.755	-.03636
		DEC 2021	-.005750	.010337	.846	-.03461
PI_total	NOV 2021	DEC 2021	-.8261750	.3063037	.058	-1.681377
		FEB 2022	-1.4230750*	.3063037	.003	-2.278277
	DEC 2021	NOV 2021	.8261750	.3063037	.058	-.029027
		FEB 2022	-.5969000	.3063037	.181	-1.452102
	FEB 2022	NOV 2021	1.4230750*	.3063037	.003	.567873
		DEC 2	9000	.3063037	.181	-.258302

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Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.03061
		FEB 2022	.03636
	DEC 2021	NOV 2021	.02711
		FEB 2022	.03461
	FEB 2022	NOV 2021	.02136
		DEC 2021	.02311
PI_total	NOV 2021	DEC 2021	.029027
		FEB 2022	-.567873
	DEC 2021	NOV 2021	1.681377
		FEB 2022	.258302
	FEB 2022	NOV 2021	2.278277
		DEC 2021	1.452102

*. The mean difference is significant at the 0.05 level.
a. Study_site = Natural soil area, Crop = Amaranthus thunbergii

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b]

Month	N	Subset for alpha = 0.05 1
FEB 2022	4	.76725
DEC 2021	4	.77300
NOV 2021	4	.77475
Sig.		.755

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Amaranthus thunbergii
b. Uses Harmonic Mean Sample Size = 4.000.

PI_total[a]

Tukey HSD[b]

Month	N	Subset for alpha = 0.05 1	2
NOV 2021	4	.946925	
DEC 2021	4	1.773100	1.773100
FEB 2022	4		2.370000
Sig.		.058	.181

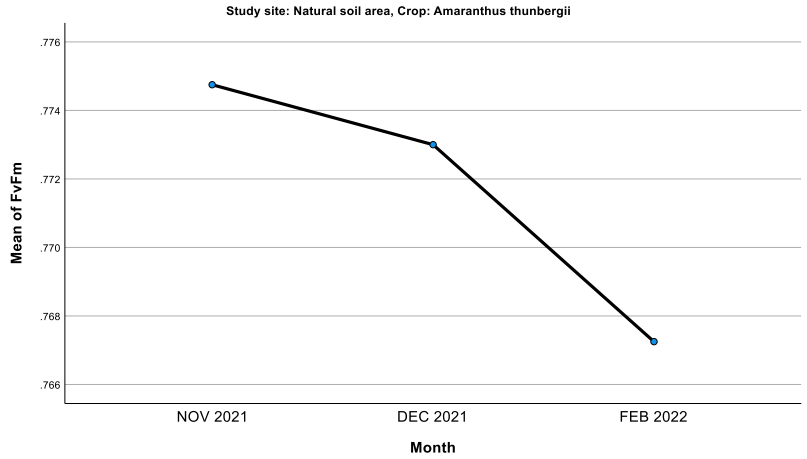
Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Amaranthus thunbergii
b. Uses Harmonic Mean Sample Size = 4.000.

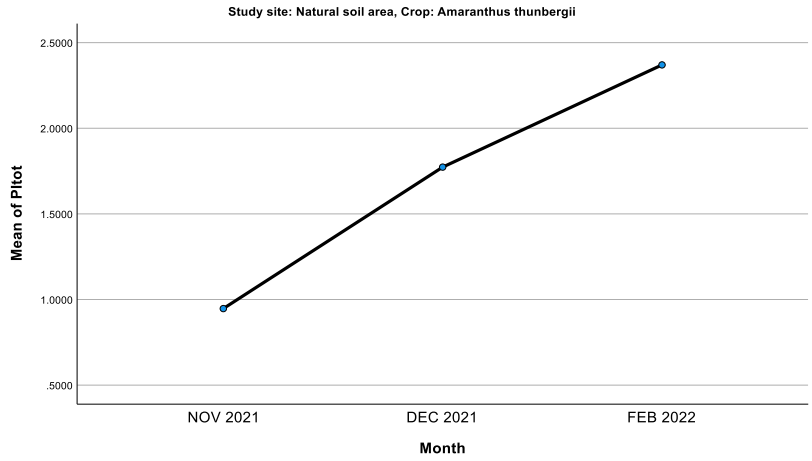
Crop[a]

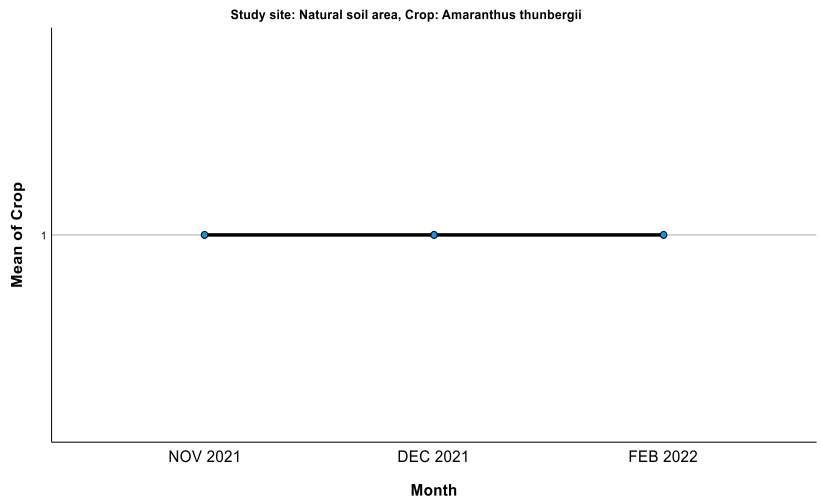
Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Amaranthus thunbergii

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Means Plots







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Study site = Natural soil area, Crop = Asystasia gangetica

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	6	.78950	.019440	.007936	.76910
	DEC 2021	9	.80267	.005568	.001856	.79839
	JAN 2022	9	.80056	.007126	.002375	.79508
	FEB 2022	9	.78633	.004690	.001563	.78273
	MAR 2022	9	.78989	.011450	.003817	.78109
	APR 2022	9	.79533	.012268	.004089	.78590
	Total	51	.79431	.011704	.001639	.79102
PI_total	NOV 2021	6	1.672567	.6721679	.2744114	.967170
	DEC 2021	9	1.545733	.6748396	.2249465	1.027006
	JAN 2022	9	1.755422	.2499397	.0833132	1.563302
	FEB 2022	9	1.197856	.1772297	.0590766	1.061625
	MAR 2022	9	1.245467	.2871910	.0957303	1.024712
	APR 2022	9	1.406078	.2561512	.0853837	1.209183
	Total	51	1.458635	.4476515	.0626838	1.332731
Crop	NOV 2021	6	2.00	.000	.000	2.00
	DEC 2021	9	2.00	.000	.000	2.00
	JAN 2022	9	2.00	.000	.000	2.00
	FEB 2022	9	2.00	.000	.000	2.00
	MAR 2022	9	2.00	.000	.000	2.00
	APR 2022	9	2.00	.000	.000	2.00
	Total	51	2.00	.000	.000	2.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.80990	.770	.810
	DEC 2021	.80695	.795	.810
	JAN 2022	.80603	.793	.815
	FEB 2022	.78994	.779	.793
	MAR 2022	.79869	.763	.804
	APR 2022	.80476	.773	.812
	Total	.79761	.763	.815
PI_total	NOV 2021	2.377964	.6789	2.4288
	DEC 2021	2.064461	.7782	2.6371
	JAN 2022	1.947543	1.3105	2.1281
	FEB 2022	1.334086	1.0461	1.4716
	MAR 2022	1.466221	1.0067	1.7683
	APR 2022	1.602973	1.0763	1.7929
	Total	1.584539	.6789	2.6371
Crop	NOV 2021	2.00	2	2
	DEC 2021	2.00	2	2
	JAN 2022	2.00	2	2
	FEB 2022	2.00	2	2
	MAR 2022	2.00	2	2
	APR 2022	2.00	2	2
	Total	2.00	2	2

a. Study_site = Natural soil area, Crop = Asystasia gangetica

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.002	5	.000	3.396
	Within Groups	.005	45	.000	
	Total	.007	50		
PI_total	Between Groups	2.181	5	.436	2.505
	Within Groups	7.838	45	.174	
	Total	10.020	50		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	45	.000	
	Total	.000	50		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.011
	Within Groups	
	Total	
PI_total	Between Groups	.044
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Asystasia gangetica

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.274	.019	.401
	Epsilon-squared	.193	-.090	.334
	Omega-squared Fixed-effect	.190	-.088	.330
	Omega-squared Random-effect	.045	-.016	.090
PI_total	Eta-squared	.218	.000	.343
	Epsilon-squared	.131	-.111	.270
	Omega-squared Fixed-effect	.129	-.109	.266
	Omega-squared Random-effect	.029	-.020	.068
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area, Crop = Asystasia gangetica
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.013167	.005540	.186	-.02965	.00332
		JAN 2022	-.011056	.005540	.361	-.02754	.00543
		FEB 2022	.003167	.005540	.992	-.01332	.01965
		MAR 2022	-.000389	.005540	1.000	-.01688	.01610
		APR 2022	-.005833	.005540	.897	-.02232	.01065
	DEC 2021	NOV 2021	.013167	.005540	.186	-.00332	.02965
		JAN 2022	.002111	.004955	.998	-.01264	.01686
		FEB 2022	.016333*	.004955	.022	.00159	.03108
		MAR 2022	.012778	.004955	.124	-.00197	.02752
		APR 2022	.007333	.004955	.678	-.00741	.02208
	JAN 2022	NOV 2021	.011056	.005540	.361	-.00543	.02754
		DEC 2021	-.002111	.004955	.998	-.01686	.01264
		FEB 2022	.014222	.004955	.064	-.00052	.02897
		MAR 2022	.010667	.004955	.280	-.00408	.02541
		APR 2022	.005222	.004955	.897	-.00952	.01997
	FEB 2022	NOV 2021	-.003167	.005540	.992	-.01965	.01332
		DEC 2021	-.016333*	.004955	.022	-.03108	-.00159
		JAN 2022	-.014222	.004955	.064	-.02897	.00052
		MAR 2022	-.003556	.004955	.979	-.01830	.01119
		APR 2022	-.009000	.004955	.466	-.02375	.00575
	MAR 2022	NOV 2021	.000389	.005540	1.000	-.01610	.01688
		DEC 2021	-.012778	.004955	.124	-.02752	.00197
		JAN 2022	-.010667	.004955	.280	-.02541	.00408
		FEB 2022	.003556	.004955	.979	-.01119	.01830
		APR 2022	-.005444	.004955	.879	-.02019	.00930
	APR 2022	NOV 2021	.005833	.005540	.897	-.01065	.02232
		DEC 2021	-.007333	.004955	.678	-.02208	.00741
		JAN 2022	-.005222	.004955	.897	-.01997	.00952
		FEB 2022	.009000	.004955	.466	-.00575	.02375
		MAR 2022	.005444	.004955	.879	-.00930	.02019
PI_total	NOV 2021	DEC 2021	.1268333	.2199620	.992	-.527769	.781436
		JAN 2022	-.0828556	.2199620	.999	-.737458	.571747
		FEB 2022	.4747111	.2199620	.277	-.179891	1.129313
		MAR 2022	.4271000	.2199620	.391	-.227502	1.081702
		APR 2022	.2664889	.2199620	.829	-.388113	.921091
	DEC 2021	NOV 2021	-.1268333	.2199620	.992	-.781436	.527769
		JAN 2022	-.2096889	.1967400	.892	-.795183	.375805
		FEB 2022	.3478778	.1967400	.496	-.237616	.933372
		MAR 2022	.3002667	.1967400	.650	-.285227	.885761
		APR 2022	.1396556	.1967400	.980	-.445839	.725150
	JAN 2022	NOV 2021	.0828556	.2199620	.999	-.571747	.737458
		DEC 2021	.2096889	.1967400	.892	-.375805	.795183
		FEB 2022	.5575667	.1967400	.070	-.027927	1.143061
		MAR 2022	.5099556	.1967400	.120	-.075539	1.095450
		APR 2022	.3493444	.1967400	.491	-.236150	.934839
	FEB 2022	NOV 2021	-.4747111	.2199620	.277	-1.129313	.179891
		DEC 2021	-.3478778	.1967400	.496	-.933372	.237616
		JAN 2022	-.5575667	.1967400	.070	-1.143061	.027927

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		MAR 2022	-.0476111	.1967400	1.000	-.633105	.537883
		APR 2022	-.2082222	.1967400	.895	-.793716	.377272
	MAR 2022	NOV 2021	-.4271000	.2199620	.391	-1.081702	.227502
		DEC 2021	-.3002667	.1967400	.650	-.885761	.285227
		JAN 2022	-.5099556	.1967400	.120	-1.095450	.075539
		FEB 2022	.0476111	.1967400	1.000	-.537883	.633105
		APR 2022	-.1606111	.1967400	.963	-.746105	.424883
	APR 2022	NOV 2021	-.2664889	.2199620	.829	-.921091	.388113
		DEC 2021	-.1396556	.1967400	.980	-.725150	.445839
		JAN 2022	-.3493444	.1967400	.491	-.934839	.236150
		FEB 2022	.2082222	.1967400	.895	-.377272	.793716
		MAR 2022	.1606111	.1967400	.963	-.424883	.746105

*. The mean difference is significant at the 0.05 level.
a. Study_site = Natural soil area, Crop = Asystasia gangetica

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
FEB 2022	9	.78633	
NOV 2021	6	.78950	.78950
MAR 2022	9	.78989	.78989
APR 2022	9	.79533	.79533
JAN 2022	9	.80056	.80056
DEC 2021	9		.80267
Sig.		.084	.131

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Asystasia gangetica
b. Uses Harmonic Mean Sample Size = 8.308.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05
		1
FEB 2022	9	1.197856
MAR 2022	9	1.245467
APR 2022	9	1.406078
DEC 2021	9	1.545733
NOV 2021	6	1.672567
JAN 2022	9	1.755422
Sig.		.090

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Asystasia gangetica
b. Uses Harmonic Mean Sample Size = 8.308.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

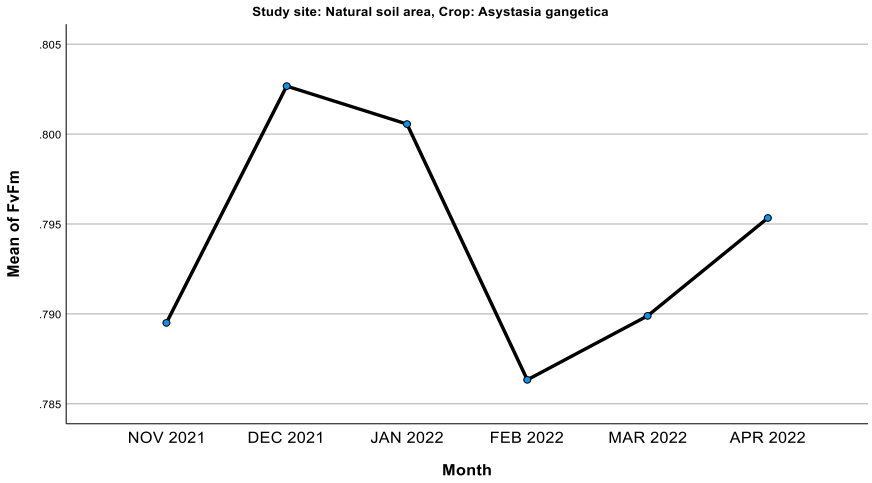
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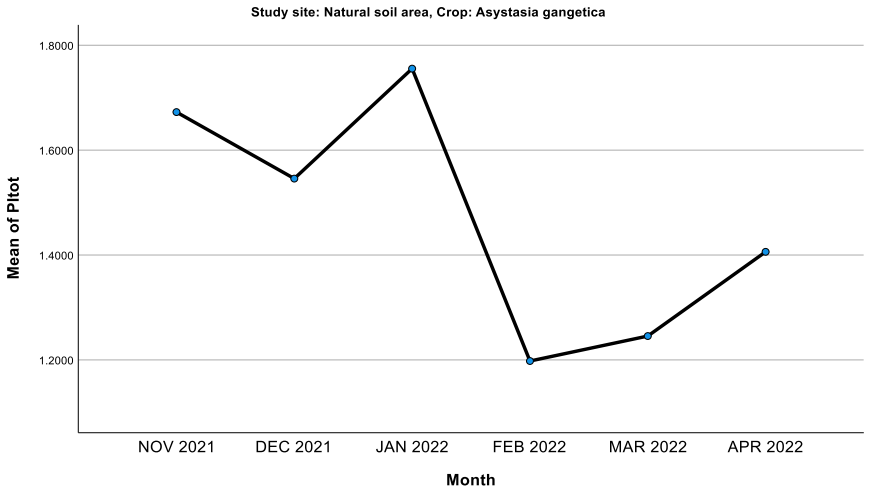
Crop[a]

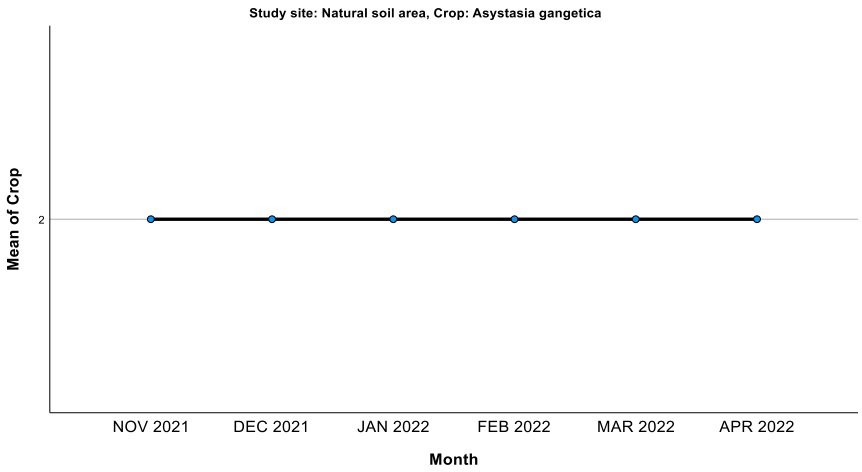
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Asystasia gangetica

Means Plots







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Study site = Natural soil area, Crop = Corchorus confusus

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	DEC 2021	9	.83833	.008337	.002779	.83193
	JAN 2022	9	.81344	.010748	.003583	.80518
	FEB 2022	9	.84089	.006528	.002176	.83587
	MAR 2022	8	.83675	.003808	.001346	.83357
	APR 2022	8	.82450	.025939	.009171	.80281
	Total	43	.83079	.016454	.002509	.82573
PI_total	DEC 2021	9	2.917656	1.3815805	.4605268	1.855679
	JAN 2022	9	2.771578	.3916072	.1305357	2.470562
	FEB 2022	9	3.218044	.9821308	.3273769	2.463112
	MAR 2022	8	3.496875	.4010972	.1418093	3.161549
	APR 2022	8	.891788	.5718735	.2021878	.413689
	Total	43	2.680809	1.2124174	.1848919	2.307682
Crop	DEC 2021	9	3.00	.000	.000	3.00
	JAN 2022	9	3.00	.000	.000	3.00
	FEB 2022	9	3.00	.000	.000	3.00
	MAR 2022	8	3.00	.000	.000	3.00
	APR 2022	8	3.00	.000	.000	3.00
	Total	43	3.00	.000	.000	3.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	DEC 2021	.84474	.823	.854
	JAN 2022	.82171	.794	.828
	FEB 2022	.84591	.831	.854
	MAR 2022	.83993	.829	.841
	APR 2022	.84619	.779	.857
	Total	.83585	.779	.857
PI_total	DEC 2021	3.979632	1.4847	5.4229
	JAN 2022	3.072594	2.0057	3.2098
	FEB 2022	3.972977	1.8933	4.8075
	MAR 2022	3.832201	3.0951	4.2875
	APR 2022	1.369886	.2267	1.8493
	Total	3.053936	.2267	5.4229
Crop	DEC 2021	3.00	3	3
	JAN 2022	3.00	3	3
	FEB 2022	3.00	3	3
	MAR 2022	3.00	3	3
	APR 2022	3.00	3	3
	Total	3.00	3	3

a. Study_site = Natural soil area, Crop = Corchorus confusus

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.005	4	.001	6.787
	Within Groups	.007	38	.000	
	Total	.011	42		
PI_total	Between Groups	34.109	4	8.527	11.728
	Within Groups	27.629	38	.727	
	Total	61.738	42		
Crop	Between Groups	.000	4	.000	.
	Within Groups	.000	38	.000	
	Total	.000	42		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Chorchorus confusus

ANOVA Effect Sizes[a,b]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.417	.123	.549
	Epsilon-squared	.355	.031	.501
	Omega-squared Fixed-effect	.350	.030	.496
	Omega-squared Random-effect	.119	.008	.197
PI_total	Eta-squared	.552	.273	.660
	Epsilon-squared	.505	.197	.624
	Omega-squared Fixed-effect	.499	.193	.618
	Omega-squared Random-effect	.200	.056	.288
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area, Crop = Chorchorus confusus

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	DEC 2021	JAN 2022	.024889*	.006228	.003	.00706	.04272
		FEB 2022	-.002556	.006228	.994	-.02039	.01528
		MAR 2022	.001583	.006420	.999	-.01680	.01996
		APR 2022	.013833	.006420	.219	-.00455	.03221
	JAN 2022	DEC 2021	-.024889*	.006228	.003	-.04272	-.00706
		FEB 2022	-.027444*	.006228	<,001	-.04528	-.00961
		MAR 2022	-.023306*	.006420	.007	-.04169	-.00493
		APR 2022	-.011056	.006420	.433	-.02944	.00732
	FEB 2022	DEC 2021	.002556	.006228	.994	-.01528	.02039
		JAN 2022	.027444*	.006228	<,001	.00961	.04528
		MAR 2022	.004139	.006420	.967	-.01424	.02252
		APR 2022	.016389	.006420	.100	-.00199	.03477
	MAR 2022	DEC 2021	-.001583	.006420	.999	-.01996	.01680
		JAN 2022	.023306*	.006420	.007	.00493	.04169
		FEB 2022	-.004139	.006420	.967	-.02252	.01424
		APR 2022	.012250	.006606	.359	-.00666	.03116
	APR 2022	DEC 2021	-.013833	.006420	.219	-.03221	.00455
		JAN 2022	.011056	.006420	.433	-.00732	.02944
		FEB 2022	-.016389	.006420	.100	-.03477	.00199
		MAR 2022	-.012250	.006606	.359	-.03116	.00666
PI_total	DEC 2021	JAN 2022	.1460778	.4019619	.996	-1.004764	1.296919
		FEB 2022	-.3003889	.4019619	.944	-1.451230	.850452
		MAR 2022	-.5792194	.4143328	.633	-1.765480	.607041
		APR 2022	2.0258681*	.4143328	<,001	.839608	3.212128
	JAN 2022	DEC 2021	-.1460778	.4019619	.996	-1.296919	1.004764
		FEB 2022	-.4464667	.4019619	.800	-1.597308	.704375
		MAR 2022	-.7252972	.4143328	.417	-1.911557	.460963
		APR 2022	1.8797903*	.4143328	<,001	.693530	3.066050
	FEB 2022	DEC 2021	.3003889	.4019619	.944	-.850452	1.451230
		JAN 2022	.4464667	.4019619	.800	-.704375	1.597308
		MAR 2022	-.2788306	.4143328	.961	-1.465091	.907430
		APR 2022	2.3262569*	.4143328	<,001	1.139997	3.512517
	MAR 2022	DEC 2021	.5792194	.4143328	.633	-.607041	1.765480
		JAN 2022	.7252972	.4143328	.417	-.460963	1.911557
		FEB 2022	.2788306	.4143328	.961	-.907430	1.465091
		APR 2022	2.6050875*	.4263449	<,001	1.384436	3.825739
	APR 2022	DEC 2021	-2.0258681*	.4143328	<,001	-3.212128	-.839608
		JAN 2022	-1.8797903*	.4143328	<,001	-3.066050	-.693530
		FEB 2022	-2.3262569*	.4143328	<,001	-3.512517	-1.139997
		MAR 2022	-2.6050875*	.4263449	<,001	-3.825739	-1.384436

*. The mean difference is significant at the 0.05 level.

a. Study_site = Natural soil area, Crop = Chorchorus confusus

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
JAN 2022	9	.81344	
APR 2022	8	.82450	.82450
MAR 2022	8		.83675
DEC 2021	9		.83833
FEB 2022	9		.84089
Sig.		.427	.097

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Corchorus confusus

b. Uses Harmonic Mean Sample Size = 8.571.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
APR 2022	8	.891788	
JAN 2022	9		2.771578
DEC 2021	9		2.917656
FEB 2022	9		3.218044
MAR 2022	8		3.496875
Sig.		1.000	.411

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Corchorus confusus

b. Uses Harmonic Mean Sample Size = 8.571.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

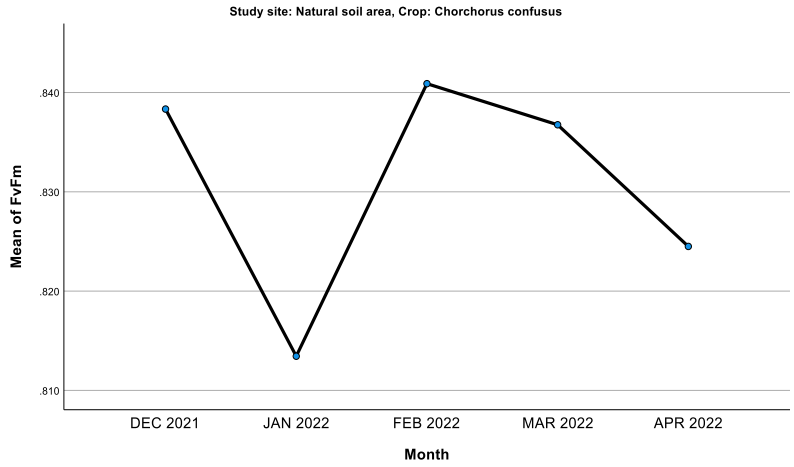
Crop[a]

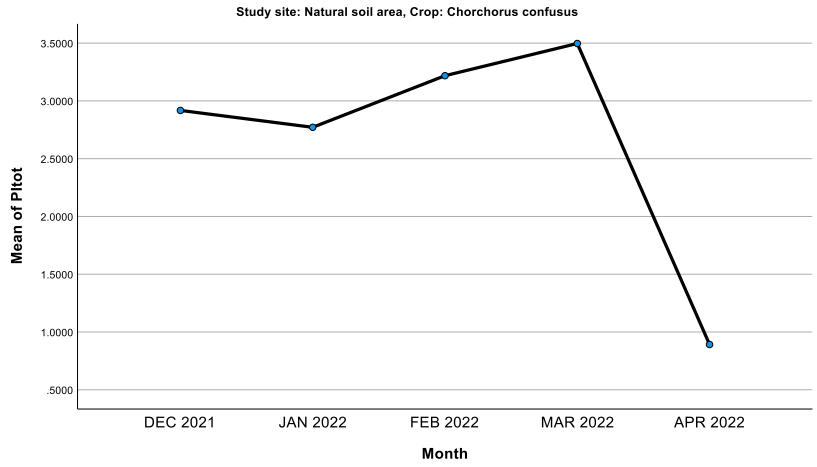
Means for groups in homogeneous subsets are displayed.[a]

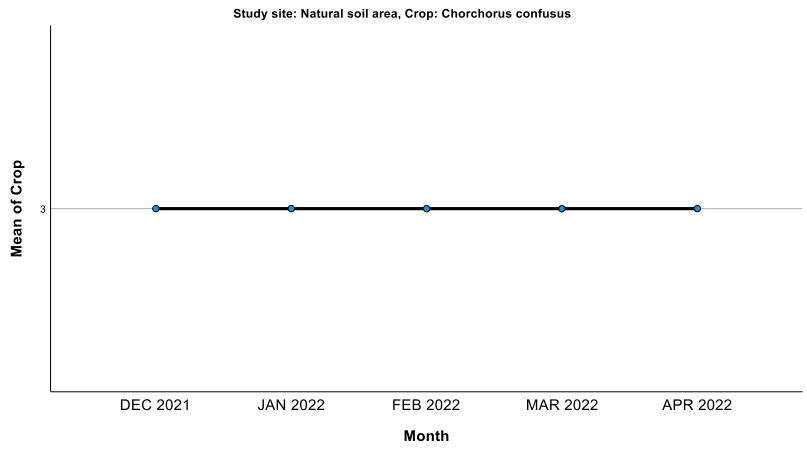
a. Study_site = Natural soil area, Crop = Chorchorus confusus

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Means Plots







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Study site = Natural soil area, Crop = Dicliptera clinopodia

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.78689	.018196	.006065	.77290
	DEC 2021	6	.78350	.007064	.002884	.77609
	JAN 2022	3	.79433	.001528	.000882	.79054
	FEB 2022	3	.77033	.002082	.001202	.76516
	MAR 2022	3	.78600	.003464	.002000	.77739
	APR 2022	3	.78267	.002517	.001453	.77642
	Total	27	.78456	.012270	.002361	.77970
PI_total	NOV 2021	9	.834322	.5142521	.1714174	.439033
	DEC 2021	6	1.289333	.3817567	.1558515	.888704
	JAN 2022	3	1.375567	.3170710	.1830610	.587919
	FEB 2022	3	1.109967	.1393705	.0804656	.763751
	MAR 2022	3	.931000	.0608570	.0351358	.779823
	APR 2022	3	1.489700	.0974280	.0562501	1.247675
	Total	27	1.109763	.4264253	.0820656	.941075
Crop	NOV 2021	9	4.00	.000	.000	4.00
	DEC 2021	6	4.00	.000	.000	4.00
	JAN 2022	3	4.00	.000	.000	4.00
	FEB 2022	3	4.00	.000	.000	4.00
	MAR 2022	3	4.00	.000	.000	4.00
	APR 2022	3	4.00	.000	.000	4.00
	Total	27	4.00	.000	.000	4.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.80088	.757	.813
	DEC 2021	.79091	.776	.795
	JAN 2022	.79813	.793	.796
	FEB 2022	.77550	.768	.772
	MAR 2022	.79461	.782	.788
	APR 2022	.78892	.780	.785
	Total	.78941	.757	.813
PI_total	NOV 2021	1.229611	.4295	1.7848
	DEC 2021	1.689962	.9940	1.9987
	JAN 2022	2.163215	1.0512	1.6848
	FEB 2022	1.456182	.9540	1.2223
	MAR 2022	1.082177	.8898	1.0009
	APR 2022	1.731725	1.3976	1.5917
	Total	1.278451	.4295	1.9987
Crop	NOV 2021	4.00	4	4
	DEC 2021	4.00	4	4
	JAN 2022	4.00	4	4
	FEB 2022	4.00	4	4
	MAR 2022	4.00	4	4
	APR 2022	4.00	4	4
	Total	4.00	4	4

a. Study_site = Natural soil area, Crop = Dicliptera clinopodia

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.001	5	.000	1.376
	Within Groups	.003	21	.000	
	Total	.004	26		
PI_total	Between Groups	1.617	5	.323	2.183
	Within Groups	3.111	21	.148	
	Total	4.728	26		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	21	.000	
	Total	.000	26		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.273
	Within Groups	
	Total	
PI_total	Between Groups	.095
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Dicliptera clinopodia

ANOVA Effect Sizes[a,b,c]

		Point Estimate	95% Confidence Interval Lower	Upper
max_quantum_yield	Eta-squared	.247	.000	.386
	Epsilon-squared	.068	-.238	.240
	Omega-squared Fixed-effect	.065	-.227	.233
	Omega-squared Random-effect	.014	-.038	.057
PI_total	Eta-squared	.342	.000	.481
	Epsilon-squared	.185	-.238	.357
	Omega-squared Fixed-effect	.180	-.227	.349
	Omega-squared Random-effect	.042	-.038	.097
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area, Crop = Dicliptera clinopodia
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	.003389	.006245	.994	-.01615	.02293
		JAN 2022	-.007444	.007899	.931	-.03216	.01727
		FEB 2022	.016556	.007899	.327	-.00816	.04127
		MAR 2022	.000889	.007899	1.000	-.02382	.02560
		APR 2022	.004222	.007899	.994	-.02049	.02894
	DEC 2021	NOV 2021	-.003389	.006245	.994	-.02293	.01615
		JAN 2022	-.010833	.008379	.785	-.03705	.01538
		FEB 2022	.013167	.008379	.625	-.01305	.03938
		MAR 2022	-.002500	.008379	1.000	-.02871	.02371
		APR 2022	.000833	.008379	1.000	-.02538	.02705
	JAN 2022	NOV 2021	.007444	.007899	.931	-.01727	.03216
		DEC 2021	.010833	.008379	.785	-.01538	.03705
		FEB 2022	.024000	.009675	.175	-.00627	.05427
		MAR 2022	.008333	.009675	.952	-.02193	.03860
		APR 2022	.011667	.009675	.829	-.01860	.04193
	FEB 2022	NOV 2021	-.016556	.007899	.327	-.04127	.00816
		DEC 2021	-.013167	.008379	.625	-.03938	.01305
		JAN 2022	-.024000	.009675	.175	-.05427	.00627
		MAR 2022	-.015667	.009675	.596	-.04593	.01460
		APR 2022	-.012333	.009675	.795	-.04260	.01793
	MAR 2022	NOV 2021	-.000889	.007899	1.000	-.02560	.02382
		DEC 2021	.002500	.008379	1.000	-.02371	.02871
		JAN 2022	-.008333	.009675	.952	-.03860	.02193
		FEB 2022	.015667	.009675	.596	-.01460	.04593
		APR 2022	.003333	.009675	.999	-.02693	.03360
	APR 2022	NOV 2021	-.004222	.007899	.994	-.02894	.02049
		DEC 2021	-.000833	.008379	1.000	-.02705	.02538
		JAN 2022	-.011667	.009675	.829	-.04193	.01860
		FEB 2022	.012333	.009675	.795	-.01793	.04260
		MAR 2022	-.003333	.009675	.999	-.03360	.02693
PI_total	NOV 2021	DEC 2021	-.4550111	.2028449	.261	-1.089609	.179587
		JAN 2022	-.5412444	.2565807	.320	-1.343955	.261466
		FEB 2022	-.2756444	.2565807	.886	-1.078355	.527066
		MAR 2022	-.0966778	.2565807	.999	-.899388	.706033
		APR 2022	-.6553778	.2565807	.153	-1.458088	.147333
	DEC 2021	NOV 2021	.4550111	.2028449	.261	-.179587	1.089609
		JAN 2022	-.0862333	.2721450	1.000	-.937636	.765169
		FEB 2022	.1793667	.2721450	.985	-.672036	1.030769
		MAR 2022	.3583333	.2721450	.773	-.493069	1.209736
		APR 2022	-.2003667	.2721450	.975	-1.051769	.651036
	JAN 2022	NOV 2021	.5412444	.2565807	.320	-.261466	1.343955
		DEC 2021	.0862333	.2721450	1.000	-.765169	.937636
		FEB 2022	.2656000	.3142459	.955	-.717515	1.248715
		MAR 2022	.4445667	.3142459	.718	-.538549	1.427682
		APR 2022	-.1141333	.3142459	.999	-1.097249	.868982
	FEB 2022	NOV 2021	.2756444	.2565807	.886	-.527066	1.078355
		DEC 2021	-.1793667	.2721450	.985	-1.030769	.672036
		JAN 2022	-.2656000	.3142459	.955	-1.248715	.717515

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		MAR 2022	.1789667	.3142459	.992	-.804149	1.162082
		APR 2022	-.3797333	.3142459	.828	-1.362849	.603382
	MAR 2022	NOV 2021	.0966778	.2565807	.999	-.706033	.899388
		DEC 2021	-.3583333	.2721450	.773	-1.209736	.493069
		JAN 2022	-.4445667	.3142459	.718	-1.427682	.538549
		FEB 2022	-.1789667	.3142459	.992	-1.162082	.804149
		APR 2022	-.5587000	.3142459	.500	-1.541815	.424415
	APR 2022	NOV 2021	.6553778	.2565807	.153	-.147333	1.458088
		DEC 2021	.2003667	.2721450	.975	-.651036	1.051769
		JAN 2022	.1141333	.3142459	.999	-.868982	1.097249
		FEB 2022	.3797333	.3142459	.828	-.603382	1.362849
		MAR 2022	.5587000	.3142459	.500	-.424415	1.541815

a. Study_site = Natural soil area, Crop = Dicliptera clinopodia

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1
FEB 2022	3	.77033
APR 2022	3	.78267
DEC 2021	6	.78350
MAR 2022	3	.78600
NOV 2021	9	.78689
JAN 2022	3	.79433
Sig.		.104

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Dicliptera clinopodia

b. Uses Harmonic Mean Sample Size = 3.724.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05 1
NOV 2021	9	.834322
MAR 2022	3	.931000
FEB 2022	3	1.109967
DEC 2021	6	1.289333
JAN 2022	3	1.375567
APR 2022	3	1.489700
Sig.		.229

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Dicliptera clinopodia

b. Uses Harmonic Mean Sample Size = 3.724.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

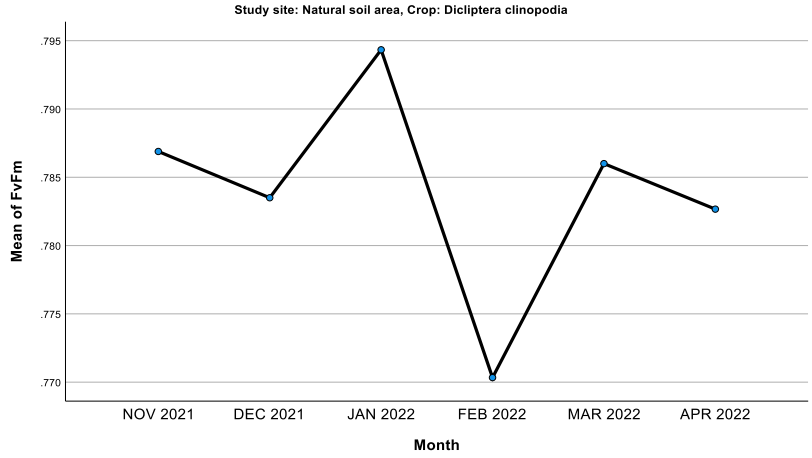
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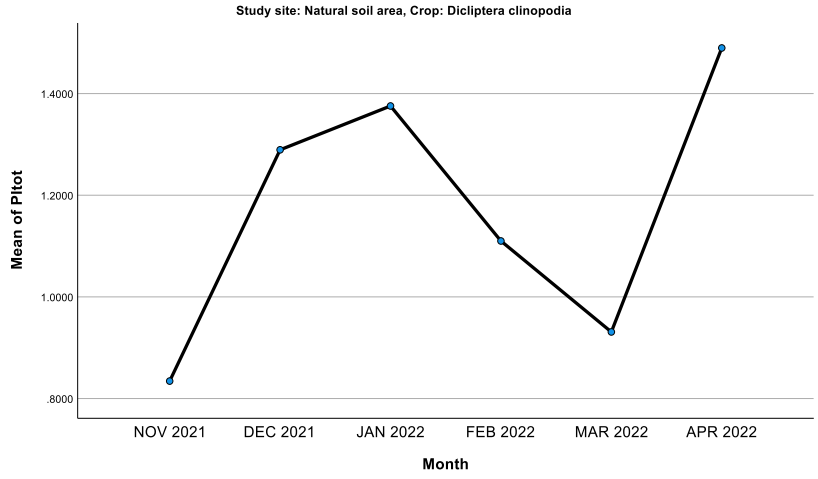
Crop[a]

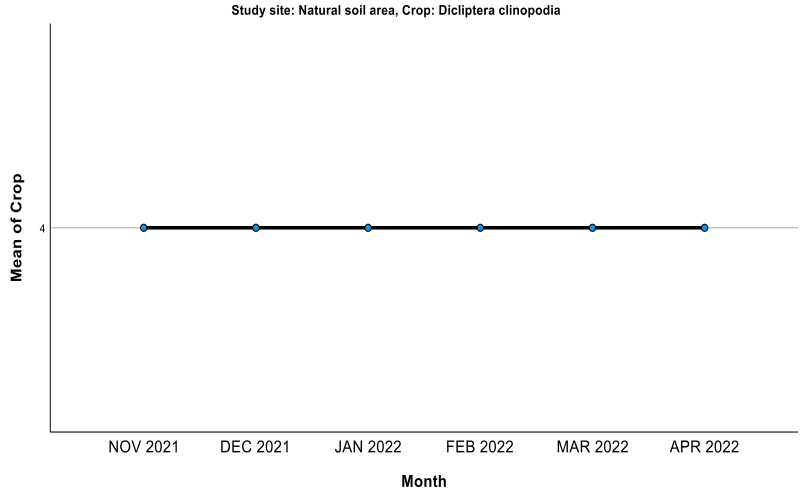
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Dicliptera clinopodia

Means Plots







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Study site = Natural soil area, Crop = Mentha aquatica

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	4	.81125	.003862	.001931	.80510
	DEC 2021	9	.82422	.003930	.001310	.82120
	JAN 2022	6	.81183	.007679	.003135	.80377
	FEB 2022	6	.82367	.005820	.002376	.81756
	MAR 2022	6	.82767	.005086	.002076	.82233
	APR 2022	8	.81950	.013969	.004939	.80782
	Total	39	.82046	.009489	.001519	.81739
PI_total	NOV 2021	4	.730725	.1091560	.0545780	.557033
	DEC 2021	9	.920156	.0900535	.0300178	.850934
	JAN 2022	6	.621433	.1259743	.0514288	.489231
	FEB 2022	6	.792817	.0479465	.0195741	.742500
	MAR 2022	6	.778050	.1362914	.0556407	.635021
	APR 2022	8	.711112	.0852148	.0301280	.639871
	Total	39	.770436	.1364919	.0218562	.726190
Crop	NOV 2021	4	5.00	.000	.000	5.00
	DEC 2021	9	5.00	.000	.000	5.00
	JAN 2022	6	5.00	.000	.000	5.00
	FEB 2022	6	5.00	.000	.000	5.00
	MAR 2022	6	5.00	.000	.000	5.00
	APR 2022	8	5.00	.000	.000	5.00
	Total	39	5.00	.000	.000	5.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.81740	.806	.815
	DEC 2021	.82724	.816	.829
	JAN 2022	.81989	.801	.821
	FEB 2022	.82977	.817	.833
	MAR 2022	.83300	.821	.834
	APR 2022	.83118	.800	.842
	Total	.82354	.800	.842
PI_total	NOV 2021	.904417	.6187	.8623
	DEC 2021	.989377	.7813	1.0977
	JAN 2022	.753635	.4469	.8124
	FEB 2022	.843133	.7329	.8654
	MAR 2022	.921079	.5787	.9354
	APR 2022	.782354	.5739	.8430
	Total	.814681	.4469	1.0977
Crop	NOV 2021	5.00	5	5
	DEC 2021	5.00	5	5
	JAN 2022	5.00	5	5
	FEB 2022	5.00	5	5
	MAR 2022	5.00	5	5
	APR 2022	5.00	5	5
	Total	5.00	5	5

a. Study_site = Natural soil area, Crop = Mentha aquatica

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.001	5	.000	4.013
	Within Groups	.002	33	.000	
	Total	.003	38		
PI_total	Between Groups	.373	5	.075	7.340
	Within Groups	.335	33	.010	
	Total	.708	38		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	33	.000	
	Total	.000	38		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.006
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Mentha aquatica

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.378	.047	.507
	Epsilon-squared	.284	-.098	.432
	Omega-squared Fixed-effect	.279	-.095	.426
	Omega-squared Random-effect	.072	-.018	.129
PI_total	Eta-squared	.527	.196	.633
	Epsilon-squared	.455	.074	.577
	Omega-squared Fixed-effect	.448	.073	.571
	Omega-squared Random-effect	.140	.015	.210
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area, Crop = Mentha aquatica

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.012972	.004825	.105	-.02756	.00162
		JAN 2022	-.000583	.005183	1.000	-.01626	.01509
		FEB 2022	-.012417	.005183	.187	-.02809	.00326
		MAR 2022	-.016417*	.005183	.036	-.03209	-.00074
		APR 2022	-.008250	.004917	.555	-.02312	.00662
	DEC 2021	NOV 2021	.012972	.004825	.105	-.00162	.02756
		JAN 2022	.012389	.004232	.062	-.00041	.02518
		FEB 2022	.000556	.004232	1.000	-.01224	.01335
		MAR 2022	-.003444	.004232	.963	-.01624	.00935
		APR 2022	.004722	.003902	.829	-.00708	.01652
	JAN 2022	NOV 2021	.000583	.005183	1.000	-.01509	.01626
		DEC 2021	-.012389	.004232	.062	-.02518	.00041
		FEB 2022	-.011833	.004636	.138	-.02585	.00218
		MAR 2022	-.015833*	.004636	.019	-.02985	-.00182
		APR 2022	-.007667	.004337	.499	-.02078	.00545
	FEB 2022	NOV 2021	.012417	.005183	.187	-.00326	.02809
		DEC 2021	-.000556	.004232	1.000	-.01335	.01224
		JAN 2022	.011833	.004636	.138	-.00218	.02585
		MAR 2022	-.004000	.004636	.953	-.01802	.01002
		APR 2022	.004167	.004337	.927	-.00895	.01728
	MAR 2022	NOV 2021	.016417*	.005183	.036	.00074	.03209
		DEC 2021	.003444	.004232	.963	-.00935	.01624
		JAN 2022	.015833*	.004636	.019	.00182	.02985
		FEB 2022	.004000	.004636	.953	-.01002	.01802
		APR 2022	.008167	.004337	.430	-.00495	.02128
	APR 2022	NOV 2021	.008250	.004917	.555	-.00662	.02312
		DEC 2021	-.004722	.003902	.829	-.01652	.00708
		JAN 2022	.007667	.004337	.499	-.00545	.02078
		FEB 2022	-.004167	.004337	.927	-.01728	.00895
		MAR 2022	-.008167	.004337	.430	-.02128	.00495
PI_total	NOV 2021	DEC 2021	-.1894306*	.0605616	.039	-.372540	-.006321
		JAN 2022	.1092917	.0650536	.554	-.087400	.305983
		FEB 2022	-.0620917	.0650536	.929	-.258783	.134600
		MAR 2022	-.0473250	.0650536	.977	-.244016	.149366
		APR 2022	.0196125	.0617152	1.000	-.166985	.206210
	DEC 2021	NOV 2021	.1894306*	.0605616	.039	.006321	.372540
		JAN 2022	.2987222*	.0531160	<,001	.138124	.459320
		FEB 2022	.1273389	.0531160	.187	-.033259	.287937
		MAR 2022	.1421056	.0531160	.108	-.018492	.302703
		APR 2022	.2090431*	.0489705	.002	.060979	.357107
	JAN 2022	NOV 2021	-.1092917	.0650536	.554	-.305983	.087400
		DEC 2021	-.2987222*	.0531160	<,001	-.459320	-.138124
		FEB 2022	-.1713833	.0581857	.060	-.347310	.004543
		MAR 2022	-.1566167	.0581857	.104	-.332543	.019310
		APR 2022	-.0896792	.0544277	.574	-.254243	.074885
	FEB 2022	NOV 2021	.0620917	.0650536	.929	-.134600	.258783
		DEC 2021	-.1273389	.0531160	.187	-.287937	.033259
		JAN 2022	.1713833	.0581857	.060	-.004543	.347310

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		MAR 2022	.0147667	.0581857	1.000	-.161160	.190693
		APR 2022	.0817042	.0544277	.666	-.082860	.246268
	MAR 2022	NOV 2021	.0473250	.0650536	.977	-.149366	.244016
		DEC 2021	-.1421056	.0531160	.108	-.302703	.018492
		JAN 2022	.1566167	.0581857	.104	-.019310	.332543
		FEB 2022	-.0147667	.0581857	1.000	-.190693	.161160
		APR 2022	.0669375	.0544277	.819	-.097626	.231501
	APR 2022	NOV 2021	-.0196125	.0617152	1.000	-.206210	.166985
		DEC 2021	-.2090431*	.0489705	.002	-.357107	-.060979
		JAN 2022	.0896792	.0544277	.574	-.074885	.254243
		FEB 2022	-.0817042	.0544277	.666	-.246268	.082860
		MAR 2022	-.0669375	.0544277	.819	-.231501	.097626

*. The mean difference is significant at the 0.05 level.
a. Study_site = Natural soil area, Crop = Mentha aquatica

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
NOV 2021	4	.81125	
JAN 2022	6	.81183	
APR 2022	8	.81950	.81950
FEB 2022	6	.82367	.82367
DEC 2021	9	.82422	.82422
MAR 2022	6		.82767
Sig.		.079	.496

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Mentha aquatica
b. Uses Harmonic Mean Sample Size = 6.085.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
JAN 2022	6	.621433	
APR 2022	8	.711112	
NOV 2021	4	.730725	
MAR 2022	6	.778050	.778050
FEB 2022	6	.792817	.792817
DEC 2021	9		.920156
Sig.		.057	.166

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Mentha aquatica
b. Uses Harmonic Mean Sample Size = 6.085.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

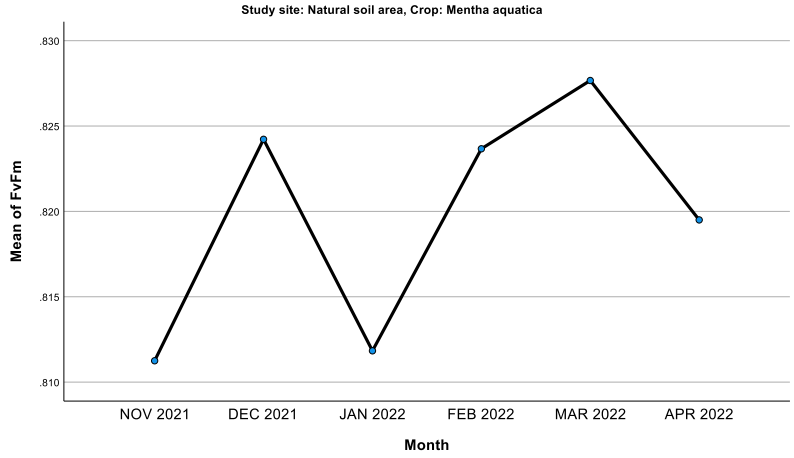
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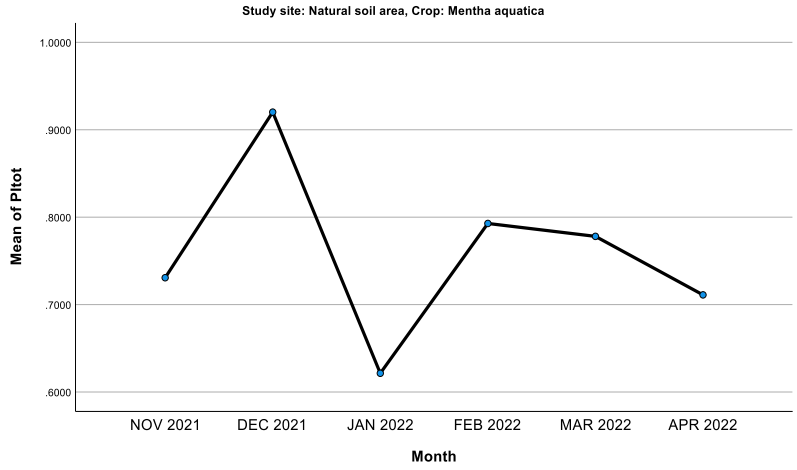
Crop[a]

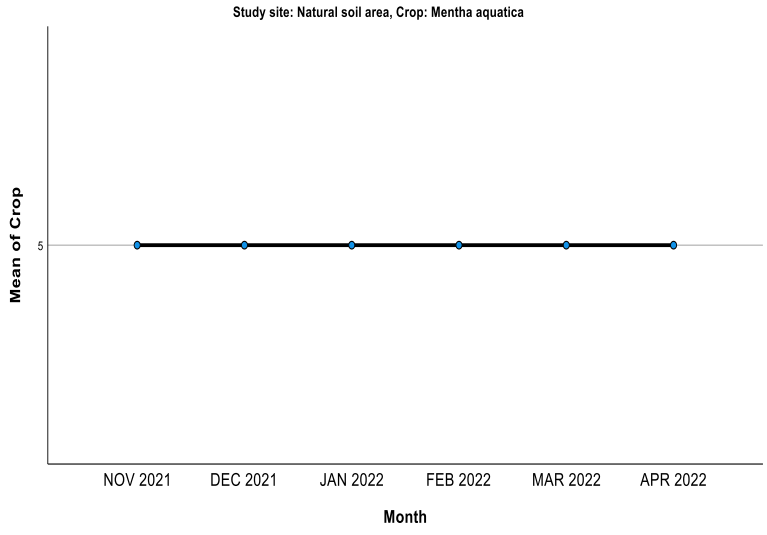
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Mentha aquatica

Means Plots







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Study site = Natural soil area, Crop = Plectranthus amboinicus

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.83900	.015914	.005305	.82677
	DEC 2021	9	.83956	.011566	.003855	.83066
	JAN 2022	9	.84178	.009418	.003139	.83454
	FEB 2022	9	.84833	.008441	.002814	.84185
	MAR 2022	9	.82289	.020673	.006891	.80700
	APR 2022	9	.83489	.009062	.003021	.82792
	Total	54	.83774	.014864	.002023	.83368
PI_total	NOV 2021	9	2.228778	.4594781	.1531594	1.875592
	DEC 2021	9	2.472589	.6028878	.2009626	2.009168
	JAN 2022	9	2.035933	.2665740	.0888580	1.831026
	FEB 2022	9	2.166267	.7629342	.2543114	1.579824
	MAR 2022	9	1.201600	.3250144	.1083381	.951772
	APR 2022	9	1.671989	.7069905	.2356635	1.128548
	Total	54	1.962859	.6734578	.0916460	1.779041
Crop	NOV 2021	9	6.00	.000	.000	6.00
	DEC 2021	9	6.00	.000	.000	6.00
	JAN 2022	9	6.00	.000	.000	6.00
	FEB 2022	9	6.00	.000	.000	6.00
	MAR 2022	9	6.00	.000	.000	6.00
	APR 2022	9	6.00	.000	.000	6.00
	Total	54	6.00	.000	.000	6.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.85123	.812	.859
	DEC 2021	.84845	.825	.853
	JAN 2022	.84902	.830	.857
	FEB 2022	.85482	.828	.856
	MAR 2022	.83878	.802	.853
	APR 2022	.84185	.824	.849
	Total	.84180	.802	.859
PI_total	NOV 2021	2.581964	1.6732	3.1391
	DEC 2021	2.936009	1.8419	3.4277
	JAN 2022	2.240840	1.5116	2.4249
	FEB 2022	2.752710	1.0667	3.1010
	MAR 2022	1.451428	.6943	1.6644
	APR 2022	2.215430	1.0745	3.0251
	Total	2.146678	.6943	3.4277
Crop	NOV 2021	6.00	6	6
	DEC 2021	6.00	6	6
	JAN 2022	6.00	6	6
	FEB 2022	6.00	6	6
	MAR 2022	6.00	6	6
	APR 2022	6.00	6	6
	Total	6.00	6	6

a. Study_site = Natural soil area, Crop = Plectranthus amboinicus

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.003	5	.001	3.702
	Within Groups	.008	48	.000	
	Total	.012	53		
PI_total	Between Groups	9.372	5	1.874	6.135
	Within Groups	14.666	48	.306	
	Total	24.038	53		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	48	.000	
	Total	.000	53		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.006
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Plectranthus amboinicus

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.278	.030	.403
	Epsilon-squared	.203	-.071	.341
	Omega-squared Fixed-effect	.200	-.070	.337
	Omega-squared Random-effect	.048	-.013	.092
PI_total	Eta-squared	.390	.121	.508
	Epsilon-squared	.326	.029	.457
	Omega-squared Fixed-effect	.322	.029	.452
	Omega-squared Random-effect	.087	.006	.142
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area, Crop = Plectranthus amboinicus

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.000556	.006255	1.000	-.01912	.01801
		JAN 2022	-.002778	.006255	.998	-.02134	.01579
		FEB 2022	-.009333	.006255	.671	-.02790	.00923
		MAR 2022	.016111	.006255	.123	-.00245	.03468
		APR 2022	.004111	.006255	.986	-.01445	.02268
	DEC 2021	NOV 2021	.000556	.006255	1.000	-.01801	.01912
		JAN 2022	-.002222	.006255	.999	-.02079	.01634
		FEB 2022	-.008778	.006255	.725	-.02734	.00979
		MAR 2022	.016667	.006255	.102	-.00190	.03523
		APR 2022	.004667	.006255	.975	-.01390	.02323
	JAN 2022	NOV 2021	.002778	.006255	.998	-.01579	.02134
		DEC 2021	.002222	.006255	.999	-.01634	.02079
		FEB 2022	-.006556	.006255	.899	-.02512	.01201
		MAR 2022	.018889*	.006255	.044	.00032	.03745
		APR 2022	.006889	.006255	.878	-.01168	.02545
	FEB 2022	NOV 2021	.009333	.006255	.671	-.00923	.02790
		DEC 2021	.008778	.006255	.725	-.00979	.02734
		JAN 2022	.006556	.006255	.899	-.01201	.02512
		MAR 2022	.025444*	.006255	.002	.00688	.04401
		APR 2022	.013444	.006255	.280	-.00512	.03201
	MAR 2022	NOV 2021	-.016111	.006255	.123	-.03468	.00245
		DEC 2021	-.016667	.006255	.102	-.03523	.00190
		JAN 2022	-.018889*	.006255	.044	-.03745	-.00032
		FEB 2022	-.025444*	.006255	.002	-.04401	-.00688
		APR 2022	-.012000	.006255	.404	-.03056	.00656
	APR 2022	NOV 2021	-.004111	.006255	.986	-.02268	.01445
		DEC 2021	-.004667	.006255	.975	-.02323	.01390
		JAN 2022	-.006889	.006255	.878	-.02545	.01168
		FEB 2022	-.013444	.006255	.280	-.03201	.00512
		MAR 2022	.012000	.006255	.404	-.00656	.03056
PI_total	NOV 2021	DEC 2021	-.2438111	.2605688	.935	-1.017152	.529530
		JAN 2022	.1928444	.2605688	.976	-.580496	.966185
		FEB 2022	.0625111	.2605688	1.000	-.710830	.835852
		MAR 2022	1.0271778*	.2605688	.003	.253837	1.800518
		APR 2022	.5567889	.2605688	.286	-.216552	1.330130
	DEC 2021	NOV 2021	.2438111	.2605688	.935	-.529530	1.017152
		JAN 2022	.4366556	.2605688	.554	-.336685	1.209996
		FEB 2022	.3063222	.2605688	.846	-.467018	1.079663
		MAR 2022	1.2709889*	.2605688	<,001	.497648	2.044330
		APR 2022	.8006000*	.2605688	.039	.027259	1.573941
	JAN 2022	NOV 2021	-.1928444	.2605688	.976	-.966185	.580496
		DEC 2021	-.4366556	.2605688	.554	-1.209996	.336685
		FEB 2022	-.1303333	.2605688	.996	-.903674	.643007
		MAR 2022	.8343333*	.2605688	.028	.060993	1.607674
		APR 2022	.3639444	.2605688	.729	-.409396	1.137285
	FEB 2022	NOV 2021	-.0625111	.2605688	1.000	-.835852	.710830
		DEC 2021	-.3063222	.2605688	.846	-1.079663	.467018
		JAN 2022	.1303333	.2605688	.996	-.643007	.903674

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		MAR 2022	.9646667*	.2605688	.007	.191326	1.738007
		APR 2022	.4942778	.2605688	.416	-.279063	1.267618
	MAR 2022	NOV 2021	-1.0271778*	.2605688	.003	-1.800518	-.253837
		DEC 2021	-1.2709889*	.2605688	<,001	-2.044330	-.497648
		JAN 2022	-.8343333*	.2605688	.028	-1.607674	-.060993
		FEB 2022	-.9646667*	.2605688	.007	-1.738007	-.191326
		APR 2022	-.4703889	.2605688	.472	-1.243730	.302952
	APR 2022	NOV 2021	-.5567889	.2605688	.286	-1.330130	.216552
		DEC 2021	-.8006000*	.2605688	.039	-1.573941	-.027259
		JAN 2022	-.3639444	.2605688	.729	-1.137285	.409396
		FEB 2022	-.4942778	.2605688	.416	-1.267618	.279063
		MAR 2022	.4703889	.2605688	.472	-.302952	1.243730

*. The mean difference is significant at the 0.05 level.
a. Study_site = Natural soil area, Crop = Plectranthus amboinicus

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b]

Month	N	Subset for alpha = 0.05	
		1	2
MAR 2022	9	.82289	
APR 2022	9	.83489	.83489
NOV 2021	9	.83900	.83900
DEC 2021	9	.83956	.83956
JAN 2022	9		.84178
FEB 2022	9		.84833
Sig.		.102	.280

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Plectranthus amboinicus
b. Uses Harmonic Mean Sample Size = 9.000.

PI_total[a]

Tukey HSD[b]

Month	N	Subset for alpha = 0.05		
		1	2	3
MAR 2022	9	1.201600		
APR 2022	9	1.671989	1.671989	
JAN 2022	9		2.035933	2.035933
FEB 2022	9		2.166267	2.166267
NOV 2021	9		2.228778	2.228778
DEC 2021	9			2.472589
Sig.		.472	.286	.554

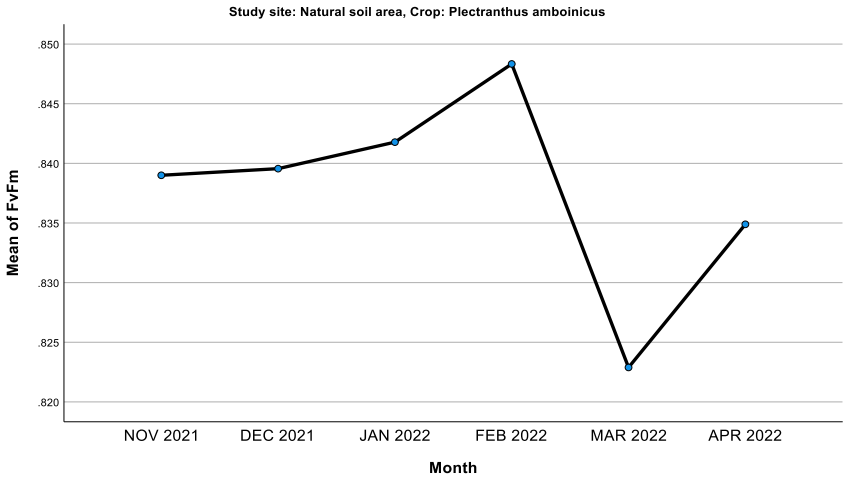
Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Plectranthus amboinicus
b. Uses Harmonic Mean Sample Size = 9.000.

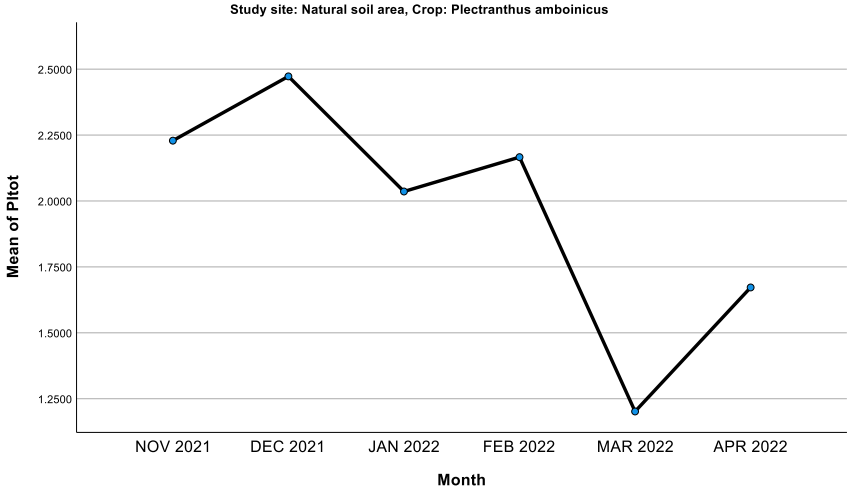
Crop[a]

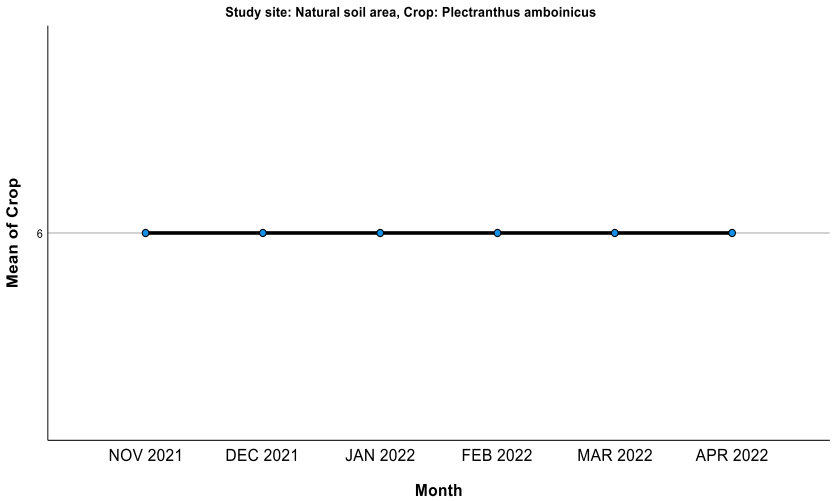
Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Plectranthus amboinicus

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Means Plots







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Study site = Natural soil area, Crop = Portulaca oleracea

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	6	.77067	.017363	.007088	.75245
	DEC 2021	9	.80044	.014647	.004882	.78919
	JAN 2022	1	.73500	.	.	.
	FEB 2022	2	.77650	.002121	.001500	.75744
	MAR 2022	8	.76100	.024565	.008685	.74046
	APR 2022	3	.78000	.021656	.012503	.72620
	Total	29	.77738	.024938	.004631	.76789
PI_total	NOV 2021	6	1.996017	.5148499	.2101866	1.455715
	DEC 2021	9	2.121889	.8394400	.2798133	1.476638
	JAN 2022	1	1.197400	.	.	.
	FEB 2022	2	1.197750	.1437548	.1016500	-.093836
	MAR 2022	8	1.483238	.8459990	.2991058	.775965
	APR 2022	3	.873833	.0925249	.0534193	.643989
	Total	29	1.694945	.7864477	.1460397	1.395796
Crop	NOV 2021	6	7.00	.000	.000	7.00
	DEC 2021	9	7.00	.000	.000	7.00
	JAN 2022	1	7.00	.	.	.
	FEB 2022	2	7.00	.000	.000	7.00
	MAR 2022	8	7.00	.000	.000	7.00
	APR 2022	3	7.00	.000	.000	7.00
	Total	29	7.00	.000	.000	7.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.78889	.751	.802
	DEC 2021	.81170	.778	.817
	JAN 2022	.	.735	.735
	FEB 2022	.79556	.775	.778
	MAR 2022	.78154	.714	.779
	APR 2022	.83380	.757	.800
	Total	.78687	.714	.817
PI_total	NOV 2021	2.536318	1.3849	2.6986
	DEC 2021	2.767140	1.0493	3.2994
	JAN 2022	.	1.1974	1.1974
	FEB 2022	2.489336	1.0961	1.2994
	MAR 2022	2.190510	.4773	2.4877
	APR 2022	1.103678	.7933	.9749
	Total	1.994094	.4773	3.2994
Crop	NOV 2021	7.00	7	7
	DEC 2021	7.00	7	7
	JAN 2022	.	7	7
	FEB 2022	7.00	7	7
	MAR 2022	7.00	7	7
	APR 2022	7.00	7	7
	Total	7.00	7	7

a. Study_site = Natural soil area, Crop = Portulaca oleracea

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.009	5	.002	4.947
	Within Groups	.008	23	.000	
	Total	.017	28		
PI_total	Between Groups	5.308	5	1.062	2.033
	Within Groups	12.010	23	.522	
	Total	17.318	28		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	23	.000	
	Total	.000	28		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.003
	Within Groups	
	Total	
PI_total	Between Groups	.112
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Portulaca oleracea

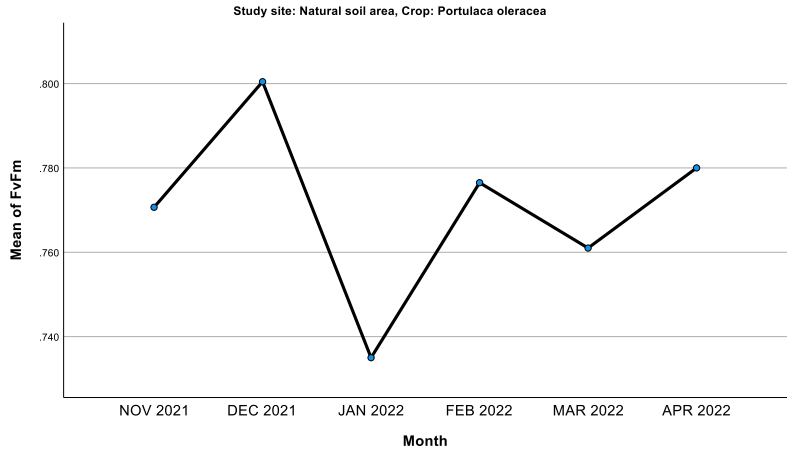
ANOVA Effect Sizes[a,b,c]

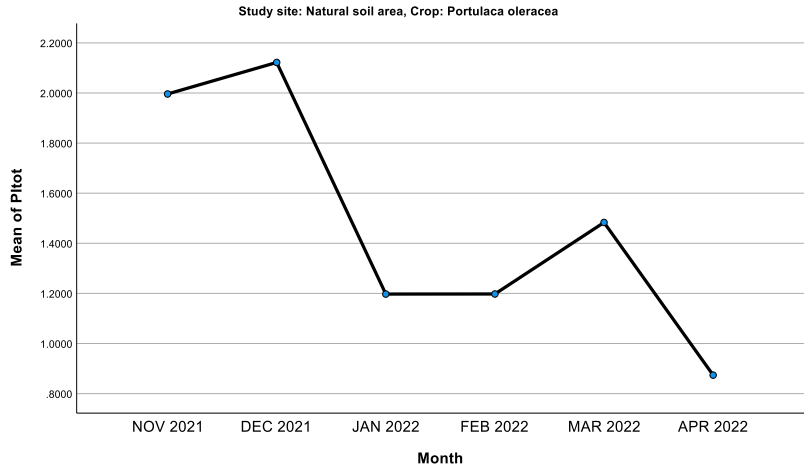
		Point Estimate	95% Confidence Interval Lower	Upper
max_quantum_yield	Eta-squared	.518	.098	.631
	Epsilon-squared	.413	-.098	.551
	Omega-squared Fixed-effect	.405	-.094	.543
	Omega-squared Random-effect	.120	-.017	.192
PI_total	Eta-squared	.306	.000	.446
	Epsilon-squared	.156	-.217	.326
	Omega-squared Fixed-effect	.151	-.208	.318
	Omega-squared Random-effect	.034	-.036	.085
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

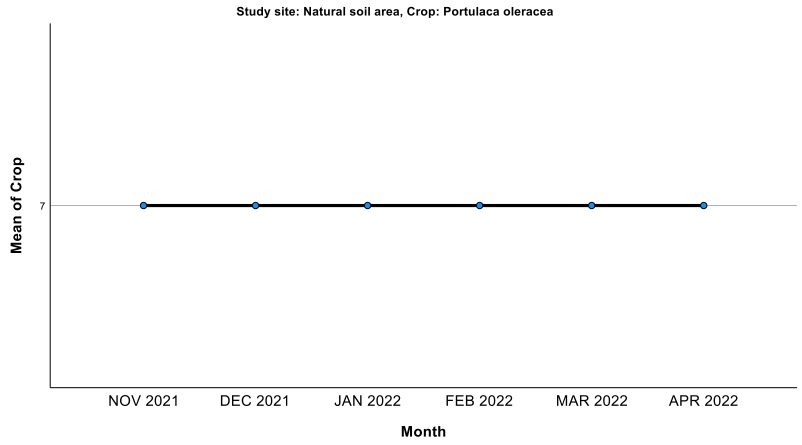
a. Study_site = Natural soil area, Crop = Portulaca oleracea
b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.
c. Negative but less biased estimates are retained, not rounded to zero.

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Means Plots







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Study site = Natural soil area, Crop = Portulacaria afra prostrata

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.84233	.013481	.004494	.83197
	DEC 2021	9	.85078	.019779	.006593	.83557
	JAN 2022	9	.81467	.018960	.006320	.80009
	FEB 2022	9	.83356	.022097	.007366	.81657
	MAR 2022	9	.82111	.023777	.007926	.80283
	APR 2022	9	.82356	.018042	.006014	.80969
	Total	54	.83100	.022574	.003072	.82484
PI_total	NOV 2021	9	3.133644	.8129936	.2709979	2.508722
	DEC 2021	9	2.695000	1.0457727	.3485909	1.891148
	JAN 2022	9	1.216056	.2982218	.0994073	.986822
	FEB 2022	9	1.430744	.4740255	.1580085	1.066376
	MAR 2022	9	1.647478	.4485169	.1495056	1.302717
	APR 2022	9	1.577133	.5241855	.1747285	1.174209
	Total	54	1.950009	.9447710	.1285671	1.692136
Crop	NOV 2021	9	8.00	.000	.000	8.00
	DEC 2021	9	8.00	.000	.000	8.00
	JAN 2022	9	8.00	.000	.000	8.00
	FEB 2022	9	8.00	.000	.000	8.00
	MAR 2022	9	8.00	.000	.000	8.00
	APR 2022	9	8.00	.000	.000	8.00
	Total	54	8.00	.000	.000	8.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.85270	.821	.866
	DEC 2021	.86598	.806	.870
	JAN 2022	.82924	.771	.833
	FEB 2022	.85054	.798	.862
	MAR 2022	.83939	.785	.859
	APR 2022	.83742	.801	.854
	Total	.83716	.771	.870
PI_total	NOV 2021	3.758567	2.1554	4.6466
	DEC 2021	3.498852	.9404	4.5624
	JAN 2022	1.445289	.7748	1.6320
	FEB 2022	1.795113	.8036	2.2942
	MAR 2022	1.992238	1.1027	2.3928
	APR 2022	1.980058	1.1180	2.7332
	Total	2.207882	.7748	4.6466
Crop	NOV 2021	8.00	8	8
	DEC 2021	8.00	8	8
	JAN 2022	8.00	8	8
	FEB 2022	8.00	8	8
	MAR 2022	8.00	8	8
	APR 2022	8.00	8	8
	Total	8.00	8	8

a. Study_site = Natural soil area, Crop = Portulacaria afra prostrata

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.009	5	.002	4.420
	Within Groups	.018	48	.000	
	Total	.027	53		
PI_total	Between Groups	26.954	5	5.391	12.713
	Within Groups	20.353	48	.424	
	Total	47.307	53		
Crop	Between Groups	.000	5	.000	.
	Within Groups	.000	48	.000	
	Total	.000	53		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	.002
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Portulacaria afra prostrata

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.315	.057	.439
	Epsilon-squared	.244	-.042	.381
	Omega-squared Fixed-effect	.241	-.041	.377
	Omega-squared Random-effect	.060	-.008	.108
PI_total	Eta-squared	.570	.324	.661
	Epsilon-squared	.525	.253	.626
	Omega-squared Fixed-effect	.520	.250	.621
	Omega-squared Random-effect	.178	.062	.247
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area, Crop = Portulacaria afra prostrata

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.008444	.009253	.941	-.03591	.01902
		JAN 2022	.027667*	.009253	.047	.00021	.05513
		FEB 2022	.008778	.009253	.931	-.01868	.03624
		MAR 2022	.021222	.009253	.217	-.00624	.04868
		APR 2022	.018778	.009253	.341	-.00868	.04624
	DEC 2021	NOV 2021	.008444	.009253	.941	-.01902	.03591
		JAN 2022	.036111*	.009253	.004	.00865	.06357
		FEB 2022	.017222	.009253	.438	-.01024	.04468
		MAR 2022	.029667*	.009253	.027	.00221	.05713
		APR 2022	.027222	.009253	.053	-.00024	.05468
	JAN 2022	NOV 2021	-.027667*	.009253	.047	-.05513	-.00021
		DEC 2021	-.036111*	.009253	.004	-.06357	-.00865
		FEB 2022	-.018889	.009253	.335	-.04635	.00857
		MAR 2022	-.006444	.009253	.981	-.03391	.02102
		APR 2022	-.008889	.009253	.928	-.03635	.01857
	FEB 2022	NOV 2021	-.008778	.009253	.931	-.03624	.01868
		DEC 2021	-.017222	.009253	.438	-.04468	.01024
		JAN 2022	.018889	.009253	.335	-.00857	.04635
		MAR 2022	.012444	.009253	.759	-.01502	.03991
		APR 2022	.010000	.009253	.887	-.01746	.03746
	MAR 2022	NOV 2021	-.021222	.009253	.217	-.04868	.00624
		DEC 2021	-.029667*	.009253	.027	-.05713	-.00221
		JAN 2022	.006444	.009253	.981	-.02102	.03391
		FEB 2022	-.012444	.009253	.759	-.03991	.01502
		APR 2022	-.002444	.009253	1.000	-.02991	.02502
	APR 2022	NOV 2021	-.018778	.009253	.341	-.04624	.00868
		DEC 2021	-.027222	.009253	.053	-.05468	.00024
		JAN 2022	.008889	.009253	.928	-.01857	.03635
		FEB 2022	-.010000	.009253	.887	-.03746	.01746
		MAR 2022	.002444	.009253	1.000	-.02502	.02991
PI_total	NOV 2021	DEC 2021	.4386444	.3069668	.710	-.472401	1.349690
		JAN 2022	1.9175889*	.3069668	<,001	1.006544	2.828634
		FEB 2022	1.7029000*	.3069668	<,001	.791855	2.613945
		MAR 2022	1.4861667*	.3069668	<,001	.575121	2.397212
		APR 2022	1.5565111*	.3069668	<,001	.645466	2.467556
	DEC 2021	NOV 2021	-.4386444	.3069668	.710	-1.349690	.472401
		JAN 2022	1.4789444*	.3069668	<,001	.567899	2.389990
		FEB 2022	1.2642556*	.3069668	.002	.353210	2.175301
		MAR 2022	1.0475222*	.3069668	.016	.136477	1.958568
		APR 2022	1.1178667*	.3069668	.008	.206821	2.028912
	JAN 2022	NOV 2021	-1.9175889*	.3069668	<,001	-2.828634	-1.006544
		DEC 2021	-1.4789444*	.3069668	<,001	-2.389990	-.567899
		FEB 2022	-.2146889	.3069668	.981	-1.125734	.696356
		MAR 2022	-.4314222	.3069668	.724	-1.342468	.479623
		APR 2022	-.3610778	.3069668	.846	-1.272123	.549968
	FEB 2022	NOV 2021	-1.7029000*	.3069668	<,001	-2.613945	-.791855
		DEC 2021	-1.2642556*	.3069668	.002	-2.175301	-.353210
		JAN 2022	.2146889	.3069668	.981	-.696356	1.125734

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		MAR 2022	-.2167333	.3069668	.980	-1.127779	.694312
		APR 2022	-.1463889	.3069668	.997	-1.057434	.764656
	MAR 2022	NOV 2021	-1.4861667*	.3069668	<,001	-2.397212	-.575121
		DEC 2021	-1.0475222*	.3069668	.016	-1.958568	-.136477
		JAN 2022	.4314222	.3069668	.724	-.479623	1.342468
		FEB 2022	.2167333	.3069668	.980	-.694312	1.127779
		APR 2022	.0703444	.3069668	1.000	-.840701	.981390
	APR 2022	NOV 2021	-1.5565111*	.3069668	<,001	-2.467556	-.645466
		DEC 2021	-1.1178667*	.3069668	.008	-2.028912	-.206821
		JAN 2022	.3610778	.3069668	.846	-.549968	1.272123
		FEB 2022	.1463889	.3069668	.997	-.764656	1.057434
		MAR 2022	-.0703444	.3069668	1.000	-.981390	.840701

*. The mean difference is significant at the 0.05 level.
a. Study_site = Natural soil area, Crop = Portulacaria afra prostrata

Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b]

Month	N	Subset for alpha = 0.05		
		1	2	3
JAN 2022	9	.81467		
MAR 2022	9	.82111	.82111	
APR 2022	9	.82356	.82356	.82356
FEB 2022	9	.83356	.83356	.83356
NOV 2021	9		.84233	.84233
DEC 2021	9			.85078
Sig.		.335	.217	.053

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Portulacaria afra prostrata
b. Uses Harmonic Mean Sample Size = 9.000.

PI_total[a]

Tukey HSD[b]

Month	N	Subset for alpha = 0.05	
		1	2
JAN 2022	9	1.216056	
FEB 2022	9	1.430744	
APR 2022	9	1.577133	
MAR 2022	9	1.647478	
DEC 2021	9		2.695000
NOV 2021	9		3.133644
Sig.		.724	.710

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Portulacaria afra prostrata
b. Uses Harmonic Mean Sample Size = 9.000.

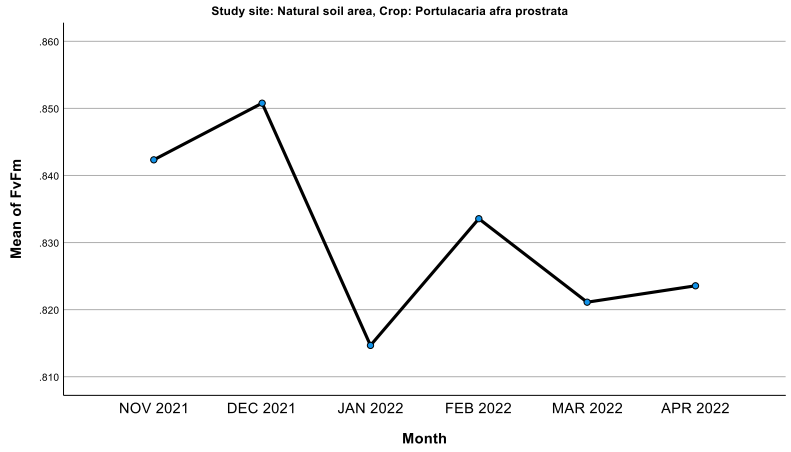
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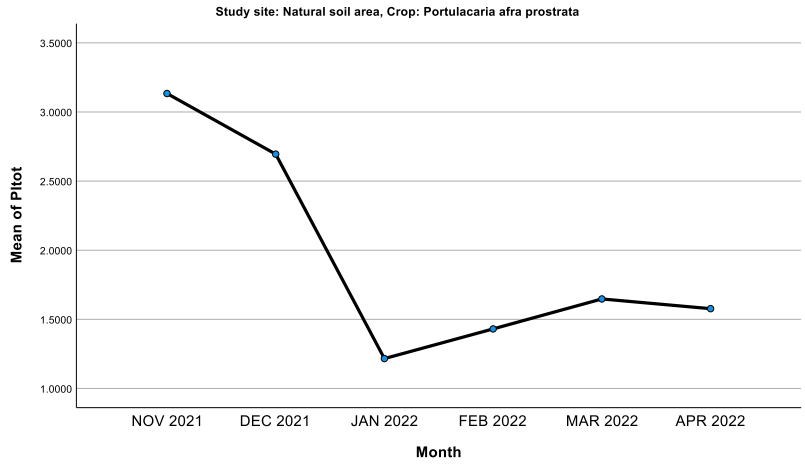
Crop[a]

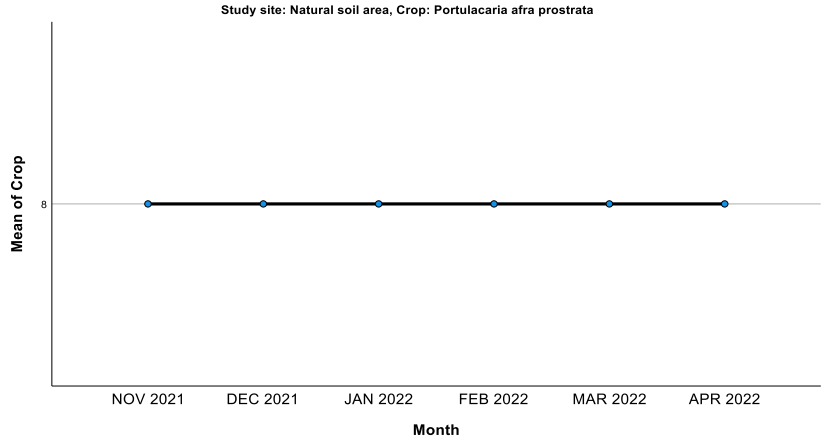
Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Portulacaria afra prostrata

Means Plots







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Study site = Natural soil area, Crop = Spinacea oleracea

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	NOV 2021	9	.81844	.016063	.005354	.80610
	DEC 2021	9	.85322	.005403	.001801	.84907
	JAN 2022	9	.83122	.020185	.006728	.81571
	FEB 2022	9	.83256	.008293	.002764	.82618
	MAR 2022	3	.81667	.003215	.001856	.80868
	Total	39	.83254	.018164	.002909	.82665
PI_total	NOV 2021	9	1.398844	.2483375	.0827792	1.207955
	DEC 2021	9	2.294722	.9500412	.3166804	1.564456
	JAN 2022	9	1.529867	.4889312	.1629771	1.154041
	FEB 2022	9	1.009033	.4001396	.1333799	.701459
	MAR 2022	3	.544900	.0273693	.0158017	.476911
	Total	39	1.480177	.7536568	.1206817	1.235870
Crop	NOV 2021	9	9.00	.000	.000	9.00
	DEC 2021	9	9.00	.000	.000	9.00
	JAN 2022	9	9.00	.000	.000	9.00
	FEB 2022	9	9.00	.000	.000	9.00
	MAR 2022	3	9.00	.000	.000	9.00
	Total	39	9.00	.000	.000	9.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	NOV 2021	.83079	.805	.850
	DEC 2021	.85738	.842	.861
	JAN 2022	.84674	.801	.857
	FEB 2022	.83893	.817	.846
	MAR 2022	.82465	.813	.819
	Total	.83843	.801	.861
PI_total	NOV 2021	1.589734	.9778	1.7588
	DEC 2021	3.024989	1.0983	3.5057
	JAN 2022	1.905692	.8101	2.2623
	FEB 2022	1.316608	.5581	1.8801
	MAR 2022	.612889	.5261	.5763
	Total	1.724484	.5261	3.5057
Crop	NOV 2021	9.00	9	9
	DEC 2021	9.00	9	9
	JAN 2022	9.00	9	9
	FEB 2022	9.00	9	9
	MAR 2022	9.00	9	9
	Total	9.00	9	9

a. Study_site = Natural soil area, Crop = Spinacea oleracea

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.006	4	.002	8.890
	Within Groups	.006	34	.000	
	Total	.013	38		
PI_total	Between Groups	10.675	4	2.669	8.318
	Within Groups	10.909	34	.321	
	Total	21.584	38		
Crop	Between Groups	.000	4	.000	.
	Within Groups	.000	34	.000	
	Total	.000	38		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
PI_total	Between Groups	<,001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Spinacea oleracea

ANOVA Effect Sizes[a,b]

		Point Estimate	95% Confidence Interval Lower	Upper
max_quantum_yield	Eta-squared	.511	.202	.630
	Epsilon-squared	.454	.108	.586
	Omega-squared Fixed-effect	.447	.106	.580
	Omega-squared Random-effect	.168	.029	.257
PI_total	Eta-squared	.495	.183	.617
	Epsilon-squared	.435	.087	.571
	Omega-squared Fixed-effect	.429	.085	.565
	Omega-squared Random-effect	.158	.023	.245
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area, Crop = Spinacea oleracea

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
max_quantum_yield	NOV 2021	DEC 2021	-.034778*	.006329	<,001	-.05300	-.01655
		JAN 2022	-.012778	.006329	.279	-.03100	.00545
		FEB 2022	-.014111	.006329	.193	-.03234	.00411
		MAR 2022	.001778	.008950	1.000	-.02399	.02755
	DEC 2021	NOV 2021	.034778*	.006329	<,001	.01655	.05300
		JAN 2022	.022000*	.006329	.012	.00378	.04022
		FEB 2022	.020667*	.006329	.020	.00244	.03889
		MAR 2022	.036556*	.008950	.002	.01078	.06233
	JAN 2022	NOV 2021	.012778	.006329	.279	-.00545	.03100
		DEC 2021	-.022000*	.006329	.012	-.04022	-.00378
		FEB 2022	-.001333	.006329	1.000	-.01956	.01689
		MAR 2022	.014556	.008950	.492	-.01122	.04033
	FEB 2022	NOV 2021	.014111	.006329	.193	-.00411	.03234
		DEC 2021	-.020667*	.006329	.020	-.03889	-.00244
		JAN 2022	.001333	.006329	1.000	-.01689	.01956
		MAR 2022	.015889	.008950	.404	-.00988	.04166
	MAR 2022	NOV 2021	-.001778	.008950	1.000	-.02755	.02399
		DEC 2021	-.036556*	.008950	.002	-.06233	-.01078
		JAN 2022	-.014556	.008950	.492	-.04033	.01122
		FEB 2022	-.015889	.008950	.404	-.04166	.00988
PI_total	NOV 2021	DEC 2021	-.8958778*	.2670196	.016	-1.664773	-.126982
		JAN 2022	-.1310222	.2670196	.988	-.899918	.637873
		FEB 2022	.3898111	.2670196	.595	-.379085	1.158707
		MAR 2022	.8539444	.3776228	.182	-.233438	1.941327
	DEC 2021	NOV 2021	.8958778*	.2670196	.016	.126982	1.664773
		JAN 2022	.7648556	.2670196	.052	-.004040	1.533751
		FEB 2022	1.2856889*	.2670196	<,001	.516793	2.054585
		MAR 2022	1.7498222*	.3776228	<,001	.662440	2.837205
	JAN 2022	NOV 2021	.1310222	.2670196	.988	-.637873	.899918
		DEC 2021	-.7648556	.2670196	.052	-1.533751	.004040
		FEB 2022	.5208333	.2670196	.311	-.248062	1.289729
		MAR 2022	.9849667	.3776228	.091	-.102416	2.072349
	FEB 2022	NOV 2021	-.3898111	.2670196	.595	-1.158707	.379085
		DEC 2021	-1.2856889*	.2670196	<,001	-2.054585	-.516793
		JAN 2022	-.5208333	.2670196	.311	-1.289729	.248062
		MAR 2022	.4641333	.3776228	.735	-.623249	1.551516
	MAR 2022	NOV 2021	-.8539444	.3776228	.182	-1.941327	.233438
		DEC 2021	-1.7498222*	.3776228	<,001	-2.837205	-.662440
		JAN 2022	-.9849667	.3776228	.091	-2.072349	.102416
		FEB 2022	-.4641333	.3776228	.735	-1.551516	.623249

*. The mean difference is significant at the 0.05 level.

a. Study_site = Natural soil area, Crop = Spinacea oleracea

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
MAR 2022	3	.81667	
NOV 2021	9	.81844	
JAN 2022	9	.83122	
FEB 2022	9	.83256	.83256
DEC 2021	9		.85322
Sig.		.234	.066

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Spinacea oleracea

b. Uses Harmonic Mean Sample Size = 6.429.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05		
		1	2	3
MAR 2022	3	.544900		
FEB 2022	9	1.009033	1.009033	
NOV 2021	9	1.398844	1.398844	1.398844
JAN 2022	9		1.529867	1.529867
DEC 2021	9			2.294722
Sig.		.074	.478	.055

Means for groups in homogeneous subsets are displayed.[a]

a. Study_site = Natural soil area, Crop = Spinacea oleracea

b. Uses Harmonic Mean Sample Size = 6.429.

c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

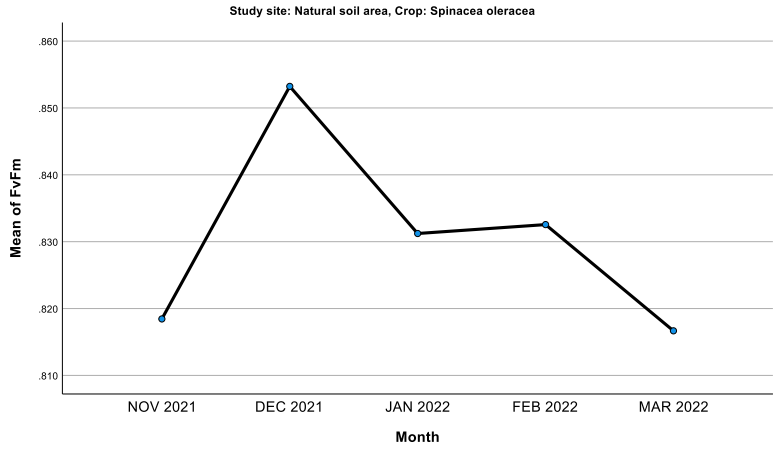
Crop[a]

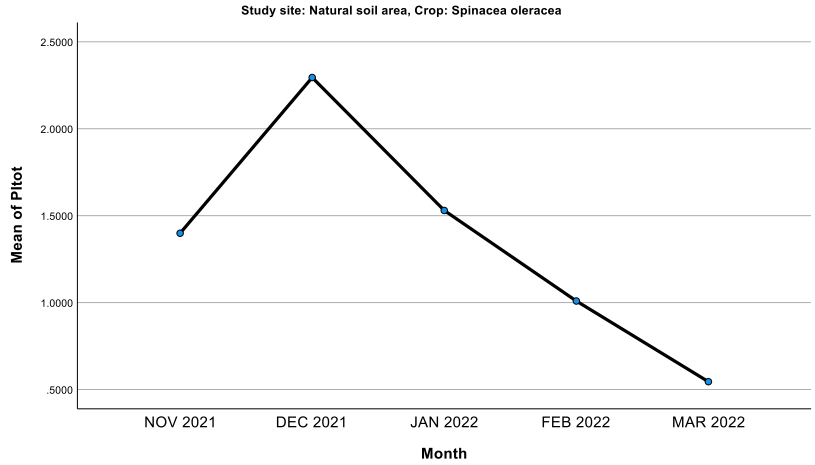
Means for groups in homogeneous subsets are displayed.[a]

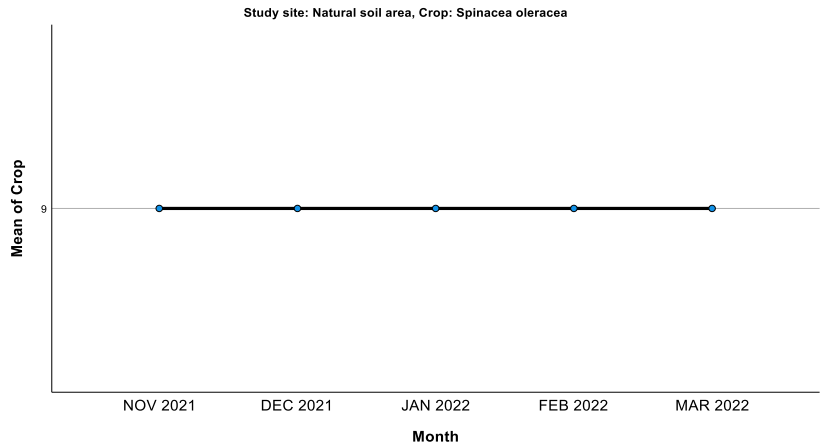
a. Study_site = Natural soil area, Crop = Spinacea oleracea

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Means Plots







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Study site = Natural soil area, Crop = Vigna unguilata

Descriptives[a]

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound
max_quantum_yield	DEC 2021	8	.81263	.008749	.003093	.80531
	JAN 2022	7	.78314	.021590	.008160	.76318
	FEB 2022	9	.82033	.013200	.004400	.81019
	MAR 2022	9	.79711	.012594	.004198	.78743
	APR 2022	9	.81200	.013210	.004403	.80185
	Total	42	.80590	.018665	.002880	.80009
PI_total	DEC 2021	8	2.307438	1.8053866	.6383006	.798097
	JAN 2022	7	.922786	.6534695	.2469882	.318427
	FEB 2022	9	3.016978	.8742321	.2914107	2.344983
	MAR 2022	9	1.342678	.8452691	.2817564	.692946
	APR 2022	9	1.604967	.3060108	.1020036	1.369746
	Total	42	1.871443	1.2171876	.1878161	1.492141
Crop	DEC 2021	8	10.00	.000	.000	10.00
	JAN 2022	7	10.00	.000	.000	10.00
	FEB 2022	9	10.00	.000	.000	10.00
	MAR 2022	9	10.00	.000	.000	10.00
	APR 2022	9	10.00	.000	.000	10.00
	Total	42	10.00	.000	.000	10.00

Descriptives[a]

		95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
max_quantum_yield	DEC 2021	.81994	.803	.825
	JAN 2022	.80311	.753	.809
	FEB 2022	.83048	.800	.834
	MAR 2022	.80679	.778	.813
	APR 2022	.82215	.796	.833
	Total	.81172	.753	.834
PI_total	DEC 2021	3.816778	1.0253	5.3550
	JAN 2022	1.527144	.2017	1.7643
	FEB 2022	3.688972	1.7950	4.0459
	MAR 2022	1.992409	.3159	2.6463
	APR 2022	1.840187	1.1840	2.0520
	Total	2.250745	.2017	5.3550
Crop	DEC 2021	10.00	10	10
	JAN 2022	10.00	10	10
	FEB 2022	10.00	10	10
	MAR 2022	10.00	10	10
	APR 2022	10.00	10	10
	Total	10.00	10	10

a. Study_site = Natural soil area, Crop = Vigna unguilata

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ANOVA[a]

		Sum of Squares	df	Mean Square	F
max_quantum_yield	Between Groups	.007	4	.002	8.625
	Within Groups	.007	37	.000	
	Total	.014	41		
PI_total	Between Groups	22.786	4	5.697	5.553
	Within Groups	37.957	37	1.026	
	Total	60.743	41		
Crop	Between Groups	.000	4	.000	.
	Within Groups	.000	37	.000	
	Total	.000	41		

ANOVA[a]

		Sig.
max_quantum_yield	Between Groups	<,001
	Within Groups	
	Total	
PI_total	Between Groups	.001
	Within Groups	
	Total	
Crop	Between Groups	.
	Within Groups	
	Total	

a. Study_site = Natural soil area, Crop = Vigna unguilata

ANOVA Effect Sizes[a,b,c]

			95% Confidence Interval	
		Point Estimate	Lower	Upper
max_quantum_yield	Eta-squared	.483	.186	.604
	Epsilon-squared	.427	.098	.562
	Omega-squared Fixed-effect	.421	.096	.556
	Omega-squared Random-effect	.154	.026	.238
PI_total	Eta-squared	.375	.081	.514
	Epsilon-squared	.308	-.018	.462
	Omega-squared Fixed-effect	.302	-.017	.456
	Omega-squared Random-effect	.098	-.004	.173
Crop	Eta-squared	.	.	.
	Epsilon-squared	.	.	.
	Omega-squared Fixed-effect	.	.	.
	Omega-squared Random-effect	.	.	.

a. Study_site = Natural soil area, Crop = Vigna unguilata

b. Eta-squared and Epsilon-squared are estimated based on the fixed-effect model.

c. Negative but less biased estimates are retained, not rounded to zero.

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Post Hoc Tests

Multiple Comparisons[a]

Tukey HSD

Dependent Variable	(I) Month	(J) Month	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
max_quantum_yield	DEC 2021	JAN 2022	.029482*	.007315	.002	.00851	.05045
		FEB 2022	-.007708	.006868	.794	-.02740	.01198
		MAR 2022	.015514	.006868	.181	-.00418	.03520
		APR 2022	.000625	.006868	1.000	-.01906	.02031
	JAN 2022	DEC 2021	-.029482*	.007315	.002	-.05045	-.00851
		FEB 2022	-.037190*	.007123	<,001	-.05761	-.01677
		MAR 2022	-.013968	.007123	.305	-.03439	.00645
		APR 2022	-.028857*	.007123	.002	-.04928	-.00844
	FEB 2022	DEC 2021	.007708	.006868	.794	-.01198	.02740
		JAN 2022	.037190*	.007123	<,001	.01677	.05761
		MAR 2022	.023222*	.006663	.011	.00412	.04232
		APR 2022	.008333	.006663	.722	-.01077	.02743
	MAR 2022	DEC 2021	-.015514	.006868	.181	-.03520	.00418
		JAN 2022	.013968	.007123	.305	-.00645	.03439
		FEB 2022	-.023222*	.006663	.011	-.04232	-.00412
		APR 2022	-.014889	.006663	.190	-.03399	.00421
	APR 2022	DEC 2021	-.000625	.006868	1.000	-.02031	.01906
		JAN 2022	.028857*	.007123	.002	.00844	.04928
		FEB 2022	-.008333	.006663	.722	-.02743	.01077
		MAR 2022	.014889	.006663	.190	-.00421	.03399
PI_total	DEC 2021	JAN 2022	1.3846518	.5242018	.083	-.118150	2.887453
		FEB 2022	-.7095403	.4921586	.605	-2.120479	.701398
		MAR 2022	.9647597	.4921586	.305	-.446179	2.375698
		APR 2022	.7024708	.4921586	.614	-.708468	2.113410
	JAN 2022	DEC 2021	-1.3846518	.5242018	.083	-2.887453	.118150
		FEB 2022	-2.0941921*	.5104305	.002	-3.557513	-.630871
		MAR 2022	-.4198921	.5104305	.922	-1.883213	1.043429
		APR 2022	-.6821810	.5104305	.671	-2.145502	.781140
	FEB 2022	DEC 2021	.7095403	.4921586	.605	-.701398	2.120479
		JAN 2022	2.0941921*	.5104305	.002	.630871	3.557513
		MAR 2022	1.6743000*	.4774640	.010	.305488	3.043112
		APR 2022	1.4120111*	.4774640	.040	.043199	2.780823
	MAR 2022	DEC 2021	-.9647597	.4921586	.305	-2.375698	.446179
		JAN 2022	.4198921	.5104305	.922	-1.043429	1.883213
		FEB 2022	-1.6743000*	.4774640	.010	-3.043112	-.305488
		APR 2022	-.2622889	.4774640	.981	-1.631101	1.106523
	APR 2022	DEC 2021	-.7024708	.4921586	.614	-2.113410	.708468
		JAN 2022	.6821810	.5104305	.671	-.781140	2.145502
		FEB 2022	-1.4120111*	.4774640	.040	-2.780823	-.043199
		MAR 2022	.2622889	.4774640	.981	-1.106523	1.631101

*. The mean difference is significant at the 0.05 level.

a. Study_site = Natural soil area, Crop = Vigna unguilata

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Homogeneous Subsets

max_quantum_yield[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05		
		1	2	3
JAN 2022	7	.78314		
MAR 2022	9	.79711	.79711	
APR 2022	9		.81200	.81200
DEC 2021	8		.81263	.81263
FEB 2022	9			.82033
Sig.		.279	.188	.750

Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Vigna unguilata
b. Uses Harmonic Mean Sample Size = 8.317.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

PI_total[a]

Tukey HSD[b,c]

Month	N	Subset for alpha = 0.05	
		1	2
JAN 2022	7	.922786	
MAR 2022	9	1.342678	
APR 2022	9	1.604967	1.604967
DEC 2021	8	2.307438	2.307438
FEB 2022	9		3.016978
Sig.		.060	.053

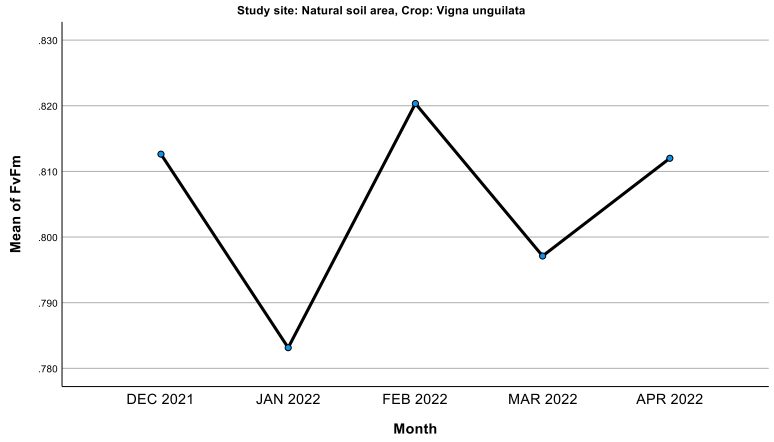
Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Vigna unguilata
b. Uses Harmonic Mean Sample Size = 8.317.
c. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

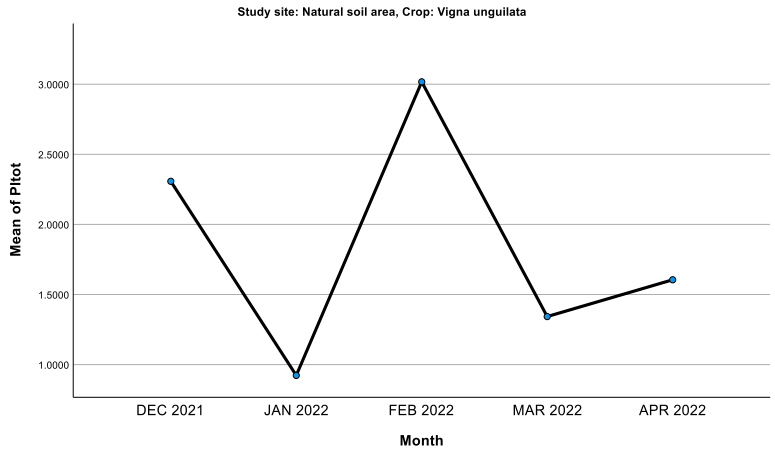
Crop[a]

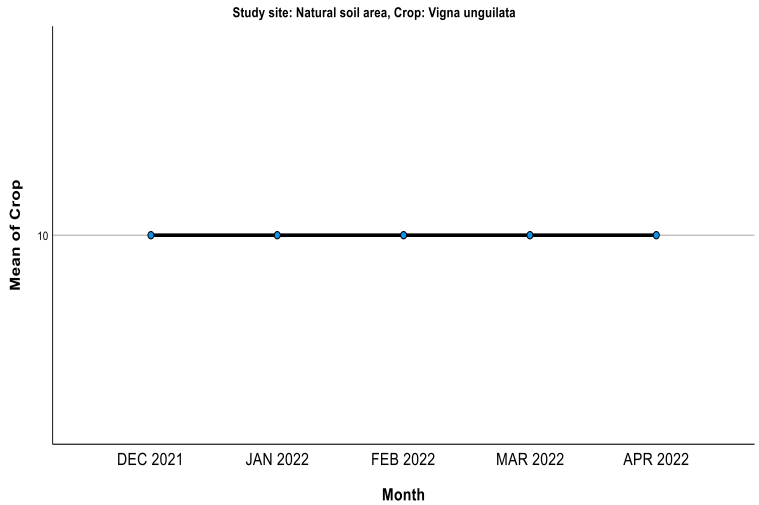
Means for groups in homogeneous subsets are displayed.[a]
a. Study_site = Natural soil area, Crop = Vigna unguilata

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Means Plots







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Appendix L: Statistical analysis results of correlation between the maximum quantum yield in the typologies and all climate and soil variables

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Correlations
Max Quantum Yield and climate and soil variables
Crop = Amaranthus thunbergii, Study site = Eco green wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.221	.223	-.153	.243	.256	-.192	-.201	-.282
	Sig. (2-tailed)		.513	.509	.653	.472	.447	.572	.554	.400
	N	11	11	11	11	11	11	11	11	11
Soil water content	Pearson Correlation	.221	1	1.000**	-.960**	.994**	.983**	-.992**	.047	-.934**
	Sig. (2-tailed)	.513		<,001	<,001	<,001	<,001	<,001	.890	<,001
	N	11	11	11	11	11	11	11	11	11
Soil temperature	Pearson Correlation	.223	1.000**	1	-.957**	.995**	.985**	-.990**	.038	-.937**
	Sig. (2-tailed)	.509	<,001		<,001	<,001	<,001	<,001	.912	<,001
	N	11	11	11	11	11	11	11	11	11
Soil Saturation Extract EC	Pearson Correlation	-.153	-.960**	-.957**	1	-.924**	-.893**	.988**	-.327	.795**
	Sig. (2-tailed)	.653	<,001	<,001		<,001	<,001	<,001	.327	.003
	N	11	11	11	11	11	11	11	11	11
Local maximum temperature	Pearson Correlation	.243	.994**	.995**	-.924**	1	.997**	-.972**	-.059	-.966**
	Sig. (2-tailed)	.472	<,001	<,001	<,001		<,001	<,001	.864	<,001
	N	11	11	11	11	11	11	11	11	11
Local minimum temperature	Pearson Correlation	.256	.983**	.985**	-.893**	.997**	1	-.952**	-.134	-.983**
	Sig. (2-tailed)	.447	<,001	<,001	<,001	<,001		<,001	.694	<,001
	N	11	11	11	11	11	11	11	11	11
Local relative humidity	Pearson Correlation	-.192	-.992**	-.990**	.988**	-.972**	-.952**	1	-.177	.879**
	Sig. (2-tailed)	.572	<,001	<,001	<,001	<,001	<,001		.603	<,001
	N	11	11	11	11	11	11	11	11	11
Precipitation	Pearson Correlation	-.201	.047	.038	-.327	-.059	-.134	-.177	1	.313
	Sig. (2-tailed)	.554	.890	.912	.327	.864	.694	.603		.348
	N	11	11	11	11	11	11	11	11	11
Daylength	Pearson Correlation	-.282	-.934**	-.937**	.795**	-.966**	-.983**	.879**	.313	1
	Sig. (2-tailed)	.400	<,001	<,001	.003	<,001	<,001	<,001	.348	
	N	11	11	11	11	11	11	11	11	11

**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Amaranthus thunbergii, Study site = Eco green wall

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Crop = Amaranthus thunbergii, Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.121	.211	-.284	.179	.205	-.081	.621*	.696**
	Sig. (2-tailed)		.681	.469	.324	.539	.482	.784	.018	.006
	N	14	14	14	14	14	14	14	14	14
Soil water content	Pearson Correlation	-.121	1	-.887**	.947**	-.791**	-.496	.920**	-.444	.025
	Sig. (2-tailed)	.681		<,001	<,001	<,001	.071	<,001	.112	.932
	N	14	14	14	14	14	14	14	14	14
Soil temperature	Pearson Correlation	.211	-.887**	1	-.934**	.981**	.829**	-.985**	.642*	.354
	Sig. (2-tailed)	.469	<,001		<,001	<,001	<,001	<,001	.013	.215
	N	14	14	14	14	14	14	14	14	14
Soil Saturation Extract EC	Pearson Correlation	-.284	.947**	-.934**	1	-.879**	-.592*	.940**	-.495	-.234
	Sig. (2-tailed)	.324	<,001	<,001		<,001	.026	<,001	.072	.421
	N	14	14	14	14	14	14	14	14	14
Local maximum temperature	Pearson Correlation	.179	-.791**	.981**	-.879**	1	.888**	-.961**	.608*	.442
	Sig. (2-tailed)	.539	<,001	<,001	<,001		<,001	<,001	.021	.113
	N	14	14	14	14	14	14	14	14	14
Local minimum temperature	Pearson Correlation	.205	-.496	.829**	-.592*	.888**	1	-.759**	.755**	.632*
	Sig. (2-tailed)	.482	.071	<,001	.026	<,001		.002	.002	.015
	N	14	14	14	14	14	14	14	14	14
Local relative humidity	Pearson Correlation	-.081	.920**	-.985**	.940**	-.961**	-.759**	1	-.513	-.205
	Sig. (2-tailed)	.784	<,001	<,001	<,001	<,001	.002		.061	.482
	N	14	14	14	14	14	14	14	14	14
Precipitation	Pearson Correlation	.621*	-.444	.642*	-.495	.608*	.755**	-.513	1	.689**
	Sig. (2-tailed)	.018	.112	.013	.072	.021	.002	.061		.006
	N	14	14	14	14	14	14	14	14	14
Daylength	Pearson Correlation	.696**	.025	.354	-.234	.442	.632*	-.205	.689**	1
	Sig. (2-tailed)	.006	.932	.215	.421	.113	.015	.482	.006	
	N	14	14	14	14	14	14	14	14	14

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Amaranthus thunbergii, Study site = Vicinity wall

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Crop = Amaranthus thunbergii, Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.055	-.231	-.242	-.242	-.245	.112	-.244	.107
	Sig. (2-tailed)		.866	.470	.449	.449	.444	.729	.445	.741
	N	12	12	12	12	12	12	12	12	12
Soil water content	Pearson Correlation	-.055	1	-.118	.060	.060	.145	.766**	.117	.780**
	Sig. (2-tailed)	.866		.715	.854	.854	.654	.004	.717	.003
	N	12	12	12	12	12	12	12	12	12
Soil temperature	Pearson Correlation	-.231	-.118	1	.984**	.984**	.966**	-.729**	.972**	-.713**
	Sig. (2-tailed)	.470	.715		<,001	<,001	<,001	.007	<,001	.009
	N	12	12	12	12	12	12	12	12	12
Soil Saturation Extract EC	Pearson Correlation	-.242	.060	.984**	1	1.000**	.996**	-.596*	.998**	-.578*
	Sig. (2-tailed)	.449	.854	<,001		.000	<,001	.041	<,001	.049
	N	12	12	12	12	12	12	12	12	12
Local maximum temperature	Pearson Correlation	-.242	.060	.984**	1.000**	1	.996**	-.596*	.998**	-.578*
	Sig. (2-tailed)	.449	.854	<,001	.000		<,001	.041	<,001	.049
	N	12	12	12	12	12	12	12	12	12
Local minimum temperature	Pearson Correlation	-.245	.145	.966**	.996**	.996**	1	-.526	1.000**	-.506
	Sig. (2-tailed)	.444	.654	<,001	<,001	<,001		.079	<,001	.093
	N	12	12	12	12	12	12	12	12	12
Local relative humidity	Pearson Correlation	.112	.766**	-.729**	-.596*	-.596*	-.526	1	-.549	1.000**
	Sig. (2-tailed)	.729	.004	.007	.041	.041	.079		.065	<,001
	N	12	12	12	12	12	12	12	12	12
Precipitation	Pearson Correlation	-.244	.117	.972**	.998**	.998**	1.000**	-.549	1	-.530
	Sig. (2-tailed)	.445	.717	<,001	<,001	<,001	<,001	.065		.076
	N	12	12	12	12	12	12	12	12	12
Daylength	Pearson Correlation	.107	.780**	-.713**	-.578*	-.578*	-.506	1.000**	-.530	1
	Sig. (2-tailed)	.741	.003	.009	.049	.049	.093	<,001	.076	
	N	12	12	12	12	12	12	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Amaranthus thunbergii, Study site = Natural soil area

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Crop = Asystasia gangetica, Study site = Eco green wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.040	-.280	-.062	-.149	-.312	.210	-.395*	-.239
	Sig. (2-tailed)		.811	.085	.708	.366	.053	.200	.013	.143
	N	39	39	39	39	39	39	39	39	39
Soil water content	Pearson Correlation	.040	1	.443**	.667**	.340*	.699**	-.207	-.366*	.261
	Sig. (2-tailed)	.811		.005	<,001	.034	<,001	.207	.022	.109
	N	39	39	39	39	39	39	39	39	39
Soil temperature	Pearson Correlation	-.280	.443**	1	.193	.911**	.884**	-.923**	.272	.159
	Sig. (2-tailed)	.085	.005		.239	<,001	<,001	<,001	.094	.333
	N	39	39	39	39	39	39	39	39	39
Soil Saturation Extract EC	Pearson Correlation	-.062	.667**	.193	1	-.090	.405*	.185	-.090	-.134
	Sig. (2-tailed)	.708	<,001	.239		.585	.010	.260	.587	.416
	N	39	39	39	39	39	39	39	39	39
Local maximum temperature	Pearson Correlation	-.149	.340*	.911**	-.090	1	.706**	-.949**	-.004	.029
	Sig. (2-tailed)	.366	.034	<,001	.585		<,001	<,001	.980	.861
	N	39	39	39	39	39	39	39	39	39
Local minimum temperature	Pearson Correlation	-.312	.699**	.884**	.405*	.706**	1	-.709**	.242	.474**
	Sig. (2-tailed)	.053	<,001	<,001	.010	<,001		<,001	.137	.002
	N	39	39	39	39	39	39	39	39	39
Local relative humidity	Pearson Correlation	.210	-.207	-.923**	.185	-.949**	-.709**	1	-.280	-.173
	Sig. (2-tailed)	.200	.207	<,001	.260	<,001	<,001		.084	.291
	N	39	39	39	39	39	39	39	39	39
Precipitation	Pearson Correlation	-.395*	-.366*	.272	-.090	-.004	.242	-.280	1	.404*
	Sig. (2-tailed)	.013	.022	.094	.587	.980	.137	.084		.011
	N	39	39	39	39	39	39	39	39	39
Daylength	Pearson Correlation	-.239	.261	.159	-.134	.029	.474**	-.173	.404*	1
	Sig. (2-tailed)	.143	.109	.333	.416	.861	.002	.291	.011	
	N	39	39	39	39	39	39	39	39	39

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Asystasia gangetica, Study site = Eco green wall

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Crop = Asystasia gangetica, Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.071	-.012	.027	.026	.013	.001	-.060	.007
	Sig. (2-tailed)		.724	.953	.892	.897	.948	.997	.768	.972
	N	27	27	27	27	27	27	27	27	27
Soil water content	Pearson Correlation	.071	1	-.805**	.900**	-.678**	-.435*	.858**	-.463*	-.215
	Sig. (2-tailed)	.724		<,001	<,001	<,001	.023	<,001	.015	.281
	N	27	27	27	27	27	27	27	27	27
Soil temperature	Pearson Correlation	-.012	-.805**	1	-.803**	.973**	.841**	-.966**	.349	.548**
	Sig. (2-tailed)	.953	<,001		<,001	<,001	<,001	<,001	.074	.003
	N	27	27	27	27	27	27	27	27	27
Soil Saturation Extract EC	Pearson Correlation	.027	.900**	-.803**	1	-.752**	-.510**	.881**	-.626**	-.520**
	Sig. (2-tailed)	.892	<,001	<,001		<,001	.007	<,001	<,001	.005
	N	27	27	27	27	27	27	27	27	27
Local maximum temperature	Pearson Correlation	.026	-.678**	.973**	-.752**	1	.896**	-.947**	.338	.627**
	Sig. (2-tailed)	.897	<,001	<,001	<,001		<,001	<,001	.085	<,001
	N	27	27	27	27	27	27	27	27	27
Local minimum temperature	Pearson Correlation	.013	-.435*	.841**	-.510**	.896**	1	-.786**	.429*	.705**
	Sig. (2-tailed)	.948	.023	<,001	.007	<,001		<,001	.026	<,001
	N	27	27	27	27	27	27	27	27	27
Local relative humidity	Pearson Correlation	.001	.858**	-.966**	.881**	-.947**	-.786**	1	-.469*	-.490**
	Sig. (2-tailed)	.997	<,001	<,001	<,001	<,001	<,001		.014	.009
	N	27	27	27	27	27	27	27	27	27
Precipitation	Pearson Correlation	-.060	-.463*	.349	-.626**	.338	.429*	-.469*	1	.576**
	Sig. (2-tailed)	.768	.015	.074	<,001	.085	.026	.014		.002
	N	27	27	27	27	27	27	27	27	27
Daylength	Pearson Correlation	.007	-.215	.548**	-.520**	.627**	.705**	-.490**	.576**	1
	Sig. (2-tailed)	.972	.281	.003	.005	<,001	<,001	.009	.002	
	N	27	27	27	27	27	27	27	27	27

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Asystasia gangetica, Study site = Vicinity wall

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Crop = Asystasia gangetica, Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.028	-.254	-.388**	-.329*	-.338*	.345*	-.322*	.173
	Sig. (2-tailed)		.844	.073	.005	.018	.015	.013	.021	.224
	N	51	51	51	51	51	51	51	51	51
Soil water content	Pearson Correlation	-.028	1	-.485**	.562**	-.475**	-.528**	.520**	.216	-.431**
	Sig. (2-tailed)	.844		<,001	<,001	<,001	<,001	<,001	.128	.002
	N	51	51	51	51	51	51	51	51	51
Soil temperature	Pearson Correlation	-.254	-.485**	1	.080	.898**	.916**	-.962**	.624**	.563**
	Sig. (2-tailed)	.073	<,001		.578	<,001	<,001	<,001	<,001	<,001
	N	51	51	51	51	51	51	51	51	51
Soil Saturation Extract EC	Pearson Correlation	-.388**	.562**	.080	1	.056	.285*	-.171	.443**	-.641**
	Sig. (2-tailed)	.005	<,001	.578		.697	.042	.229	.001	<,001
	N	51	51	51	51	51	51	51	51	51
Local maximum temperature	Pearson Correlation	-.329*	-.475**	.898**	.056	1	.811**	-.948**	.586**	.499**
	Sig. (2-tailed)	.018	<,001	<,001	.697		<,001	<,001	<,001	<,001
	N	51	51	51	51	51	51	51	51	51
Local minimum temperature	Pearson Correlation	-.338*	-.528**	.916**	.285*	.811**	1	-.952**	.515**	.227
	Sig. (2-tailed)	.015	<,001	<,001	.042	<,001		<,001	<,001	.110
	N	51	51	51	51	51	51	51	51	51
Local relative humidity	Pearson Correlation	.345*	.520**	-.962**	-.171	-.948**	-.952**	1	-.608**	-.394**
	Sig. (2-tailed)	.013	<,001	<,001	.229	<,001	<,001		<,001	.004
	N	51	51	51	51	51	51	51	51	51
Precipitation	Pearson Correlation	-.322*	.216	.624**	.443**	.586**	.515**	-.608**	1	.155
	Sig. (2-tailed)	.021	.128	<,001	.001	<,001	<,001	<,001		.279
	N	51	51	51	51	51	51	51	51	51
Daylength	Pearson Correlation	.173	-.431**	.563**	-.641**	.499**	.227	-.394**	.155	1
	Sig. (2-tailed)	.224	.002	<,001	<,001	<,001	.110	.004	.279	
	N	51	51	51	51	51	51	51	51	51

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Asystasia gangetica, Study site = Natural soil area

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Crop = Corchorus confusus, Study site = Eco green wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.139	-.163	-.274	-.109	-.125	.052	-.005	.161
	Sig. (2-tailed)		.548	.479	.229	.639	.588	.822	.984	.485
	N	21	21	21	21	21	21	21	21	21
Soil water content	Pearson Correlation	-.139	1	.803**	.837**	.569**	.930**	-.538*	.421	.600**
	Sig. (2-tailed)	.548		<,001	<,001	.007	<,001	.012	.057	.004
	N	21	21	21	21	21	21	21	21	21
Soil temperature	Pearson Correlation	-.163	.803**	1	.639**	.908**	.938**	-.893**	.652**	.464*
	Sig. (2-tailed)	.479	<,001		.002	<,001	<,001	<,001	.001	.034
	N	21	21	21	21	21	21	21	21	21
Soil Saturation Extract EC	Pearson Correlation	-.274	.837**	.639**	1	.310	.746**	-.228	.328	.213
	Sig. (2-tailed)	.229	<,001	.002		.172	<,001	.320	.147	.355
	N	21	21	21	21	21	21	21	21	21
Local maximum temperature	Pearson Correlation	-.109	.569**	.908**	.310	1	.738**	-.980**	.470*	.305
	Sig. (2-tailed)	.639	.007	<,001	.172		<,001	<,001	.032	.178
	N	21	21	21	21	21	21	21	21	21
Local minimum temperature	Pearson Correlation	-.125	.930**	.938**	.746**	.738**	1	-.747**	.692**	.667**
	Sig. (2-tailed)	.588	<,001	<,001	<,001	<,001		<,001	<,001	<,001
	N	21	21	21	21	21	21	21	21	21
Local relative humidity	Pearson Correlation	.052	-.538*	-.893**	-.228	-.980**	-.747**	1	-.588**	-.440*
	Sig. (2-tailed)	.822	.012	<,001	.320	<,001	<,001		.005	.046
	N	21	21	21	21	21	21	21	21	21
Precipitation	Pearson Correlation	-.005	.421	.652**	.328	.470*	.692**	-.588**	1	.672**
	Sig. (2-tailed)	.984	.057	.001	.147	.032	<,001	.005		<,001
	N	21	21	21	21	21	21	21	21	21
Daylength	Pearson Correlation	.161	.600**	.464*	.213	.305	.667**	-.440*	.672**	1
	Sig. (2-tailed)	.485	.004	.034	.355	.178	<,001	.046	<,001	
	N	21	21	21	21	21	21	21	21	21

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Corchorus confusus, Study site = Eco green wall

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Crop = Corchorus confusus, Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.064	.071	.144	-.003	-.099	.157	-.404*	.256
	Sig. (2-tailed)		.715	.684	.409	.988	.570	.367	.016	.137
	N	35	35	35	35	35	35	35	35	35
Soil water content	Pearson Correlation	.064	1	-.862**	.945**	-.706**	-.496**	.892**	-.403*	.134
	Sig. (2-tailed)	.715		<,001	<,001	<,001	.002	<,001	.016	.444
	N	35	35	35	35	35	35	35	35	35
Soil temperature	Pearson Correlation	.071	-.862**	1	-.790**	.950**	.783**	-.945**	.016	-.168
	Sig. (2-tailed)	.684	<,001		<,001	<,001	<,001	<,001	.929	.335
	N	35	35	35	35	35	35	35	35	35
Soil Saturation Extract EC	Pearson Correlation	.144	.945**	-.790**	1	-.693**	-.519**	.895**	-.575**	-.080
	Sig. (2-tailed)	.409	<,001	<,001		<,001	.001	<,001	<,001	.648
	N	35	35	35	35	35	35	35	35	35
Local maximum temperature	Pearson Correlation	-.003	-.706**	.950**	-.693**	1	.886**	-.926**	-.063	-.143
	Sig. (2-tailed)	.988	<,001	<,001	<,001		<,001	<,001	.717	.414
	N	35	35	35	35	35	35	35	35	35
Local minimum temperature	Pearson Correlation	-.099	-.496**	.783**	-.519**	.886**	1	-.784**	.039	.052
	Sig. (2-tailed)	.570	.002	<,001	.001	<,001		<,001	.822	.767
	N	35	35	35	35	35	35	35	35	35
Local relative humidity	Pearson Correlation	.157	.892**	-.945**	.895**	-.926**	-.784**	1	-.259	.149
	Sig. (2-tailed)	.367	<,001	<,001	<,001	<,001	<,001		.134	.395
	N	35	35	35	35	35	35	35	35	35
Precipitation	Pearson Correlation	-.404*	-.403*	.016	-.575**	-.063	.039	-.259	1	.428*
	Sig. (2-tailed)	.016	.016	.929	<,001	.717	.822	.134		.010
	N	35	35	35	35	35	35	35	35	35
Daylength	Pearson Correlation	.256	.134	-.168	-.080	-.143	.052	.149	.428*	1
	Sig. (2-tailed)	.137	.444	.335	.648	.414	.767	.395	.010	
	N	35	35	35	35	35	35	35	35	35

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Corchorus confusus, Study site = Vicinity wall

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Crop = Corchorus confusus, Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.504**	.088	.343*	.221	-.024	-.092	.403**	.023
	Sig. (2-tailed)		<,001	.577	.024	.154	.879	.556	.007	.882
	N	43	43	43	43	43	43	43	43	43
Soil water content	Pearson Correlation	.504**	1	-.495**	.508**	-.298	-.538**	.449**	.133	-.416**
	Sig. (2-tailed)	<,001		<,001	<,001	.052	<,001	.003	.395	.006
	N	43	43	43	43	43	43	43	43	43
Soil temperature	Pearson Correlation	.088	-.495**	1	.126	.969**	.915**	-.978**	.673**	.534**
	Sig. (2-tailed)	.577	<,001		.420	<,001	<,001	<,001	<,001	<,001
	N	43	43	43	43	43	43	43	43	43
Soil Saturation Extract EC	Pearson Correlation	.343*	.508**	.126	1	.238	.342*	-.284	.431**	-.643**
	Sig. (2-tailed)	.024	<,001	.420		.124	.025	.065	.004	<,001
	N	43	43	43	43	43	43	43	43	43
Local maximum temperature	Pearson Correlation	.221	-.298	.969**	.238	1	.857**	-.963**	.829**	.479**
	Sig. (2-tailed)	.154	.052	<,001	.124		<,001	<,001	<,001	.001
	N	43	43	43	43	43	43	43	43	43
Local minimum temperature	Pearson Correlation	-.024	-.538**	.915**	.342*	.857**	1	-.963**	.568**	.190
	Sig. (2-tailed)	.879	<,001	<,001	.025	<,001		<,001	<,001	.223
	N	43	43	43	43	43	43	43	43	43
Local relative humidity	Pearson Correlation	-.092	.449**	-.978**	-.284	-.963**	-.963**	1	-.729**	-.351*
	Sig. (2-tailed)	.556	.003	<,001	.065	<,001	<,001		<,001	.021
	N	43	43	43	43	43	43	43	43	43
Precipitation	Pearson Correlation	.403**	.133	.673**	.431**	.829**	.568**	-.729**	1	.168
	Sig. (2-tailed)	.007	.395	<,001	.004	<,001	<,001	<,001		.280
	N	43	43	43	43	43	43	43	43	43
Daylength	Pearson Correlation	.023	-.416**	.534**	-.643**	.479**	.190	-.351*	.168	1
	Sig. (2-tailed)	.882	.006	<,001	<,001	.001	.223	.021	.280	
	N	43	43	43	43	43	43	43	43	43

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Corchorus confusus, Study site = Natural soil area

Crop = Dicliptera clinopodia , Study site = Eco green wall

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Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.009	-.462	.281	-.367	-.324	.517*	-.582*	-.221
	Sig. (2-tailed)		.974	.062	.274	.148	.205	.034	.014	.394
	N	17	17	17	17	17	17	17	17	17
Soil water content	Pearson Correlation	.009	1	.535*	.752**	.450	.785**	-.412	-.114	.732**
	Sig. (2-tailed)	.974		.027	<,001	.070	<,001	.101	.664	<,001
	N	17	17	17	17	17	17	17	17	17
Soil temperature	Pearson Correlation	-.462	.535*	1	-.017	.946**	.888**	-.978**	.396	.504*
	Sig. (2-tailed)	.062	.027		.949	<,001	<,001	<,001	.116	.039
	N	17	17	17	17	17	17	17	17	17
Soil Saturation Extract EC	Pearson Correlation	.281	.752**	-.017	1	-.190	.435	.202	-.083	.743**
	Sig. (2-tailed)	.274	<,001	.949		.465	.081	.438	.752	<,001
	N	17	17	17	17	17	17	17	17	17
Local maximum temperature	Pearson Correlation	-.367	.450	.946**	-.190	1	.735**	-.966**	.138	.230
	Sig. (2-tailed)	.148	.070	<,001	.465		<,001	<,001	.596	.374
	N	17	17	17	17	17	17	17	17	17
Local minimum temperature	Pearson Correlation	-.324	.785**	.888**	.435	.735**	1	-.781**	.408	.826**
	Sig. (2-tailed)	.205	<,001	<,001	.081	<,001		<,001	.104	<,001
	N	17	17	17	17	17	17	17	17	17
Local relative humidity	Pearson Correlation	.517*	-.412	-.978**	.202	-.966**	-.781**	1	-.370	-.344
	Sig. (2-tailed)	.034	.101	<,001	.438	<,001	<,001		.144	.176
	N	17	17	17	17	17	17	17	17	17
Precipitation	Pearson Correlation	-.582*	-.114	.396	-.083	.138	.408	-.370	1	.527*
	Sig. (2-tailed)	.014	.664	.116	.752	.596	.104	.144		.030
	N	17	17	17	17	17	17	17	17	17
Daylength	Pearson Correlation	-.221	.732**	.504*	.743**	.230	.826**	-.344	.527*	1
	Sig. (2-tailed)	.394	<,001	.039	<,001	.374	<,001	.176	.030	
	N	17	17	17	17	17	17	17	17	17

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Dicliptera clinopodia , Study site = Eco green wall

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Crop = Dicliptera clinopodia , Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.112	.026	-.165	.178	-.092	-.075	-.444	.403
	Sig. (2-tailed)		.658	.920	.512	.481	.717	.767	.065	.098
	N	18	18	18	18	18	18	18	18	18
Soil water content	Pearson Correlation	.112	1	-.892**	.934**	-.640**	-.458	.794**	-.402	.404
	Sig. (2-tailed)	.658		<,001	<,001	.004	.056	<,001	.099	.097
	N	18	18	18	18	18	18	18	18	18
Soil temperature	Pearson Correlation	.026	-.892**	1	-.927**	.917**	.775**	-.983**	-.045	-.620**
	Sig. (2-tailed)	.920	<,001		<,001	<,001	<,001	<,001	.860	.006
	N	18	18	18	18	18	18	18	18	18
Soil Saturation Extract EC	Pearson Correlation	-.165	.934**	-.927**	1	-.772**	-.490*	.866**	-.129	.290
	Sig. (2-tailed)	.512	<,001	<,001		<,001	.039	<,001	.610	.243
	N	18	18	18	18	18	18	18	18	18
Local maximum temperature	Pearson Correlation	.178	-.640**	.917**	-.772**	1	.896**	-.974**	-.437	-.665**
	Sig. (2-tailed)	.481	.004	<,001	<,001		<,001	<,001	.070	.003
	N	18	18	18	18	18	18	18	18	18
Local minimum temperature	Pearson Correlation	-.092	-.458	.775**	-.490*	.896**	1	-.859**	-.464	-.911**
	Sig. (2-tailed)	.717	.056	<,001	.039	<,001		<,001	.053	<,001
	N	18	18	18	18	18	18	18	18	18
Local relative humidity	Pearson Correlation	-.075	.794**	-.983**	.866**	-.974**	-.859**	1	.222	.675**
	Sig. (2-tailed)	.767	<,001	<,001	<,001	<,001	<,001		.377	.002
	N	18	18	18	18	18	18	18	18	18
Precipitation	Pearson Correlation	-.444	-.402	-.045	-.129	-.437	-.464	.222	1	.205
	Sig. (2-tailed)	.065	.099	.860	.610	.070	.053	.377		.415
	N	18	18	18	18	18	18	18	18	18
Daylength	Pearson Correlation	.403	.404	-.620**	.290	-.665**	-.911**	.675**	.205	1
	Sig. (2-tailed)	.098	.097	.006	.243	.003	<,001	.002	.415	
	N	18	18	18	18	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Dicliptera clinopodia , Study site = Vicinity wall

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Crop = Dicliptera clinopodia , Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.275	-.124	-.263	-.240	-.136	.036	-.431*	.084
	Sig. (2-tailed)		.165	.539	.185	.228	.499	.859	.025	.676
	N	27	27	27	27	27	27	27	27	27
Soil water content	Pearson Correlation	-.275	1	-.378	.486*	-.125	-.080	.640**	.230	-.297
	Sig. (2-tailed)	.165		.052	.010	.533	.692	<,001	.250	.132
	N	27	27	27	27	27	27	27	27	27
Soil temperature	Pearson Correlation	-.124	-.378	1	.265	.959**	.784**	-.689**	.690**	.358
	Sig. (2-tailed)	.539	.052		.182	<,001	<,001	<,001	<,001	.067
	N	27	27	27	27	27	27	27	27	27
Soil Saturation Extract EC	Pearson Correlation	-.263	.486*	.265	1	.401*	.626**	.005	.527**	-.668**
	Sig. (2-tailed)	.185	.010	.182		.038	<,001	.979	.005	<,001
	N	27	27	27	27	27	27	27	27	27
Local maximum temperature	Pearson Correlation	-.240	-.125	.959**	.401*	1	.819**	-.545**	.850**	.294
	Sig. (2-tailed)	.228	.533	<,001	.038		<,001	.003	<,001	.137
	N	27	27	27	27	27	27	27	27	27
Local minimum temperature	Pearson Correlation	-.136	-.080	.784**	.626**	.819**	1	-.226	.635**	-.111
	Sig. (2-tailed)	.499	.692	<,001	<,001	<,001		.258	<,001	.581
	N	27	27	27	27	27	27	27	27	27
Local relative humidity	Pearson Correlation	.036	.640**	-.689**	.005	-.545**	-.226	1	-.349	-.236
	Sig. (2-tailed)	.859	<,001	<,001	.979	.003	.258		.075	.236
	N	27	27	27	27	27	27	27	27	27
Precipitation	Pearson Correlation	-.431*	.230	.690**	.527**	.850**	.635**	-.349	1	.054
	Sig. (2-tailed)	.025	.250	<,001	.005	<,001	<,001	.075		.789
	N	27	27	27	27	27	27	27	27	27
Daylength	Pearson Correlation	.084	-.297	.358	-.668**	.294	-.111	-.236	.054	1
	Sig. (2-tailed)	.676	.132	.067	<,001	.137	.581	.236	.789	
	N	27	27	27	27	27	27	27	27	27

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Dicliptera clinopodia , Study site = Natural soil area

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Crop = Mentha aquatica, Study site = Eco green wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.089	-.368*	.286	-.591**	-.139	.533**	-.067	.063
	Sig. (2-tailed)		.617	.032	.102	<,001	.431	.001	.705	.723
	N	34	34	34	34	34	34	34	34	34
Soil water content	Pearson Correlation	.089	1	.376*	.824**	.225	.646**	-.100	-.221	.356*
	Sig. (2-tailed)	.617		.029	<,001	.202	<,001	.572	.210	.039
	N	34	34	34	34	34	34	34	34	34
Soil temperature	Pearson Correlation	-.368*	.376*	1	.339	.906**	.891**	-.927**	.605**	.412*
	Sig. (2-tailed)	.032	.029		.050	<,001	<,001	<,001	<,001	.015
	N	34	34	34	34	34	34	34	34	34
Soil Saturation Extract EC	Pearson Correlation	.286	.824**	.339	1	.102	.534**	.027	-.147	.075
	Sig. (2-tailed)	.102	<,001	.050		.566	.001	.879	.405	.674
	N	34	34	34	34	34	34	34	34	34
Local maximum temperature	Pearson Correlation	-.591**	.225	.906**	.102	1	.668**	-.947**	.381*	.149
	Sig. (2-tailed)	<,001	.202	<,001	.566		<,001	<,001	.026	.400
	N	34	34	34	34	34	34	34	34	34
Local minimum temperature	Pearson Correlation	-.139	.646**	.891**	.534**	.668**	1	-.721**	.562**	.692**
	Sig. (2-tailed)	.431	<,001	<,001	.001	<,001		<,001	<,001	<,001
	N	34	34	34	34	34	34	34	34	34
Local relative humidity	Pearson Correlation	.533**	-.100	-.927**	.027	-.947**	-.721**	1	-.642**	-.364*
	Sig. (2-tailed)	.001	.572	<,001	.879	<,001	<,001		<,001	.035
	N	34	34	34	34	34	34	34	34	34
Precipitation	Pearson Correlation	-.067	-.221	.605**	-.147	.381*	.562**	-.642**	1	.629**
	Sig. (2-tailed)	.705	.210	<,001	.405	.026	<,001	<,001		<,001
	N	34	34	34	34	34	34	34	34	34
Daylength	Pearson Correlation	.063	.356*	.412*	.075	.149	.692**	-.364*	.629**	1
	Sig. (2-tailed)	.723	.039	.015	.674	.400	<,001	.035	<,001	
	N	34	34	34	34	34	34	34	34	34

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Mentha aquatica, Study site = Eco green wall

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Crop = Mentha aquatica, Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.382*	-.034	.312	.080	.152	.064	-.360*	.219
	Sig. (2-tailed)		.023	.847	.068	.648	.383	.715	.034	.206
	N	35	35	35	35	35	35	35	35	35
Soil water content	Pearson Correlation	.382*	1	-.775**	.882**	-.604**	-.256	.780**	-.397*	.074
	Sig. (2-tailed)	.023		<,001	<,001	<,001	.137	<,001	.018	.673
	N	35	35	35	35	35	35	35	35	35
Soil temperature	Pearson Correlation	-.034	-.775**	1	-.701**	.954**	.744**	-.961**	.197	.223
	Sig. (2-tailed)	.847	<,001		<,001	<,001	<,001	<,001	.256	.197
	N	35	35	35	35	35	35	35	35	35
Soil Saturation Extract EC	Pearson Correlation	.312	.882**	-.701**	1	-.628**	-.180	.744**	-.461**	-.230
	Sig. (2-tailed)	.068	<,001	<,001		<,001	.299	<,001	.005	.183
	N	35	35	35	35	35	35	35	35	35
Local maximum temperature	Pearson Correlation	.080	-.604**	.954**	-.628**	1	.800**	-.938**	.119	.309
	Sig. (2-tailed)	.648	<,001	<,001	<,001		<,001	<,001	.497	.071
	N	35	35	35	35	35	35	35	35	35
Local minimum temperature	Pearson Correlation	.152	-.256	.744**	-.180	.800**	1	-.716**	.238	.373*
	Sig. (2-tailed)	.383	.137	<,001	.299	<,001		<,001	.168	.027
	N	35	35	35	35	35	35	35	35	35
Local relative humidity	Pearson Correlation	.064	.780**	-.961**	.744**	-.938**	-.716**	1	-.324	-.194
	Sig. (2-tailed)	.715	<,001	<,001	<,001	<,001	<,001		.057	.263
	N	35	35	35	35	35	35	35	35	35
Precipitation	Pearson Correlation	-.360*	-.397*	.197	-.461**	.119	.238	-.324	1	.400*
	Sig. (2-tailed)	.034	.018	.256	.005	.497	.168	.057		.017
	N	35	35	35	35	35	35	35	35	35
Daylength	Pearson Correlation	.219	.074	.223	-.230	.309	.373*	-.194	.400*	1
	Sig. (2-tailed)	.206	.673	.197	.183	.071	.027	.263	.017	
	N	35	35	35	35	35	35	35	35	35

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Mentha aquatica, Study site = Vicinity wall

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Crop = Mentha aquatica, Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.508**	.019	.398*	.129	.099	.121	.247	-.090
	Sig. (2-tailed)		<,001	.910	.012	.436	.548	.462	.129	.587
	N	39	39	39	39	39	39	39	39	39
Soil water content	Pearson Correlation	.508**	1	-.477**	.467**	-.280	-.366*	.543**	.123	-.366*
	Sig. (2-tailed)	<,001		.002	.003	.084	.022	<,001	.457	.022
	N	39	39	39	39	39	39	39	39	39
Soil temperature	Pearson Correlation	.019	-.477**	1	.145	.970**	.839**	-.882**	.684**	.517**
	Sig. (2-tailed)	.910	.002		.378	<,001	<,001	<,001	<,001	<,001
	N	39	39	39	39	39	39	39	39	39
Soil Saturation Extract EC	Pearson Correlation	.398*	.467**	.145	1	.254	.472**	-.146	.433**	-.650**
	Sig. (2-tailed)	.012	.003	.378		.119	.002	.375	.006	<,001
	N	39	39	39	39	39	39	39	39	39
Local maximum temperature	Pearson Correlation	.129	-.280	.970**	.254	1	.824**	-.826**	.830**	.466**
	Sig. (2-tailed)	.436	.084	<,001	.119		<,001	<,001	<,001	.003
	N	39	39	39	39	39	39	39	39	39
Local minimum temperature	Pearson Correlation	.099	-.366*	.839**	.472**	.824**	1	-.645**	.597**	.072
	Sig. (2-tailed)	.548	.022	<,001	.002	<,001		<,001	<,001	.665
	N	39	39	39	39	39	39	39	39	39
Local relative humidity	Pearson Correlation	.121	.543**	-.882**	-.146	-.826**	-.645**	1	-.602**	-.361*
	Sig. (2-tailed)	.462	<,001	<,001	.375	<,001	<,001		<,001	.024
	N	39	39	39	39	39	39	39	39	39
Precipitation	Pearson Correlation	.247	.123	.684**	.433**	.830**	.597**	-.602**	1	.167
	Sig. (2-tailed)	.129	.457	<,001	.006	<,001	<,001	<,001		.310
	N	39	39	39	39	39	39	39	39	39
Daylength	Pearson Correlation	-.090	-.366*	.517**	-.650**	.466**	.072	-.361*	.167	1
	Sig. (2-tailed)	.587	.022	<,001	<,001	.003	.665	.024	.310	
	N	39	39	39	39	39	39	39	39	39

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Mentha aquatica, Study site = Natural soil area

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Crop = Plectranthus amboinicus, Study site = Eco green wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.113	-.173	-.070	-.162	-.006	.165	-.105	.285*
	Sig. (2-tailed)		.436	.230	.631	.262	.967	.252	.470	.045
	N	50	50	50	50	50	50	50	50	50
Soil water content	Pearson Correlation	.113	1	.516**	.734**	.409**	.722**	-.252	-.308*	.289*
	Sig. (2-tailed)	.436		<,001	<,001	.003	<,001	.077	.029	.042
	N	50	50	50	50	50	50	50	50	50
Soil temperature	Pearson Correlation	-.173	.516**	1	.324*	.894**	.908**	-.912**	.365**	.364**
	Sig. (2-tailed)	.230	<,001		.022	<,001	<,001	<,001	.009	.009
	N	50	50	50	50	50	50	50	50	50
Soil Saturation Extract EC	Pearson Correlation	-.070	.734**	.324*	1	.037	.492**	.077	-.106	-.068
	Sig. (2-tailed)	.631	<,001	.022		.799	<,001	.593	.463	.637
	N	50	50	50	50	50	50	50	50	50
Local maximum temperature	Pearson Correlation	-.162	.409**	.894**	.037	1	.712**	-.937**	.071	.191
	Sig. (2-tailed)	.262	.003	<,001	.799		<,001	<,001	.625	.185
	N	50	50	50	50	50	50	50	50	50
Local minimum temperature	Pearson Correlation	-.006	.722**	.908**	.492**	.712**	1	-.728**	.334*	.607**
	Sig. (2-tailed)	.967	<,001	<,001	<,001	<,001		<,001	.018	<,001
	N	50	50	50	50	50	50	50	50	50
Local relative humidity	Pearson Correlation	.165	-.252	-.912**	.077	-.937**	-.728**	1	-.388**	-.367**
	Sig. (2-tailed)	.252	.077	<,001	.593	<,001	<,001		.005	.009
	N	50	50	50	50	50	50	50	50	50
Precipitation	Pearson Correlation	-.105	-.308*	.365**	-.106	.071	.334*	-.388**	1	.515**
	Sig. (2-tailed)	.470	.029	.009	.463	.625	.018	.005		<,001
	N	50	50	50	50	50	50	50	50	50
Daylength	Pearson Correlation	.285*	.289*	.364**	-.068	.191	.607**	-.367**	.515**	1
	Sig. (2-tailed)	.045	.042	.009	.637	.185	<,001	.009	<,001	
	N	50	50	50	50	50	50	50	50	50

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Plectranthus amboinicus, Study site = Eco green wall

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Crop = Plectranthus amboinicus, Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.456**	.351**	-.413**	.314*	.089	-.342*	.040	-.002
	Sig. (2-tailed)		<,001	.009	.002	.021	.523	.011	.772	.988
	N	54	54	54	54	54	54	54	54	54
Soil water content	Pearson Correlation	-.456**	1	-.892**	.859**	-.832**	-.566**	.814**	-.507**	-.154
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	<,001	<,001	.265
	N	54	54	54	54	54	54	54	54	54
Soil temperature	Pearson Correlation	.351**	-.892**	1	-.724**	.972**	.729**	-.827**	.449**	.353**
	Sig. (2-tailed)	.009	<,001		<,001	<,001	<,001	<,001	<,001	.009
	N	54	54	54	54	54	54	54	54	54
Soil Saturation Extract EC	Pearson Correlation	-.413**	.859**	-.724**	1	-.760**	-.278*	.845**	-.608**	-.508**
	Sig. (2-tailed)	.002	<,001	<,001		<,001	.042	<,001	<,001	<,001
	N	54	54	54	54	54	54	54	54	54
Local maximum temperature	Pearson Correlation	.314*	-.832**	.972**	-.760**	1	.619**	-.905**	.464**	.503**
	Sig. (2-tailed)	.021	<,001	<,001	<,001		<,001	<,001	<,001	<,001
	N	54	54	54	54	54	54	54	54	54
Local minimum temperature	Pearson Correlation	.089	-.566**	.729**	-.278*	.619**	1	-.295*	.576**	.185
	Sig. (2-tailed)	.523	<,001	<,001	.042	<,001		.030	<,001	.180
	N	54	54	54	54	54	54	54	54	54
Local relative humidity	Pearson Correlation	-.342*	.814**	-.827**	.845**	-.905**	-.295*	1	-.428**	-.427**
	Sig. (2-tailed)	.011	<,001	<,001	<,001	<,001	.030		.001	.001
	N	54	54	54	54	54	54	54	54	54
Precipitation	Pearson Correlation	.040	-.507**	.449**	-.608**	.464**	.576**	-.428**	1	.498**
	Sig. (2-tailed)	.772	<,001	<,001	<,001	<,001	<,001	.001		<,001
	N	54	54	54	54	54	54	54	54	54
Daylength	Pearson Correlation	-.002	-.154	.353**	-.508**	.503**	.185	-.427**	.498**	1
	Sig. (2-tailed)	.988	.265	.009	<,001	<,001	.180	.001	<,001	
	N	54	54	54	54	54	54	54	54	54

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Plectranthus amboinicus, Study site = Vicinity wall

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Crop = Plectranthus amboinicus, Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.198	.190	-.249	.209	.048	-.181	.261	.271*
	Sig. (2-tailed)		.151	.170	.070	.130	.728	.191	.056	.047
	N	54	54	54	54	54	54	54	54	54
Soil water content	Pearson Correlation	-.198	1	-.416**	.570**	-.201	-.231	.509**	.190	-.453**
	Sig. (2-tailed)	.151		.002	<,001	.146	.092	<,001	.168	<,001
	N	54	54	54	54	54	54	54	54	54
Soil temperature	Pearson Correlation	.190	-.416**	1	.174	.967**	.824**	-.831**	.685**	.510**
	Sig. (2-tailed)	.170	.002		.208	<,001	<,001	<,001	<,001	<,001
	N	54	54	54	54	54	54	54	54	54
Soil Saturation Extract EC	Pearson Correlation	-.249	.570**	.174	1	.308*	.498**	-.070	.470**	-.641**
	Sig. (2-tailed)	.070	<,001	.208		.024	<,001	.613	<,001	<,001
	N	54	54	54	54	54	54	54	54	54
Local maximum temperature	Pearson Correlation	.209	-.201	.967**	.308*	1	.825**	-.759**	.838**	.430**
	Sig. (2-tailed)	.130	.146	<,001	.024		<,001	<,001	<,001	.001
	N	54	54	54	54	54	54	54	54	54
Local minimum temperature	Pearson Correlation	.048	-.231	.824**	.498**	.825**	1	-.492**	.602**	.063
	Sig. (2-tailed)	.728	.092	<,001	<,001	<,001		<,001	<,001	.650
	N	54	54	54	54	54	54	54	54	54
Local relative humidity	Pearson Correlation	-.181	.509**	-.831**	-.070	-.759**	-.492**	1	-.548**	-.408**
	Sig. (2-tailed)	.191	<,001	<,001	.613	<,001	<,001		<,001	.002
	N	54	54	54	54	54	54	54	54	54
Precipitation	Pearson Correlation	.261	.190	.685**	.470**	.838**	.602**	-.548**	1	.133
	Sig. (2-tailed)	.056	.168	<,001	<,001	<,001	<,001	<,001		.337
	N	54	54	54	54	54	54	54	54	54
Daylength	Pearson Correlation	.271*	-.453**	.510**	-.641**	.430**	.063	-.408**	.133	1
	Sig. (2-tailed)	.047	<,001	<,001	<,001	.001	.650	.002	.337	
	N	54	54	54	54	54	54	54	54	54

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Plectranthus amboinicus, Study site = Natural soil area

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Crop = Portulaca oleracea, Study site = Eco green wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.012	-.123	.140	-.318	-.003	.152	.312	.228
	Sig. (2-tailed)		.942	.469	.408	.055	.988	.370	.060	.174
	N	37	37	37	37	37	37	37	37	37
Soil water content	Pearson Correlation	.012	1	.484**	.728**	.381*	.723**	-.294	-.175	.524**
	Sig. (2-tailed)	.942		.002	<,001	.020	<,001	.078	.300	<,001
	N	37	37	37	37	37	37	37	37	37
Soil temperature	Pearson Correlation	-.123	.484**	1	.234	.915**	.896**	-.949**	.486**	.480**
	Sig. (2-tailed)	.469	.002		.164	<,001	<,001	<,001	.002	.003
	N	37	37	37	37	37	37	37	37	37
Soil Saturation Extract EC	Pearson Correlation	.140	.728**	.234	1	-.004	.472**	.068	-.069	.228
	Sig. (2-tailed)	.408	<,001	.164		.983	.003	.688	.685	.175
	N	37	37	37	37	37	37	37	37	37
Local maximum temperature	Pearson Correlation	-.318	.381*	.915**	-.004	1	.704**	-.955**	.207	.223
	Sig. (2-tailed)	.055	.020	<,001	.983		<,001	<,001	.220	.185
	N	37	37	37	37	37	37	37	37	37
Local minimum temperature	Pearson Correlation	-.003	.723**	.896**	.472**	.704**	1	-.756**	.475**	.760**
	Sig. (2-tailed)	.988	<,001	<,001	.003	<,001		<,001	.003	<,001
	N	37	37	37	37	37	37	37	37	37
Local relative humidity	Pearson Correlation	.152	-.294	-.949**	.068	-.955**	-.756**	1	-.468**	-.382*
	Sig. (2-tailed)	.370	.078	<,001	.688	<,001	<,001		.003	.020
	N	37	37	37	37	37	37	37	37	37
Precipitation	Pearson Correlation	.312	-.175	.486**	-.069	.207	.475**	-.468**	1	.574**
	Sig. (2-tailed)	.060	.300	.002	.685	.220	.003	.003		<,001
	N	37	37	37	37	37	37	37	37	37
Daylength	Pearson Correlation	.228	.524**	.480**	.228	.223	.760**	-.382*	.574**	1
	Sig. (2-tailed)	.174	<,001	.003	.175	.185	<,001	.020	<,001	
	N	37	37	37	37	37	37	37	37	37

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Portulaca oleracea, Study site = Eco green wall

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Crop = Portulaca oleracea, Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.436**	-.364*	.491**	-.369*	-.268	.320	-.413*	-.233
	Sig. (2-tailed)		.010	.034	.003	.032	.125	.065	.015	.186
	N	34	34	34	34	34	34	34	34	34
Soil water content	Pearson Correlation	.436**	1	-.956**	.892**	-.978**	-.585**	.856**	-.492**	.124
	Sig. (2-tailed)	.010		<,001	<,001	<,001	<,001	<,001	.003	.484
	N	34	34	34	34	34	34	34	34	34
Soil temperature	Pearson Correlation	-.364*	-.956**	1	-.737**	.984**	.712**	-.733**	.359*	-.227
	Sig. (2-tailed)	.034	<,001		<,001	<,001	<,001	<,001	.037	.197
	N	34	34	34	34	34	34	34	34	34
Soil Saturation Extract EC	Pearson Correlation	.491**	.892**	-.737**	1	-.805**	-.282	.854**	-.541**	-.201
	Sig. (2-tailed)	.003	<,001	<,001		<,001	.106	<,001	<,001	.255
	N	34	34	34	34	34	34	34	34	34
Local maximum temperature	Pearson Correlation	-.369*	-.978**	.984**	-.805**	1	.585**	-.840**	.324	-.250
	Sig. (2-tailed)	.032	<,001	<,001	<,001		<,001	<,001	.062	.153
	N	34	34	34	34	34	34	34	34	34
Local minimum temperature	Pearson Correlation	-.268	-.585**	.712**	-.282	.585**	1	-.116	.578**	-.065
	Sig. (2-tailed)	.125	<,001	<,001	.106	<,001		.513	<,001	.717
	N	34	34	34	34	34	34	34	34	34
Local relative humidity	Pearson Correlation	.320	.856**	-.733**	.854**	-.840**	-.116	1	-.239	.300
	Sig. (2-tailed)	.065	<,001	<,001	<,001	<,001	.513		.173	.085
	N	34	34	34	34	34	34	34	34	34
Precipitation	Pearson Correlation	-.413*	-.492**	.359*	-.541**	.324	.578**	-.239	1	.312
	Sig. (2-tailed)	.015	.003	.037	<,001	.062	<,001	.173		.073
	N	34	34	34	34	34	34	34	34	34
Daylength	Pearson Correlation	-.233	.124	-.227	-.201	-.250	-.065	.300	.312	1
	Sig. (2-tailed)	.186	.484	.197	.255	.153	.717	.085	.073	
	N	34	34	34	34	34	34	34	34	34

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Portulaca oleracea, Study site = Vicinity wall

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Crop = Portulaca oleracea, Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.417*	-.404*	-.370*	-.114	-.445*	.416*	-.005	.343
	Sig. (2-tailed)		.024	.030	.048	.558	.016	.025	.978	.068
	N	29	29	29	29	29	29	29	29	29
Soil water content	Pearson Correlation	.417*	1	-.280	.348	.185	.051	.576**	.105	-.134
	Sig. (2-tailed)	.024		.141	.064	.335	.792	.001	.589	.490
	N	29	29	29	29	29	29	29	29	29
Soil temperature	Pearson Correlation	-.404*	-.280	1	.433*	.805**	.786**	-.663**	.702**	.122
	Sig. (2-tailed)	.030	.141		.019	<,001	<,001	<,001	<,001	.528
	N	29	29	29	29	29	29	29	29	29
Soil Saturation Extract EC	Pearson Correlation	-.370*	.348	.433*	1	.553**	.780**	-.239	.352	-.730**
	Sig. (2-tailed)	.048	.064	.019		.002	<,001	.211	.061	<,001
	N	29	29	29	29	29	29	29	29	29
Local maximum temperature	Pearson Correlation	-.114	.185	.805**	.553**	1	.626**	-.581**	.852**	.056
	Sig. (2-tailed)	.558	.335	<,001	.002		<,001	<,001	<,001	.774
	N	29	29	29	29	29	29	29	29	29
Local minimum temperature	Pearson Correlation	-.445*	.051	.786**	.780**	.626**	1	-.264	.586**	-.361
	Sig. (2-tailed)	.016	.792	<,001	<,001	<,001		.166	<,001	.055
	N	29	29	29	29	29	29	29	29	29
Local relative humidity	Pearson Correlation	.416*	.576**	-.663**	-.239	-.581**	-.264	1	-.384*	.027
	Sig. (2-tailed)	.025	.001	<,001	.211	<,001	.166		.040	.891
	N	29	29	29	29	29	29	29	29	29
Precipitation	Pearson Correlation	-.005	.105	.702**	.352	.852**	.586**	-.384*	1	.085
	Sig. (2-tailed)	.978	.589	<,001	.061	<,001	<,001	.040		.661
	N	29	29	29	29	29	29	29	29	29
Daylength	Pearson Correlation	.343	-.134	.122	-.730**	.056	-.361	.027	.085	1
	Sig. (2-tailed)	.068	.490	.528	<,001	.774	.055	.891	.661	
	N	29	29	29	29	29	29	29	29	29

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Portulaca oleracea, Study site = Natural soil area

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Crop = Portulacaria afra prostrata, Study site = Eco green wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.184	-.317*	-.099	-.301*	-.232	.321*	-.070	.008
	Sig. (2-tailed)		.188	.021	.480	.029	.095	.019	.617	.954
	N	53	53	53	53	53	53	53	53	53
Soil water content	Pearson Correlation	-.184	1	.506**	.712**	.401**	.721**	-.257	-.309*	.299*
	Sig. (2-tailed)	.188		<,001	<,001	.003	<,001	.063	.024	.030
	N	53	53	53	53	53	53	53	53	53
Soil temperature	Pearson Correlation	-.317*	.506**	1	.282*	.900**	.902**	-.916**	.355**	.337*
	Sig. (2-tailed)	.021	<,001		.041	<,001	<,001	<,001	.009	.013
	N	53	53	53	53	53	53	53	53	53
Soil Saturation Extract EC	Pearson Correlation	-.099	.712**	.282*	1	-.003	.467**	.111	-.105	-.070
	Sig. (2-tailed)	.480	<,001	.041		.985	<,001	.430	.454	.618
	N	53	53	53	53	53	53	53	53	53
Local maximum temperature	Pearson Correlation	-.301*	.401**	.900**	-.003	1	.709**	-.944**	.070	.167
	Sig. (2-tailed)	.029	.003	<,001	.985		<,001	<,001	.618	.231
	N	53	53	53	53	53	53	53	53	53
Local minimum temperature	Pearson Correlation	-.232	.721**	.902**	.467**	.709**	1	-.725**	.330*	.596**
	Sig. (2-tailed)	.095	<,001	<,001	<,001	<,001		<,001	.016	<,001
	N	53	53	53	53	53	53	53	53	53
Local relative humidity	Pearson Correlation	.321*	-.257	-.916**	.111	-.944**	-.725**	1	-.367**	-.334*
	Sig. (2-tailed)	.019	.063	<,001	.430	<,001	<,001		.007	.014
	N	53	53	53	53	53	53	53	53	53
Precipitation	Pearson Correlation	-.070	-.309*	.355**	-.105	.070	.330*	-.367**	1	.503**
	Sig. (2-tailed)	.617	.024	.009	.454	.618	.016	.007		<,001
	N	53	53	53	53	53	53	53	53	53
Daylength	Pearson Correlation	.008	.299*	.337*	-.070	.167	.596**	-.334*	.503**	1
	Sig. (2-tailed)	.954	.030	.013	.618	.231	<,001	.014	<,001	
	N	53	53	53	53	53	53	53	53	53

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Portulacaria afra prostrata, Study site = Eco green wall

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Crop = Portulacaria afra prostrata, Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.048	.186	-.155	.266	.298*	-.123	.119	.627**
	Sig. (2-tailed)		.742	.197	.281	.061	.035	.393	.410	<,001
	N	50	50	50	50	50	50	50	50	50
Soil water content	Pearson Correlation	.048	1	-.789**	.875**	-.608**	-.315*	.835**	-.464**	-.126
	Sig. (2-tailed)	.742		<,001	<,001	<,001	.026	<,001	<,001	.382
	N	50	50	50	50	50	50	50	50	50
Soil temperature	Pearson Correlation	.186	-.789**	1	-.717**	.950**	.748**	-.952**	.157	.305*
	Sig. (2-tailed)	.197	<,001		<,001	<,001	<,001	<,001	.276	.031
	N	50	50	50	50	50	50	50	50	50
Soil Saturation Extract EC	Pearson Correlation	-.155	.875**	-.717**	1	-.647**	-.268	.826**	-.575**	-.472**
	Sig. (2-tailed)	.281	<,001	<,001		<,001	.059	<,001	<,001	<,001
	N	50	50	50	50	50	50	50	50	50
Local maximum temperature	Pearson Correlation	.266	-.608**	.950**	-.647**	1	.809**	-.927**	.086	.393**
	Sig. (2-tailed)	.061	<,001	<,001	<,001		<,001	<,001	.554	.005
	N	50	50	50	50	50	50	50	50	50
Local minimum temperature	Pearson Correlation	.298*	-.315*	.748**	-.268	.809**	1	-.687**	.177	.367**
	Sig. (2-tailed)	.035	.026	<,001	.059	<,001		<,001	.218	.009
	N	50	50	50	50	50	50	50	50	50
Local relative humidity	Pearson Correlation	-.123	.835**	-.952**	.826**	-.927**	-.687**	1	-.332*	-.294*
	Sig. (2-tailed)	.393	<,001	<,001	<,001	<,001	<,001		.019	.039
	N	50	50	50	50	50	50	50	50	50
Precipitation	Pearson Correlation	.119	-.464**	.157	-.575**	.086	.177	-.332*	1	.461**
	Sig. (2-tailed)	.410	<,001	.276	<,001	.554	.218	.019		<,001
	N	50	50	50	50	50	50	50	50	50
Daylength	Pearson Correlation	.627**	-.126	.305*	-.472**	.393**	.367**	-.294*	.461**	1
	Sig. (2-tailed)	<,001	.382	.031	<,001	.005	.009	.039	<,001	
	N	50	50	50	50	50	50	50	50	50

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Portulacaria afra prostrata, Study site = Vicinity wall

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Crop = Portulacaria afra prostrata, Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.231	-.131	-.192	-.070	-.351**	.049	.070	.228
	Sig. (2-tailed)		.093	.346	.165	.614	.009	.727	.615	.097
	N	54	54	54	54	54	54	54	54	54
Soil water content	Pearson Correlation	.231	1	-.416**	.570**	-.201	-.231	.509**	.190	-.450**
	Sig. (2-tailed)	.093		.002	<,001	.146	.092	<,001	.168	<,001
	N	54	54	54	54	54	54	54	54	54
Soil temperature	Pearson Correlation	-.131	-.416**	1	.174	.967**	.824**	-.831**	.685**	.513**
	Sig. (2-tailed)	.346	.002		.208	<,001	<,001	<,001	<,001	<,001
	N	54	54	54	54	54	54	54	54	54
Soil Saturation Extract EC	Pearson Correlation	-.192	.570**	.174	1	.308*	.498**	-.070	.470**	-.637**
	Sig. (2-tailed)	.165	<,001	.208		.024	<,001	.613	<,001	<,001
	N	54	54	54	54	54	54	54	54	54
Local maximum temperature	Pearson Correlation	-.070	-.201	.967**	.308*	1	.825**	-.759**	.838**	.434**
	Sig. (2-tailed)	.614	.146	<,001	.024		<,001	<,001	<,001	.001
	N	54	54	54	54	54	54	54	54	54
Local minimum temperature	Pearson Correlation	-.351**	-.231	.824**	.498**	.825**	1	-.492**	.602**	.070
	Sig. (2-tailed)	.009	.092	<,001	<,001	<,001		<,001	<,001	.614
	N	54	54	54	54	54	54	54	54	54
Local relative humidity	Pearson Correlation	.049	.509**	-.831**	-.070	-.759**	-.492**	1	-.548**	-.405**
	Sig. (2-tailed)	.727	<,001	<,001	.613	<,001	<,001		<,001	.002
	N	54	54	54	54	54	54	54	54	54
Precipitation	Pearson Correlation	.070	.190	.685**	.470**	.838**	.602**	-.548**	1	.137
	Sig. (2-tailed)	.615	.168	<,001	<,001	<,001	<,001	<,001		.324
	N	54	54	54	54	54	54	54	54	54
Daylength	Pearson Correlation	.228	-.450**	.513**	-.637**	.434**	.070	-.405**	.137	1
	Sig. (2-tailed)	.097	<,001	<,001	<,001	.001	.614	.002	.324	
	N	54	54	54	54	54	54	54	54	54

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Portulacaria afra prostrata, Study site = Natural soil area

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Crop = Spinacea oleracea, Study site = Eco green wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.017	-.141	-.236	-.155	-.058	.024	.372*	.354
	Sig. (2-tailed)		.928	.449	.201	.406	.758	.896	.039	.051
	N	31	31	31	31	31	31	31	31	31
Soil water content	Pearson Correlation	.017	1	.726**	.642**	.474**	.952**	-.499**	.758**	.731**
	Sig. (2-tailed)	.928		<,001	<,001	.007	<,001	.004	<,001	<,001
	N	31	31	31	31	31	31	31	31	31
Soil temperature	Pearson Correlation	-.141	.726**	1	.274	.934**	.896**	-.930**	.596**	.315
	Sig. (2-tailed)	.449	<,001		.136	<,001	<,001	<,001	<,001	.085
	N	31	31	31	31	31	31	31	31	31
Soil Saturation Extract EC	Pearson Correlation	-.236	.642**	.274	1	-.063	.489**	.092	.492**	.123
	Sig. (2-tailed)	.201	<,001	.136		.735	.005	.621	.005	.509
	N	31	31	31	31	31	31	31	31	31
Local maximum temperature	Pearson Correlation	-.155	.474**	.934**	-.063	1	.720**	-.985**	.357*	.184
	Sig. (2-tailed)	.406	.007	<,001	.735		<,001	<,001	.049	.321
	N	31	31	31	31	31	31	31	31	31
Local minimum temperature	Pearson Correlation	-.058	.952**	.896**	.489**	.720**	1	-.732**	.706**	.634**
	Sig. (2-tailed)	.758	<,001	<,001	.005	<,001		<,001	<,001	<,001
	N	31	31	31	31	31	31	31	31	31
Local relative humidity	Pearson Correlation	.024	-.499**	-.930**	.092	-.985**	-.732**	1	-.468**	-.263
	Sig. (2-tailed)	.896	.004	<,001	.621	<,001	<,001		.008	.153
	N	31	31	31	31	31	31	31	31	31
Precipitation	Pearson Correlation	.372*	.758**	.596**	.492**	.357*	.706**	-.468**	1	.523**
	Sig. (2-tailed)	.039	<,001	<,001	.005	.049	<,001	.008		.003
	N	31	31	31	31	31	31	31	31	31
Daylength	Pearson Correlation	.354	.731**	.315	.123	.184	.634**	-.263	.523**	1
	Sig. (2-tailed)	.051	<,001	.085	.509	.321	<,001	.153	.003	
	N	31	31	31	31	31	31	31	31	31

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Spinacea oleracea, Study site = Eco green wall

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Crop = Spinacea oleracea, Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.038	.062	-.110	.086	-.114	-.047	-.245	.032
	Sig. (2-tailed)		.812	.695	.488	.589	.471	.769	.118	.842
	N	42	42	42	42	42	42	42	42	42
Soil water content	Pearson Correlation	-.038	1	-.835**	.898**	-.739**	-.428**	.889**	-.425**	-.299
	Sig. (2-tailed)	.812		<,001	<,001	<,001	.005	<,001	.005	.054
	N	42	42	42	42	42	42	42	42	42
Soil temperature	Pearson Correlation	.062	-.835**	1	-.761**	.978**	.805**	-.965**	.314*	.538**
	Sig. (2-tailed)	.695	<,001		<,001	<,001	<,001	<,001	.043	<,001
	N	42	42	42	42	42	42	42	42	42
Soil Saturation Extract EC	Pearson Correlation	-.110	.898**	-.761**	1	-.733**	-.391*	.857**	-.592**	-.577**
	Sig. (2-tailed)	.488	<,001	<,001		<,001	.011	<,001	<,001	<,001
	N	42	42	42	42	42	42	42	42	42
Local maximum temperature	Pearson Correlation	.086	-.739**	.978**	-.733**	1	.854**	-.952**	.333*	.620**
	Sig. (2-tailed)	.589	<,001	<,001	<,001		<,001	<,001	.031	<,001
	N	42	42	42	42	42	42	42	42	42
Local minimum temperature	Pearson Correlation	-.114	-.428**	.805**	-.391*	.854**	1	-.746**	.408**	.617**
	Sig. (2-tailed)	.471	.005	<,001	.011	<,001		<,001	.007	<,001
	N	42	42	42	42	42	42	42	42	42
Local relative humidity	Pearson Correlation	-.047	.889**	-.965**	.857**	-.952**	-.746**	1	-.464**	-.519**
	Sig. (2-tailed)	.769	<,001	<,001	<,001	<,001	<,001		.002	<,001
	N	42	42	42	42	42	42	42	42	42
Precipitation	Pearson Correlation	-.245	-.425**	.314*	-.592**	.333*	.408**	-.464**	1	.605**
	Sig. (2-tailed)	.118	.005	.043	<,001	.031	.007	.002		<,001
	N	42	42	42	42	42	42	42	42	42
Daylength	Pearson Correlation	.032	-.299	.538**	-.577**	.620**	.617**	-.519**	.605**	1
	Sig. (2-tailed)	.842	.054	<,001	<,001	<,001	<,001	<,001	<,001	
	N	42	42	42	42	42	42	42	42	42

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Spinacea oleracea, Study site = Vicinity wall

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Crop = Spinacea oleracea, Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.359*	-.167	-.141	-.004	-.066	.459**	.054	.505**
	Sig. (2-tailed)		.025	.310	.391	.979	.689	.003	.744	.001
	N	39	39	39	39	39	39	39	39	39
Soil water content	Pearson Correlation	.359*	1	-.381*	.471**	.528**	-.378*	.006	.296	-.176
	Sig. (2-tailed)	.025		.017	.002	<,001	.018	.970	.067	.285
	N	39	39	39	39	39	39	39	39	39
Soil temperature	Pearson Correlation	-.167	-.381*	1	.501**	.471**	.935**	-.406*	.705**	-.241
	Sig. (2-tailed)	.310	.017		.001	.002	<,001	.010	<,001	.139
	N	39	39	39	39	39	39	39	39	39
Soil Saturation Extract EC	Pearson Correlation	-.141	.471**	.501**	1	.861**	.424**	-.570**	.755**	-.777**
	Sig. (2-tailed)	.391	.002	.001		<,001	.007	<,001	<,001	<,001
	N	39	39	39	39	39	39	39	39	39
Local maximum temperature	Pearson Correlation	-.004	.528**	.471**	.861**	1	.270	-.698**	.932**	-.512**
	Sig. (2-tailed)	.979	<,001	.002	<,001		.096	<,001	<,001	<,001
	N	39	39	39	39	39	39	39	39	39
Local minimum temperature	Pearson Correlation	-.066	-.378*	.935**	.424**	.270	1	-.091	.526**	-.142
	Sig. (2-tailed)	.689	.018	<,001	.007	.096		.583	<,001	.390
	N	39	39	39	39	39	39	39	39	39
Local relative humidity	Pearson Correlation	.459**	.006	-.406*	-.570**	-.698**	-.091	1	-.607**	.678**
	Sig. (2-tailed)	.003	.970	.010	<,001	<,001	.583		<,001	<,001
	N	39	39	39	39	39	39	39	39	39
Precipitation	Pearson Correlation	.054	.296	.705**	.755**	.932**	.526**	-.607**	1	-.307
	Sig. (2-tailed)	.744	.067	<,001	<,001	<,001	<,001	<,001		.057
	N	39	39	39	39	39	39	39	39	39
Daylength	Pearson Correlation	.505**	-.176	-.241	-.777**	-.512**	-.142	.678**	-.307	1
	Sig. (2-tailed)	.001	.285	.139	<,001	<,001	.390	<,001	.057	
	N	39	39	39	39	39	39	39	39	39

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Spinacea oleracea, Study site = Natural soil area

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Crop = Vigna unguilata, Study site = Eco green wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	-.050	-.185	-.143	-.384*	.004	.170	.281	.392*
	Sig. (2-tailed)		.785	.311	.434	.030	.985	.352	.120	.027
	N	32	32	32	32	32	32	32	32	32
Soil water content	Pearson Correlation	-.050	1	.310	.857**	.179	.643**	-.036	-.230	.528**
	Sig. (2-tailed)	.785		.084	<,001	.327	<,001	.846	.206	.002
	N	32	32	32	32	32	32	32	32	32
Soil temperature	Pearson Correlation	-.185	.310	1	.307	.886**	.887**	-.952**	.598**	.534**
	Sig. (2-tailed)	.311	.084		.088	<,001	<,001	<,001	<,001	.002
	N	32	32	32	32	32	32	32	32	32
Soil Saturation Extract EC	Pearson Correlation	-.143	.857**	.307	1	.089	.547**	-.003	-.111	.320
	Sig. (2-tailed)	.434	<,001	.088		.627	.001	.989	.547	.075
	N	32	32	32	32	32	32	32	32	32
Local maximum temperature	Pearson Correlation	-.384*	.179	.886**	.089	1	.660**	-.908**	.282	.208
	Sig. (2-tailed)	.030	.327	<,001	.627		<,001	<,001	.118	.253
	N	32	32	32	32	32	32	32	32	32
Local minimum temperature	Pearson Correlation	.004	.643**	.887**	.547**	.660**	1	-.741**	.516**	.810**
	Sig. (2-tailed)	.985	<,001	<,001	.001	<,001		<,001	.003	<,001
	N	32	32	32	32	32	32	32	32	32
Local relative humidity	Pearson Correlation	.170	-.036	-.952**	-.003	-.908**	-.741**	1	-.656**	-.425*
	Sig. (2-tailed)	.352	.846	<,001	.989	<,001	<,001		<,001	.015
	N	32	32	32	32	32	32	32	32	32
Precipitation	Pearson Correlation	.281	-.230	.598**	-.111	.282	.516**	-.656**	1	.583**
	Sig. (2-tailed)	.120	.206	<,001	.547	.118	.003	<,001		<,001
	N	32	32	32	32	32	32	32	32	32
Daylength	Pearson Correlation	.392*	.528**	.534**	.320	.208	.810**	-.425*	.583**	1
	Sig. (2-tailed)	.027	.002	.002	.075	.253	<,001	.015	<,001	
	N	32	32	32	32	32	32	32	32	32

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Vigna unguilata, Study site = Eco green wall

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Crop = Vigna unguilata, Study site = Vicinity wall

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.177	-.307*	.007	-.280	-.469**	.292	-.121	.082
	Sig. (2-tailed)		.246	.040	.965	.062	.001	.052	.430	.594
	N	45	45	45	45	45	45	45	45	45
Soil water content	Pearson Correlation	.177	1	-.758**	.896**	-.568**	-.279	.773**	-.434**	-.080
	Sig. (2-tailed)	.246		<,001	<,001	<,001	.063	<,001	.003	.600
	N	45	45	45	45	45	45	45	45	45
Soil temperature	Pearson Correlation	-.307*	-.758**	1	-.719**	.951**	.773**	-.955**	.176	.373*
	Sig. (2-tailed)	.040	<,001		<,001	<,001	<,001	<,001	.247	.012
	N	45	45	45	45	45	45	45	45	45
Soil Saturation Extract EC	Pearson Correlation	.007	.896**	-.719**	1	-.628**	-.301*	.785**	-.552**	-.364*
	Sig. (2-tailed)	.965	<,001	<,001		<,001	.044	<,001	<,001	.014
	N	45	45	45	45	45	45	45	45	45
Local maximum temperature	Pearson Correlation	-.280	-.568**	.951**	-.628**	1	.847**	-.930**	.104	.453**
	Sig. (2-tailed)	.062	<,001	<,001	<,001		<,001	<,001	.497	.002
	N	45	45	45	45	45	45	45	45	45
Local minimum temperature	Pearson Correlation	-.469**	-.279	.773**	-.301*	.847**	1	-.748**	.225	.554**
	Sig. (2-tailed)	.001	.063	<,001	.044	<,001		<,001	.136	<,001
	N	45	45	45	45	45	45	45	45	45
Local relative humidity	Pearson Correlation	.292	.773**	-.955**	.785**	-.930**	-.748**	1	-.342*	-.370*
	Sig. (2-tailed)	.052	<,001	<,001	<,001	<,001	<,001		.022	.012
	N	45	45	45	45	45	45	45	45	45
Precipitation	Pearson Correlation	-.121	-.434**	.176	-.552**	.104	.225	-.342*	1	.487**
	Sig. (2-tailed)	.430	.003	.247	<,001	.497	.136	.022		<,001
	N	45	45	45	45	45	45	45	45	45
Daylength	Pearson Correlation	.082	-.080	.373*	-.364*	.453**	.554**	-.370*	.487**	1
	Sig. (2-tailed)	.594	.600	.012	.014	.002	<,001	.012	<,001	
	N	45	45	45	45	45	45	45	45	45

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Vigna unguilata, Study site = Vicinity wall

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Crop = Vigna unguilata, Study site = Natural soil area

Correlations[a]

		FvFm	Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength
FvFm	Pearson Correlation	1	.467**	-.130	.201	.354*	-.279	-.175	.384*	-.120
	Sig. (2-tailed)		.002	.412	.202	.022	.073	.267	.012	.449
	N	42	42	42	42	42	42	42	42	42
Soil water content	Pearson Correlation	.467**	1	-.546**	.491**	.232	-.689**	.062	-.004	-.408**
	Sig. (2-tailed)	.002		<,001	<,001	.139	<,001	.695	.978	.007
	N	42	42	42	42	42	42	42	42	42
Soil temperature	Pearson Correlation	-.130	-.546**	1	.093	.664**	.913**	-.833**	.705**	.587**
	Sig. (2-tailed)	.412	<,001		.560	<,001	<,001	<,001	<,001	<,001
	N	42	42	42	42	42	42	42	42	42
Soil Saturation Extract EC	Pearson Correlation	.201	.491**	.093	1	.550**	.194	-.552**	.348*	-.605**
	Sig. (2-tailed)	.202	<,001	.560		<,001	.220	<,001	.024	<,001
	N	42	42	42	42	42	42	42	42	42
Local maximum temperature	Pearson Correlation	.354*	.232	.664**	.550**	1	.453**	-.938**	.915**	.242
	Sig. (2-tailed)	.022	.139	<,001	<,001		.003	<,001	<,001	.122
	N	42	42	42	42	42	42	42	42	42
Local minimum temperature	Pearson Correlation	-.279	-.689**	.913**	.194	.453**	1	-.726**	.522**	.301
	Sig. (2-tailed)	.073	<,001	<,001	.220	.003		<,001	<,001	.053
	N	42	42	42	42	42	42	42	42	42
Local relative humidity	Pearson Correlation	-.175	.062	-.833**	-.552**	-.938**	-.726**	1	-.899**	-.226
	Sig. (2-tailed)	.267	.695	<,001	<,001	<,001	<,001		<,001	.150
	N	42	42	42	42	42	42	42	42	42
Precipitation	Pearson Correlation	.384*	-.004	.705**	.348*	.915**	.522**	-.899**	1	.275
	Sig. (2-tailed)	.012	.978	<,001	.024	<,001	<,001	<,001		.078
	N	42	42	42	42	42	42	42	42	42
Daylength	Pearson Correlation	-.120	-.408**	.587**	-.605**	.242	.301	-.226	.275	1
	Sig. (2-tailed)	.449	.007	<,001	<,001	.122	.053	.150	.078	
	N	42	42	42	42	42	42	42	42	42

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Vigna unguilata, Study site = Natural soil area

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Appendix M: Statistical analysis results of correlation between the total performance index in the typologies and all climate and soil variables

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Correlations: PItotal and soil and climate variables
Crop = Amaranthus thunbergii, Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	1.000**	-.960**	.994**	.983**	-.992**	.047	-.934**	-.380
	Sig. (2-tailed)		<,001	<,001	<,001	<,001	<,001	.890	<,001	.248
	N	11	11	11	11	11	11	11	11	11
Soil temperature	Pearson Correlation	1.000**	1	-.957**	.995**	.985**	-.990**	.038	-.937**	-.380
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.912	<,001	.250
	N	11	11	11	11	11	11	11	11	11
Soil Saturation Extract EC	Pearson Correlation	-.960**	-.957**	1	-.924**	-.893**	.988**	-.327	.795**	.392
	Sig. (2-tailed)	<,001	<,001		<,001	<,001	<,001	.327	.003	.234
	N	11	11	11	11	11	11	11	11	11
Local maximum temperature	Pearson Correlation	.994**	.995**	-.924**	1	.997**	-.972**	-.059	-.966**	-.368
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	.864	<,001	.265
	N	11	11	11	11	11	11	11	11	11
Local minimum temperature	Pearson Correlation	.983**	.985**	-.893**	.997**	1	-.952**	-.134	-.983**	-.357
	Sig. (2-tailed)	<,001	<,001	<,001	<,001		<,001	.694	<,001	.281
	N	11	11	11	11	11	11	11	11	11
Local relative humidity	Pearson Correlation	-.992**	-.990**	.988**	-.972**	-.952**	1	-.177	.879**	.389
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001		.603	<,001	.236
	N	11	11	11	11	11	11	11	11	11
Precipitation	Pearson Correlation	.047	.038	-.327	-.059	-.134	-.177	1	.313	-.112
	Sig. (2-tailed)	.890	.912	.327	.864	.694	.603		.348	.744
	N	11	11	11	11	11	11	11	11	11
Daylength	Pearson Correlation	-.934**	-.937**	.795**	-.966**	-.983**	.879**	.313	1	.322
	Sig. (2-tailed)	<,001	<,001	.003	<,001	<,001	<,001	.348		.335
	N	11	11	11	11	11	11	11	11	11
PItot	Pearson Correlation	-.380	-.380	.392	-.368	-.357	.389	-.112	.322	1
	Sig. (2-tailed)	.248	.250	.234	.265	.281	.236	.744	.335	
	N	11	11	11	11	11	11	11	11	11

**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Amaranthus thunbergii, Study site = Eco green wall

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Crop = Amaranthus thunbergii, Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.887**	.947**	-.791**	-.496	.920**	-.444	.025	.224
	Sig. (2-tailed)		<,001	<,001	<,001	.071	<,001	.112	.932	.442
	N	14	14	14	14	14	14	14	14	14
Soil temperature	Pearson Correlation	-.887**	1	-.934**	.981**	.829**	-.985**	.642*	.354	-.349
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.013	.215	.221
	N	14	14	14	14	14	14	14	14	14
Soil Saturation Extract EC	Pearson Correlation	.947**	-.934**	1	-.879**	-.592*	.940**	-.495	-.234	.221
	Sig. (2-tailed)	<,001	<,001		<,001	.026	<,001	.072	.421	.448
	N	14	14	14	14	14	14	14	14	14
Local maximum temperature	Pearson Correlation	-.791**	.981**	-.879**	1	.888**	-.961**	.608*	.442	-.306
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	.021	.113	.288
	N	14	14	14	14	14	14	14	14	14
Local minimum temperature	Pearson Correlation	-.496	.829**	-.592*	.888**	1	-.759**	.755**	.632*	-.484
	Sig. (2-tailed)	.071	<,001	.026	<,001		.002	.002	.015	.080
	N	14	14	14	14	14	14	14	14	14
Local relative humidity	Pearson Correlation	.920**	-.985**	.940**	-.961**	-.759**	1	-.513	-.205	.238
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	.002		.061	.482	.412
	N	14	14	14	14	14	14	14	14	14
Precipitation	Pearson Correlation	-.444	.642*	-.495	.608*	.755**	-.513	1	.689**	-.784**
	Sig. (2-tailed)	.112	.013	.072	.021	.002	.061		.006	<,001
	N	14	14	14	14	14	14	14	14	14
Daylength	Pearson Correlation	.025	.354	-.234	.442	.632*	-.205	.689**	1	-.479
	Sig. (2-tailed)	.932	.215	.421	.113	.015	.482	.006		.083
	N	14	14	14	14	14	14	14	14	14
PItot	Pearson Correlation	.224	-.349	.221	-.306	-.484	.238	-.784**	-.479	1
	Sig. (2-tailed)	.442	.221	.448	.288	.080	.412	<,001	.083	
	N	14	14	14	14	14	14	14	14	14

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Amaranthus thunbergii, Study site = Vicinity wall

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Crop = Amaranthus thunbergii, Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.118	.060	.060	.145	.766**	.117	.780**	.486
	Sig. (2-tailed)		.715	.854	.854	.654	.004	.717	.003	.109
	N	12	12	12	12	12	12	12	12	12
Soil temperature	Pearson Correlation	-.118	1	.984**	.984**	.966**	-.729**	.972**	-.713**	.624*
	Sig. (2-tailed)	.715		<,001	<,001	<,001	.007	<,001	.009	.030
	N	12	12	12	12	12	12	12	12	12
Soil Saturation Extract EC	Pearson Correlation	.060	.984**	1	1.000**	.996**	-.596*	.998**	-.578*	.714**
	Sig. (2-tailed)	.854	<,001		.000	<,001	.041	<,001	.049	.009
	N	12	12	12	12	12	12	12	12	12
Local maximum temperature	Pearson Correlation	.060	.984**	1.000**	1	.996**	-.596*	.998**	-.578*	.714**
	Sig. (2-tailed)	.854	<,001	.000		<,001	.041	<,001	.049	.009
	N	12	12	12	12	12	12	12	12	12
Local minimum temperature	Pearson Correlation	.145	.966**	.996**	.996**	1	-.526	1.000**	-.506	.749**
	Sig. (2-tailed)	.654	<,001	<,001	<,001		.079	<,001	.093	.005
	N	12	12	12	12	12	12	12	12	12
Local relative humidity	Pearson Correlation	.766**	-.729**	-.596*	-.596*	-.526	1	-.549	1.000**	-.069
	Sig. (2-tailed)	.004	.007	.041	.041	.079		.065	<,001	.831
	N	12	12	12	12	12	12	12	12	12
Precipitation	Pearson Correlation	.117	.972**	.998**	.998**	1.000**	-.549	1	-.530	.739**
	Sig. (2-tailed)	.717	<,001	<,001	<,001	<,001	.065		.076	.006
	N	12	12	12	12	12	12	12	12	12
Daylength	Pearson Correlation	.780**	-.713**	-.578*	-.578*	-.506	1.000**	-.530	1	-.050
	Sig. (2-tailed)	.003	.009	.049	.049	.093	<,001	.076		.877
	N	12	12	12	12	12	12	12	12	12
PItot	Pearson Correlation	.486	.624*	.714**	.714**	.749**	-.069	.739**	-.050	1
	Sig. (2-tailed)	.109	.030	.009	.009	.005	.831	.006	.877	
	N	12	12	12	12	12	12	12	12	12

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Amaranthus thunbergii, Study site = Natural soil area

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Crop = Asystasia gangetica, Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	.443**	.667**	.340*	.699**	-.207	-.366*	.261	-.143
	Sig. (2-tailed)		.005	<,001	.034	<,001	.207	.022	.109	.384
	N	39	39	39	39	39	39	39	39	39
Soil temperature	Pearson Correlation	.443**	1	.193	.911**	.884**	-.923**	.272	.159	-.512**
	Sig. (2-tailed)	.005		.239	<,001	<,001	<,001	.094	.333	<,001
	N	39	39	39	39	39	39	39	39	39
Soil Saturation Extract EC	Pearson Correlation	.667**	.193	1	-.090	.405*	.185	-.090	-.134	.025
	Sig. (2-tailed)	<,001	.239		.585	.010	.260	.587	.416	.880
	N	39	39	39	39	39	39	39	39	39
Local maximum temperature	Pearson Correlation	.340*	.911**	-.090	1	.706**	-.949**	-.004	.029	-.335*
	Sig. (2-tailed)	.034	<,001	.585		<,001	<,001	.980	.861	.037
	N	39	39	39	39	39	39	39	39	39
Local minimum temperature	Pearson Correlation	.699**	.884**	.405*	.706**	1	-.709**	.242	.474**	-.580**
	Sig. (2-tailed)	<,001	<,001	.010	<,001		<,001	.137	.002	<,001
	N	39	39	39	39	39	39	39	39	39
Local relative humidity	Pearson Correlation	-.207	-.923**	.185	-.949**	-.709**	1	-.280	-.173	.504**
	Sig. (2-tailed)	.207	<,001	.260	<,001	<,001		.084	.291	.001
	N	39	39	39	39	39	39	39	39	39
Precipitation	Pearson Correlation	-.366*	.272	-.090	-.004	.242	-.280	1	.404*	-.605**
	Sig. (2-tailed)	.022	.094	.587	.980	.137	.084		.011	<,001
	N	39	39	39	39	39	39	39	39	39
Daylength	Pearson Correlation	.261	.159	-.134	.029	.474**	-.173	.404*	1	-.596**
	Sig. (2-tailed)	.109	.333	.416	.861	.002	.291	.011		<,001
	N	39	39	39	39	39	39	39	39	39
PItot	Pearson Correlation	-.143	-.512**	.025	-.335*	-.580**	.504**	-.605**	-.596**	1
	Sig. (2-tailed)	.384	<,001	.880	.037	<,001	.001	<,001	<,001	
	N	39	39	39	39	39	39	39	39	39

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Asystasia gangetica, Study site = Eco green wall

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Crop = Asystasia gangetica, Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.805**	.900**	-.678**	-.435*	.858**	-.463*	-.215	-.021
	Sig. (2-tailed)		<,001	<,001	<,001	.023	<,001	.015	.281	.918
	N	27	27	27	27	27	27	27	27	27
Soil temperature	Pearson Correlation	-.805**	1	-.803**	.973**	.841**	-.966**	.349	.548**	.060
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.074	.003	.767
	N	27	27	27	27	27	27	27	27	27
Soil Saturation Extract EC	Pearson Correlation	.900**	-.803**	1	-.752**	-.510**	.881**	-.626**	-.520**	-.020
	Sig. (2-tailed)	<,001	<,001		<,001	.007	<,001	<,001	.005	.922
	N	27	27	27	27	27	27	27	27	27
Local maximum temperature	Pearson Correlation	-.678**	.973**	-.752**	1	.896**	-.947**	.338	.627**	.112
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	.085	<,001	.577
	N	27	27	27	27	27	27	27	27	27
Local minimum temperature	Pearson Correlation	-.435*	.841**	-.510**	.896**	1	-.786**	.429*	.705**	.028
	Sig. (2-tailed)	.023	<,001	.007	<,001		<,001	.026	<,001	.889
	N	27	27	27	27	27	27	27	27	27
Local relative humidity	Pearson Correlation	.858**	-.966**	.881**	-.947**	-.786**	1	-.469*	-.490**	-.125
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001		.014	.009	.533
	N	27	27	27	27	27	27	27	27	27
Precipitation	Pearson Correlation	-.463*	.349	-.626**	.338	.429*	-.469*	1	.576**	-.144
	Sig. (2-tailed)	.015	.074	<,001	.085	.026	.014		.002	.474
	N	27	27	27	27	27	27	27	27	27
Daylength	Pearson Correlation	-.215	.548**	-.520**	.627**	.705**	-.490**	.576**	1	-.185
	Sig. (2-tailed)	.281	.003	.005	<,001	<,001	.009	.002		.355
	N	27	27	27	27	27	27	27	27	27
PItot	Pearson Correlation	-.021	.060	-.020	.112	.028	-.125	-.144	-.185	1
	Sig. (2-tailed)	.918	.767	.922	.577	.889	.533	.474	.355	
	N	27	27	27	27	27	27	27	27	27

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Asystasia gangetica, Study site = Vicinity wall

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Crop = Asystasia gangetica, Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.485**	.562**	-.475**	-.528**	.520**	.216	-.431**	-.329*
	Sig. (2-tailed)		<,001	<,001	<,001	<,001	<,001	.128	.002	.018
	N	51	51	51	51	51	51	51	51	51
Soil temperature	Pearson Correlation	-.485**	1	.080	.898**	.916**	-.962**	.624**	.563**	-.054
	Sig. (2-tailed)	<,001		.578	<,001	<,001	<,001	<,001	<,001	.705
	N	51	51	51	51	51	51	51	51	51
Soil Saturation Extract EC	Pearson Correlation	.562**	.080	1	.056	.285*	-.171	.443**	-.641**	-.432**
	Sig. (2-tailed)	<,001	.578		.697	.042	.229	.001	<,001	.002
	N	51	51	51	51	51	51	51	51	51
Local maximum temperature	Pearson Correlation	-.475**	.898**	.056	1	.811**	-.948**	.586**	.499**	-.045
	Sig. (2-tailed)	<,001	<,001	.697		<,001	<,001	<,001	<,001	.754
	N	51	51	51	51	51	51	51	51	51
Local minimum temperature	Pearson Correlation	-.528**	.916**	.285*	.811**	1	-.952**	.515**	.227	-.091
	Sig. (2-tailed)	<,001	<,001	.042	<,001		<,001	<,001	.110	.524
	N	51	51	51	51	51	51	51	51	51
Local relative humidity	Pearson Correlation	.520**	-.962**	-.171	-.948**	-.952**	1	-.608**	-.394**	.075
	Sig. (2-tailed)	<,001	<,001	.229	<,001	<,001		<,001	.004	.601
	N	51	51	51	51	51	51	51	51	51
Precipitation	Pearson Correlation	.216	.624**	.443**	.586**	.515**	-.608**	1	.155	-.314*
	Sig. (2-tailed)	.128	<,001	.001	<,001	<,001	<,001		.279	.025
	N	51	51	51	51	51	51	51	51	51
Daylength	Pearson Correlation	-.431**	.563**	-.641**	.499**	.227	-.394**	.155	1	.220
	Sig. (2-tailed)	.002	<,001	<,001	<,001	.110	.004	.279		.120
	N	51	51	51	51	51	51	51	51	51
PItot	Pearson Correlation	-.329*	-.054	-.432**	-.045	-.091	.075	-.314*	.220	1
	Sig. (2-tailed)	.018	.705	.002	.754	.524	.601	.025	.120	
	N	51	51	51	51	51	51	51	51	51

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Asystasia gangetica, Study site = Natural soil area

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Crop = Corchorus confusus, Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	.803**	.837**	.569**	.930**	-.538*	.421	.600**	.534*
	Sig. (2-tailed)		<,001	<,001	.007	<,001	.012	.057	.004	.013
	N	21	21	21	21	21	21	21	21	21
Soil temperature	Pearson Correlation	.803**	1	.639**	.908**	.938**	-.893**	.652**	.464*	.458*
	Sig. (2-tailed)	<,001		.002	<,001	<,001	<,001	.001	.034	.037
	N	21	21	21	21	21	21	21	21	21
Soil Saturation Extract EC	Pearson Correlation	.837**	.639**	1	.310	.746**	-.228	.328	.213	.453*
	Sig. (2-tailed)	<,001	.002		.172	<,001	.320	.147	.355	.039
	N	21	21	21	21	21	21	21	21	21
Local maximum temperature	Pearson Correlation	.569**	.908**	.310	1	.738**	-.980**	.470*	.305	.388
	Sig. (2-tailed)	.007	<,001	.172		<,001	<,001	.032	.178	.082
	N	21	21	21	21	21	21	21	21	21
Local minimum temperature	Pearson Correlation	.930**	.938**	.746**	.738**	1	-.747**	.692**	.667**	.471*
	Sig. (2-tailed)	<,001	<,001	<,001	<,001		<,001	<,001	<,001	.031
	N	21	21	21	21	21	21	21	21	21
Local relative humidity	Pearson Correlation	-.538*	-.893**	-.228	-.980**	-.747**	1	-.588**	-.440*	-.333
	Sig. (2-tailed)	.012	<,001	.320	<,001	<,001		.005	.046	.140
	N	21	21	21	21	21	21	21	21	21
Precipitation	Pearson Correlation	.421	.652**	.328	.470*	.692**	-.588**	1	.672**	.081
	Sig. (2-tailed)	.057	.001	.147	.032	<,001	.005		<,001	.725
	N	21	21	21	21	21	21	21	21	21
Daylength	Pearson Correlation	.600**	.464*	.213	.305	.667**	-.440*	.672**	1	.175
	Sig. (2-tailed)	.004	.034	.355	.178	<,001	.046	<,001		.449
	N	21	21	21	21	21	21	21	21	21
PItot	Pearson Correlation	.534*	.458*	.453*	.388	.471*	-.333	.081	.175	1
	Sig. (2-tailed)	.013	.037	.039	.082	.031	.140	.725	.449	
	N	21	21	21	21	21	21	21	21	21

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Corchorus confusus, Study site = Eco green wall

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Crop = Corchorus confusus, Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.862**	.945**	-.706**	-.496**	.892**	-.403*	.134	.290
	Sig. (2-tailed)		<,001	<,001	<,001	.002	<,001	.016	.444	.091
	N	35	35	35	35	35	35	35	35	35
Soil temperature	Pearson Correlation	-.862**	1	-.790**	.950**	.783**	-.945**	.016	-.168	-.097
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.929	.335	.578
	N	35	35	35	35	35	35	35	35	35
Soil Saturation Extract EC	Pearson Correlation	.945**	-.790**	1	-.693**	-.519**	.895**	-.575**	-.080	.311
	Sig. (2-tailed)	<,001	<,001		<,001	.001	<,001	<,001	.648	.069
	N	35	35	35	35	35	35	35	35	35
Local maximum temperature	Pearson Correlation	-.706**	.950**	-.693**	1	.886**	-.926**	-.063	-.143	-.062
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	.717	.414	.723
	N	35	35	35	35	35	35	35	35	35
Local minimum temperature	Pearson Correlation	-.496**	.783**	-.519**	.886**	1	-.784**	.039	.052	.000
	Sig. (2-tailed)	.002	<,001	.001	<,001		<,001	.822	.767	.999
	N	35	35	35	35	35	35	35	35	35
Local relative humidity	Pearson Correlation	.892**	-.945**	.895**	-.926**	-.784**	1	-.259	.149	.241
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001		.134	.395	.163
	N	35	35	35	35	35	35	35	35	35
Precipitation	Pearson Correlation	-.403*	.016	-.575**	-.063	.039	-.259	1	.428*	-.356*
	Sig. (2-tailed)	.016	.929	<,001	.717	.822	.134		.010	.036
	N	35	35	35	35	35	35	35	35	35
Daylength	Pearson Correlation	.134	-.168	-.080	-.143	.052	.149	.428*	1	.227
	Sig. (2-tailed)	.444	.335	.648	.414	.767	.395	.010		.189
	N	35	35	35	35	35	35	35	35	35
PItot	Pearson Correlation	.290	-.097	.311	-.062	.000	.241	-.356*	.227	1
	Sig. (2-tailed)	.091	.578	.069	.723	.999	.163	.036	.189	
	N	35	35	35	35	35	35	35	35	35

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Corchorus confusus, Study site = Vicinity wall

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Crop = Corchorus confusus, Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.495**	.508**	-.298	-.538**	.449**	.133	-.416**	-.076
	Sig. (2-tailed)		<,001	<,001	.052	<,001	.003	.395	.006	.626
	N	43	43	43	43	43	43	43	43	43
Soil temperature	Pearson Correlation	-.495**	1	.126	.969**	.915**	-.978**	.673**	.534**	.565**
	Sig. (2-tailed)	<,001		.420	<,001	<,001	<,001	<,001	<,001	<,001
	N	43	43	43	43	43	43	43	43	43
Soil Saturation Extract EC	Pearson Correlation	.508**	.126	1	.238	.342*	-.284	.431**	-.643**	.085
	Sig. (2-tailed)	<,001	.420		.124	.025	.065	.004	<,001	.588
	N	43	43	43	43	43	43	43	43	43
Local maximum temperature	Pearson Correlation	-.298	.969**	.238	1	.857**	-.963**	.829**	.479**	.556**
	Sig. (2-tailed)	.052	<,001	.124		<,001	<,001	<,001	.001	<,001
	N	43	43	43	43	43	43	43	43	43
Local minimum temperature	Pearson Correlation	-.538**	.915**	.342*	.857**	1	-.963**	.568**	.190	.415**
	Sig. (2-tailed)	<,001	<,001	.025	<,001		<,001	<,001	.223	.006
	N	43	43	43	43	43	43	43	43	43
Local relative humidity	Pearson Correlation	.449**	-.978**	-.284	-.963**	-.963**	1	-.729**	-.351*	-.491**
	Sig. (2-tailed)	.003	<,001	.065	<,001	<,001		<,001	.021	<,001
	N	43	43	43	43	43	43	43	43	43
Precipitation	Pearson Correlation	.133	.673**	.431**	.829**	.568**	-.729**	1	.168	.317*
	Sig. (2-tailed)	.395	<,001	.004	<,001	<,001	<,001		.280	.038
	N	43	43	43	43	43	43	43	43	43
Daylength	Pearson Correlation	-.416**	.534**	-.643**	.479**	.190	-.351*	.168	1	.490**
	Sig. (2-tailed)	.006	<,001	<,001	.001	.223	.021	.280		<,001
	N	43	43	43	43	43	43	43	43	43
PItot	Pearson Correlation	-.076	.565**	.085	.556**	.415**	-.491**	.317*	.490**	1
	Sig. (2-tailed)	.626	<,001	.588	<,001	.006	<,001	.038	<,001	
	N	43	43	43	43	43	43	43	43	43

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Corchorus confusus, Study site = Natural soil area

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Crop = Dicliptera clinopodia , Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	.535*	.752**	.450	.785**	-.412	-.114	.732**	-.197
	Sig. (2-tailed)		.027	<,001	.070	<,001	.101	.664	<,001	.447
	N	17	17	17	17	17	17	17	17	17
Soil temperature	Pearson Correlation	.535*	1	-.017	.946**	.888**	-.978**	.396	.504*	-.099
	Sig. (2-tailed)	.027		.949	<,001	<,001	<,001	.116	.039	.705
	N	17	17	17	17	17	17	17	17	17
Soil Saturation Extract EC	Pearson Correlation	.752**	-.017	1	-.190	.435	.202	-.083	.743**	-.471
	Sig. (2-tailed)	<,001	.949		.465	.081	.438	.752	<,001	.057
	N	17	17	17	17	17	17	17	17	17
Local maximum temperature	Pearson Correlation	.450	.946**	-.190	1	.735**	-.966**	.138	.230	.208
	Sig. (2-tailed)	.070	<,001	.465		<,001	<,001	.596	.374	.422
	N	17	17	17	17	17	17	17	17	17
Local minimum temperature	Pearson Correlation	.785**	.888**	.435	.735**	1	-.781**	.408	.826**	-.379
	Sig. (2-tailed)	<,001	<,001	.081	<,001		<,001	.104	<,001	.134
	N	17	17	17	17	17	17	17	17	17
Local relative humidity	Pearson Correlation	-.412	-.978**	.202	-.966**	-.781**	1	-.370	-.344	-.010
	Sig. (2-tailed)	.101	<,001	.438	<,001	<,001		.144	.176	.968
	N	17	17	17	17	17	17	17	17	17
Precipitation	Pearson Correlation	-.114	.396	-.083	.138	.408	-.370	1	.527*	-.738**
	Sig. (2-tailed)	.664	.116	.752	.596	.104	.144		.030	<,001
	N	17	17	17	17	17	17	17	17	17
Daylength	Pearson Correlation	.732**	.504*	.743**	.230	.826**	-.344	.527*	1	-.748**
	Sig. (2-tailed)	<,001	.039	<,001	.374	<,001	.176	.030		<,001
	N	17	17	17	17	17	17	17	17	17
PItot	Pearson Correlation	-.197	-.099	-.471	.208	-.379	-.010	-.738**	-.748**	1
	Sig. (2-tailed)	.447	.705	.057	.422	.134	.968	<,001	<,001	
	N	17	17	17	17	17	17	17	17	17

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Dicliptera clinopodia , Study site = Eco green wall

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Crop = Dicliptera clinopodia , Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.892**	.934**	-.640**	-.458	.794**	-.402	.404	-.049
	Sig. (2-tailed)		<,001	<,001	.004	.056	<,001	.099	.097	.848
	N	18	18	18	18	18	18	18	18	18
Soil temperature	Pearson Correlation	-.892**	1	-.927**	.917**	.775**	-.983**	-.045	-.620**	.292
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.860	.006	.239
	N	18	18	18	18	18	18	18	18	18
Soil Saturation Extract EC	Pearson Correlation	.934**	-.927**	1	-.772**	-.490*	.866**	-.129	.290	-.147
	Sig. (2-tailed)	<,001	<,001		<,001	.039	<,001	.610	.243	.561
	N	18	18	18	18	18	18	18	18	18
Local maximum temperature	Pearson Correlation	-.640**	.917**	-.772**	1	.896**	-.974**	-.437	-.665**	.451
	Sig. (2-tailed)	.004	<,001	<,001		<,001	<,001	.070	.003	.060
	N	18	18	18	18	18	18	18	18	18
Local minimum temperature	Pearson Correlation	-.458	.775**	-.490*	.896**	1	-.859**	-.464	-.911**	.486*
	Sig. (2-tailed)	.056	<,001	.039	<,001		<,001	.053	<,001	.041
	N	18	18	18	18	18	18	18	18	18
Local relative humidity	Pearson Correlation	.794**	-.983**	.866**	-.974**	-.859**	1	.222	.675**	-.374
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001		.377	.002	.127
	N	18	18	18	18	18	18	18	18	18
Precipitation	Pearson Correlation	-.402	-.045	-.129	-.437	-.464	.222	1	.205	-.462
	Sig. (2-tailed)	.099	.860	.610	.070	.053	.377		.415	.053
	N	18	18	18	18	18	18	18	18	18
Daylength	Pearson Correlation	.404	-.620**	.290	-.665**	-.911**	.675**	.205	1	-.370
	Sig. (2-tailed)	.097	.006	.243	.003	<,001	.002	.415		.131
	N	18	18	18	18	18	18	18	18	18
PItot	Pearson Correlation	-.049	.292	-.147	.451	.486*	-.374	-.462	-.370	1
	Sig. (2-tailed)	.848	.239	.561	.060	.041	.127	.053	.131	
	N	18	18	18	18	18	18	18	18	18

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Dicliptera clinopodia , Study site = Vicinity wall

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Crop = Dicliptera clinopodia , Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.378	.486*	-.125	-.080	.640**	.230	-.297	.153
	Sig. (2-tailed)		.052	.010	.533	.692	<,001	.250	.132	.446
	N	27	27	27	27	27	27	27	27	27
Soil temperature	Pearson Correlation	-.378	1	.265	.959**	.784**	-.689**	.690**	.358	-.118
	Sig. (2-tailed)	.052		.182	<,001	<,001	<,001	<,001	.067	.557
	N	27	27	27	27	27	27	27	27	27
Soil Saturation Extract EC	Pearson Correlation	.486*	.265	1	.401*	.626**	.005	.527**	-.668**	.032
	Sig. (2-tailed)	.010	.182		.038	<,001	.979	.005	<,001	.876
	N	27	27	27	27	27	27	27	27	27
Local maximum temperature	Pearson Correlation	-.125	.959**	.401*	1	.819**	-.545**	.850**	.294	-.047
	Sig. (2-tailed)	.533	<,001	.038		<,001	.003	<,001	.137	.814
	N	27	27	27	27	27	27	27	27	27
Local minimum temperature	Pearson Correlation	-.080	.784**	.626**	.819**	1	-.226	.635**	-.111	.166
	Sig. (2-tailed)	.692	<,001	<,001	<,001		.258	<,001	.581	.409
	N	27	27	27	27	27	27	27	27	27
Local relative humidity	Pearson Correlation	.640**	-.689**	.005	-.545**	-.226	1	-.349	-.236	.431*
	Sig. (2-tailed)	<,001	<,001	.979	.003	.258		.075	.236	.025
	N	27	27	27	27	27	27	27	27	27
Precipitation	Pearson Correlation	.230	.690**	.527**	.850**	.635**	-.349	1	.054	.013
	Sig. (2-tailed)	.250	<,001	.005	<,001	<,001	.075		.789	.949
	N	27	27	27	27	27	27	27	27	27
Daylength	Pearson Correlation	-.297	.358	-.668**	.294	-.111	-.236	.054	1	-.099
	Sig. (2-tailed)	.132	.067	<,001	.137	.581	.236	.789		.622
	N	27	27	27	27	27	27	27	27	27
PItot	Pearson Correlation	.153	-.118	.032	-.047	.166	.431*	.013	-.099	1
	Sig. (2-tailed)	.446	.557	.876	.814	.409	.025	.949	.622	
	N	27	27	27	27	27	27	27	27	27

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Dicliptera clinopodia , Study site = Natural soil area

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Crop = Mentha aquatica, Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	.376*	.824**	.225	.646**	-.100	-.221	.356*	-.543**
	Sig. (2-tailed)		.029	<,001	.202	<,001	.572	.210	.039	<,001
	N	34	34	34	34	34	34	34	34	34
Soil temperature	Pearson Correlation	.376*	1	.339	.906**	.891**	-.927**	.605**	.412*	-.214
	Sig. (2-tailed)	.029		.050	<,001	<,001	<,001	<,001	.015	.225
	N	34	34	34	34	34	34	34	34	34
Soil Saturation Extract EC	Pearson Correlation	.824**	.339	1	.102	.534**	.027	-.147	.075	-.376*
	Sig. (2-tailed)	<,001	.050		.566	.001	.879	.405	.674	.029
	N	34	34	34	34	34	34	34	34	34
Local maximum temperature	Pearson Correlation	.225	.906**	.102	1	.668**	-.947**	.381*	.149	-.278
	Sig. (2-tailed)	.202	<,001	.566		<,001	<,001	.026	.400	.111
	N	34	34	34	34	34	34	34	34	34
Local minimum temperature	Pearson Correlation	.646**	.891**	.534**	.668**	1	-.721**	.562**	.692**	-.242
	Sig. (2-tailed)	<,001	<,001	.001	<,001		<,001	<,001	<,001	.169
	N	34	34	34	34	34	34	34	34	34
Local relative humidity	Pearson Correlation	-.100	-.927**	.027	-.947**	-.721**	1	-.642**	-.364*	.134
	Sig. (2-tailed)	.572	<,001	.879	<,001	<,001		<,001	.035	.450
	N	34	34	34	34	34	34	34	34	34
Precipitation	Pearson Correlation	-.221	.605**	-.147	.381*	.562**	-.642**	1	.629**	.329
	Sig. (2-tailed)	.210	<,001	.405	.026	<,001	<,001		<,001	.057
	N	34	34	34	34	34	34	34	34	34
Daylength	Pearson Correlation	.356*	.412*	.075	.149	.692**	-.364*	.629**	1	.052
	Sig. (2-tailed)	.039	.015	.674	.400	<,001	.035	<,001		.771
	N	34	34	34	34	34	34	34	34	34
PItot	Pearson Correlation	-.543**	-.214	-.376*	-.278	-.242	.134	.329	.052	1
	Sig. (2-tailed)	<,001	.225	.029	.111	.169	.450	.057	.771	
	N	34	34	34	34	34	34	34	34	34

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Mentha aquatica, Study site = Eco green wall

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Crop = Mentha aquatica, Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.775**	.882**	-.604**	-.256	.780**	-.397*	.074	.254
	Sig. (2-tailed)		<,001	<,001	<,001	.137	<,001	.018	.673	.141
	N	35	35	35	35	35	35	35	35	35
Soil temperature	Pearson Correlation	-.775**	1	-.701**	.954**	.744**	-.961**	.197	.223	-.283
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.256	.197	.100
	N	35	35	35	35	35	35	35	35	35
Soil Saturation Extract EC	Pearson Correlation	.882**	-.701**	1	-.628**	-.180	.744**	-.461**	-.230	.436**
	Sig. (2-tailed)	<,001	<,001		<,001	.299	<,001	.005	.183	.009
	N	35	35	35	35	35	35	35	35	35
Local maximum temperature	Pearson Correlation	-.604**	.954**	-.628**	1	.800**	-.938**	.119	.309	-.317
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	.497	.071	.063
	N	35	35	35	35	35	35	35	35	35
Local minimum temperature	Pearson Correlation	-.256	.744**	-.180	.800**	1	-.716**	.238	.373*	-.311
	Sig. (2-tailed)	.137	<,001	.299	<,001		<,001	.168	.027	.069
	N	35	35	35	35	35	35	35	35	35
Local relative humidity	Pearson Correlation	.780**	-.961**	.744**	-.938**	-.716**	1	-.324	-.194	.312
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001		.057	.263	.068
	N	35	35	35	35	35	35	35	35	35
Precipitation	Pearson Correlation	-.397*	.197	-.461**	.119	.238	-.324	1	.400*	-.551**
	Sig. (2-tailed)	.018	.256	.005	.497	.168	.057		.017	<,001
	N	35	35	35	35	35	35	35	35	35
Daylength	Pearson Correlation	.074	.223	-.230	.309	.373*	-.194	.400*	1	-.487**
	Sig. (2-tailed)	.673	.197	.183	.071	.027	.263	.017		.003
	N	35	35	35	35	35	35	35	35	35
PItot	Pearson Correlation	.254	-.283	.436**	-.317	-.311	.312	-.551**	-.487**	1
	Sig. (2-tailed)	.141	.100	.009	.063	.069	.068	<,001	.003	
	N	35	35	35	35	35	35	35	35	35

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Mentha aquatica, Study site = Vicinity wall

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Crop = Mentha aquatica, Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.477**	.467**	-.280	-.366*	.543**	.123	-.366*	.545**
	Sig. (2-tailed)		.002	.003	.084	.022	<,001	.457	.022	<,001
	N	39	39	39	39	39	39	39	39	39
Soil temperature	Pearson Correlation	-.477**	1	.145	.970**	.839**	-.882**	.684**	.517**	-.100
	Sig. (2-tailed)	.002		.378	<,001	<,001	<,001	<,001	<,001	.544
	N	39	39	39	39	39	39	39	39	39
Soil Saturation Extract EC	Pearson Correlation	.467**	.145	1	.254	.472**	-.146	.433**	-.650**	-.007
	Sig. (2-tailed)	.003	.378		.119	.002	.375	.006	<,001	.964
	N	39	39	39	39	39	39	39	39	39
Local maximum temperature	Pearson Correlation	-.280	.970**	.254	1	.824**	-.826**	.830**	.466**	.019
	Sig. (2-tailed)	.084	<,001	.119		<,001	<,001	<,001	.003	.908
	N	39	39	39	39	39	39	39	39	39
Local minimum temperature	Pearson Correlation	-.366*	.839**	.472**	.824**	1	-.645**	.597**	.072	-.260
	Sig. (2-tailed)	.022	<,001	.002	<,001		<,001	<,001	.665	.110
	N	39	39	39	39	39	39	39	39	39
Local relative humidity	Pearson Correlation	.543**	-.882**	-.146	-.826**	-.645**	1	-.602**	-.361*	.212
	Sig. (2-tailed)	<,001	<,001	.375	<,001	<,001		<,001	.024	.195
	N	39	39	39	39	39	39	39	39	39
Precipitation	Pearson Correlation	.123	.684**	.433**	.830**	.597**	-.602**	1	.167	.174
	Sig. (2-tailed)	.457	<,001	.006	<,001	<,001	<,001		.310	.290
	N	39	39	39	39	39	39	39	39	39
Daylength	Pearson Correlation	-.366*	.517**	-.650**	.466**	.072	-.361*	.167	1	.244
	Sig. (2-tailed)	.022	<,001	<,001	.003	.665	.024	.310		.134
	N	39	39	39	39	39	39	39	39	39
PItot	Pearson Correlation	.545**	-.100	-.007	.019	-.260	.212	.174	.244	1
	Sig. (2-tailed)	<,001	.544	.964	.908	.110	.195	.290	.134	
	N	39	39	39	39	39	39	39	39	39

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Mentha aquatica, Study site = Natural soil area

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Crop = Plectranthus amboinicus, Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	.516**	.734**	.409**	.722**	-.252	-.308*	.289*	.147
	Sig. (2-tailed)		<,001	<,001	.003	<,001	.077	.029	.042	.307
	N	50	50	50	50	50	50	50	50	50
Soil temperature	Pearson Correlation	.516**	1	.324*	.894**	.908**	-.912**	.365**	.364**	-.317*
	Sig. (2-tailed)	<,001		.022	<,001	<,001	<,001	.009	.009	.025
	N	50	50	50	50	50	50	50	50	50
Soil Saturation Extract EC	Pearson Correlation	.734**	.324*	1	.037	.492**	.077	-.106	-.068	-.204
	Sig. (2-tailed)	<,001	.022		.799	<,001	.593	.463	.637	.156
	N	50	50	50	50	50	50	50	50	50
Local maximum temperature	Pearson Correlation	.409**	.894**	.037	1	.712**	-.937**	.071	.191	-.185
	Sig. (2-tailed)	.003	<,001	.799		<,001	<,001	.625	.185	.198
	N	50	50	50	50	50	50	50	50	50
Local minimum temperature	Pearson Correlation	.722**	.908**	.492**	.712**	1	-.728**	.334*	.607**	-.137
	Sig. (2-tailed)	<,001	<,001	<,001	<,001		<,001	.018	<,001	.344
	N	50	50	50	50	50	50	50	50	50
Local relative humidity	Pearson Correlation	-.252	-.912**	.077	-.937**	-.728**	1	-.388**	-.367**	.242
	Sig. (2-tailed)	.077	<,001	.593	<,001	<,001		.005	.009	.091
	N	50	50	50	50	50	50	50	50	50
Precipitation	Pearson Correlation	-.308*	.365**	-.106	.071	.334*	-.388**	1	.515**	-.361**
	Sig. (2-tailed)	.029	.009	.463	.625	.018	.005		<,001	.010
	N	50	50	50	50	50	50	50	50	50
Daylength	Pearson Correlation	.289*	.364**	-.068	.191	.607**	-.367**	.515**	1	.246
	Sig. (2-tailed)	.042	.009	.637	.185	<,001	.009	<,001		.086
	N	50	50	50	50	50	50	50	50	50
PItot	Pearson Correlation	.147	-.317*	-.204	-.185	-.137	.242	-.361**	.246	1
	Sig. (2-tailed)	.307	.025	.156	.198	.344	.091	.010	.086	
	N	50	50	50	50	50	50	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Plectranthus amboinicus, Study site = Eco green wall

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Crop = Plectranthus amboinicus, Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.892**	.859**	-.832**	-.566**	.814**	-.507**	-.154	-.108
	Sig. (2-tailed)		<,001	<,001	<,001	<,001	<,001	<,001	.265	.438
	N	54	54	54	54	54	54	54	54	54
Soil temperature	Pearson Correlation	-.892**	1	-.724**	.972**	.729**	-.827**	.449**	.353**	-.026
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	<,001	.009	.854
	N	54	54	54	54	54	54	54	54	54
Soil Saturation Extract EC	Pearson Correlation	.859**	-.724**	1	-.760**	-.278*	.845**	-.608**	-.508**	-.010
	Sig. (2-tailed)	<,001	<,001		<,001	.042	<,001	<,001	<,001	.941
	N	54	54	54	54	54	54	54	54	54
Local maximum temperature	Pearson Correlation	-.832**	.972**	-.760**	1	.619**	-.905**	.464**	.503**	-.076
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	<,001	<,001	.583
	N	54	54	54	54	54	54	54	54	54
Local minimum temperature	Pearson Correlation	-.566**	.729**	-.278*	.619**	1	-.295*	.576**	.185	-.118
	Sig. (2-tailed)	<,001	<,001	.042	<,001		.030	<,001	.180	.397
	N	54	54	54	54	54	54	54	54	54
Local relative humidity	Pearson Correlation	.814**	-.827**	.845**	-.905**	-.295*	1	-.428**	-.427**	.000
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	.030		.001	.001	.999
	N	54	54	54	54	54	54	54	54	54
Precipitation	Pearson Correlation	-.507**	.449**	-.608**	.464**	.576**	-.428**	1	.498**	-.173
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001	.001		<,001	.212
	N	54	54	54	54	54	54	54	54	54
Daylength	Pearson Correlation	-.154	.353**	-.508**	.503**	.185	-.427**	.498**	1	-.332*
	Sig. (2-tailed)	.265	.009	<,001	<,001	.180	.001	<,001		.014
	N	54	54	54	54	54	54	54	54	54
PItot	Pearson Correlation	-.108	-.026	-.010	-.076	-.118	.000	-.173	-.332*	1
	Sig. (2-tailed)	.438	.854	.941	.583	.397	.999	.212	.014	
	N	54	54	54	54	54	54	54	54	54

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Plectranthus amboinicus, Study site = Vicinity wall

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Crop = Plectranthus amboinicus, Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.416**	.570**	-.201	-.231	.509**	.190	-.453**	-.131
	Sig. (2-tailed)		.002	<,001	.146	.092	<,001	.168	<,001	.344
	N	54	54	54	54	54	54	54	54	54
Soil temperature	Pearson Correlation	-.416**	1	.174	.967**	.824**	-.831**	.685**	.510**	.033
	Sig. (2-tailed)	.002		.208	<,001	<,001	<,001	<,001	<,001	.813
	N	54	54	54	54	54	54	54	54	54
Soil Saturation Extract EC	Pearson Correlation	.570**	.174	1	.308*	.498**	-.070	.470**	-.641**	-.468**
	Sig. (2-tailed)	<,001	.208		.024	<,001	.613	<,001	<,001	<,001
	N	54	54	54	54	54	54	54	54	54
Local maximum temperature	Pearson Correlation	-.201	.967**	.308*	1	.825**	-.759**	.838**	.430**	.046
	Sig. (2-tailed)	.146	<,001	.024		<,001	<,001	<,001	.001	.743
	N	54	54	54	54	54	54	54	54	54
Local minimum temperature	Pearson Correlation	-.231	.824**	.498**	.825**	1	-.492**	.602**	.063	-.223
	Sig. (2-tailed)	.092	<,001	<,001	<,001		<,001	<,001	.650	.105
	N	54	54	54	54	54	54	54	54	54
Local relative humidity	Pearson Correlation	.509**	-.831**	-.070	-.759**	-.492**	1	-.548**	-.408**	-.056
	Sig. (2-tailed)	<,001	<,001	.613	<,001	<,001		<,001	.002	.689
	N	54	54	54	54	54	54	54	54	54
Precipitation	Pearson Correlation	.190	.685**	.470**	.838**	.602**	-.548**	1	.133	.095
	Sig. (2-tailed)	.168	<,001	<,001	<,001	<,001	<,001		.337	.494
	N	54	54	54	54	54	54	54	54	54
Daylength	Pearson Correlation	-.453**	.510**	-.641**	.430**	.063	-.408**	.133	1	.446**
	Sig. (2-tailed)	<,001	<,001	<,001	.001	.650	.002	.337		<,001
	N	54	54	54	54	54	54	54	54	54
PItot	Pearson Correlation	-.131	.033	-.468**	.046	-.223	-.056	.095	.446**	1
	Sig. (2-tailed)	.344	.813	<,001	.743	.105	.689	.494	<,001	
	N	54	54	54	54	54	54	54	54	54

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Plectranthus amboinicus, Study site = Natural soil area

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Crop = Portulaca oleracea, Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	.484**	.728**	.381*	.723**	-.294	-.175	.524**	-.251
	Sig. (2-tailed)		.002	<,001	.020	<,001	.078	.300	<,001	.134
	N	37	37	37	37	37	37	37	37	37
Soil temperature	Pearson Correlation	.484**	1	.234	.915**	.896**	-.949**	.486**	.480**	-.434**
	Sig. (2-tailed)	.002		.164	<,001	<,001	<,001	.002	.003	.007
	N	37	37	37	37	37	37	37	37	37
Soil Saturation Extract EC	Pearson Correlation	.728**	.234	1	-.004	.472**	.068	-.069	.228	-.117
	Sig. (2-tailed)	<,001	.164		.983	.003	.688	.685	.175	.489
	N	37	37	37	37	37	37	37	37	37
Local maximum temperature	Pearson Correlation	.381*	.915**	-.004	1	.704**	-.955**	.207	.223	-.301
	Sig. (2-tailed)	.020	<,001	.983		<,001	<,001	.220	.185	.071
	N	37	37	37	37	37	37	37	37	37
Local minimum temperature	Pearson Correlation	.723**	.896**	.472**	.704**	1	-.756**	.475**	.760**	-.499**
	Sig. (2-tailed)	<,001	<,001	.003	<,001		<,001	.003	<,001	.002
	N	37	37	37	37	37	37	37	37	37
Local relative humidity	Pearson Correlation	-.294	-.949**	.068	-.955**	-.756**	1	-.468**	-.382*	.387*
	Sig. (2-tailed)	.078	<,001	.688	<,001	<,001		.003	.020	.018
	N	37	37	37	37	37	37	37	37	37
Precipitation	Pearson Correlation	-.175	.486**	-.069	.207	.475**	-.468**	1	.574**	-.409*
	Sig. (2-tailed)	.300	.002	.685	.220	.003	.003		<,001	.012
	N	37	37	37	37	37	37	37	37	37
Daylength	Pearson Correlation	.524**	.480**	.228	.223	.760**	-.382*	.574**	1	-.493**
	Sig. (2-tailed)	<,001	.003	.175	.185	<,001	.020	<,001		.002
	N	37	37	37	37	37	37	37	37	37
PItot	Pearson Correlation	-.251	-.434**	-.117	-.301	-.499**	.387*	-.409*	-.493**	1
	Sig. (2-tailed)	.134	.007	.489	.071	.002	.018	.012	.002	
	N	37	37	37	37	37	37	37	37	37

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Portulaca oleracea, Study site = Eco green wall

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Crop = Portulaca oleracea, Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.956**	.892**	-.978**	-.585**	.856**	-.492**	.124	.203
	Sig. (2-tailed)		<,001	<,001	<,001	<,001	<,001	.003	.484	.249
	N	34	34	34	34	34	34	34	34	34
Soil temperature	Pearson Correlation	-.956**	1	-.737**	.984**	.712**	-.733**	.359*	-.227	-.231
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.037	.197	.190
	N	34	34	34	34	34	34	34	34	34
Soil Saturation Extract EC	Pearson Correlation	.892**	-.737**	1	-.805**	-.282	.854**	-.541**	-.201	.111
	Sig. (2-tailed)	<,001	<,001		<,001	.106	<,001	<,001	.255	.534
	N	34	34	34	34	34	34	34	34	34
Local maximum temperature	Pearson Correlation	-.978**	.984**	-.805**	1	.585**	-.840**	.324	-.250	-.191
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	.062	.153	.278
	N	34	34	34	34	34	34	34	34	34
Local minimum temperature	Pearson Correlation	-.585**	.712**	-.282	.585**	1	-.116	.578**	-.065	-.337
	Sig. (2-tailed)	<,001	<,001	.106	<,001		.513	<,001	.717	.051
	N	34	34	34	34	34	34	34	34	34
Local relative humidity	Pearson Correlation	.856**	-.733**	.854**	-.840**	-.116	1	-.239	.300	.054
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	.513		.173	.085	.762
	N	34	34	34	34	34	34	34	34	34
Precipitation	Pearson Correlation	-.492**	.359*	-.541**	.324	.578**	-.239	1	.312	-.248
	Sig. (2-tailed)	.003	.037	<,001	.062	<,001	.173		.073	.157
	N	34	34	34	34	34	34	34	34	34
Daylength	Pearson Correlation	.124	-.227	-.201	-.250	-.065	.300	.312	1	.026
	Sig. (2-tailed)	.484	.197	.255	.153	.717	.085	.073		.882
	N	34	34	34	34	34	34	34	34	34
PItot	Pearson Correlation	.203	-.231	.111	-.191	-.337	.054	-.248	.026	1
	Sig. (2-tailed)	.249	.190	.534	.278	.051	.762	.157	.882	
	N	34	34	34	34	34	34	34	34	34

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Portulaca oleracea, Study site = Vicinity wall

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Crop = Portulaca oleracea, Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.280	.348	.185	.051	.576**	.105	-.134	.021
	Sig. (2-tailed)		.141	.064	.335	.792	.001	.589	.490	.913
	N	29	29	29	29	29	29	29	29	29
Soil temperature	Pearson Correlation	-.280	1	.433*	.805**	.786**	-.663**	.702**	.122	-.106
	Sig. (2-tailed)	.141		.019	<,001	<,001	<,001	<,001	.528	.585
	N	29	29	29	29	29	29	29	29	29
Soil Saturation Extract EC	Pearson Correlation	.348	.433*	1	.553**	.780**	-.239	.352	-.730**	-.372*
	Sig. (2-tailed)	.064	.019		.002	<,001	.211	.061	<,001	.047
	N	29	29	29	29	29	29	29	29	29
Local maximum temperature	Pearson Correlation	.185	.805**	.553**	1	.626**	-.581**	.852**	.056	-.054
	Sig. (2-tailed)	.335	<,001	.002		<,001	<,001	<,001	.774	.780
	N	29	29	29	29	29	29	29	29	29
Local minimum temperature	Pearson Correlation	.051	.786**	.780**	.626**	1	-.264	.586**	-.361	-.353
	Sig. (2-tailed)	.792	<,001	<,001	<,001		.166	<,001	.055	.060
	N	29	29	29	29	29	29	29	29	29
Local relative humidity	Pearson Correlation	.576**	-.663**	-.239	-.581**	-.264	1	-.384*	.027	.027
	Sig. (2-tailed)	.001	<,001	.211	<,001	.166		.040	.891	.889
	N	29	29	29	29	29	29	29	29	29
Precipitation	Pearson Correlation	.105	.702**	.352	.852**	.586**	-.384*	1	.085	-.155
	Sig. (2-tailed)	.589	<,001	.061	<,001	<,001	.040		.661	.421
	N	29	29	29	29	29	29	29	29	29
Daylength	Pearson Correlation	-.134	.122	-.730**	.056	-.361	.027	.085	1	.463*
	Sig. (2-tailed)	.490	.528	<,001	.774	.055	.891	.661		.011
	N	29	29	29	29	29	29	29	29	29
PItot	Pearson Correlation	.021	-.106	-.372*	-.054	-.353	.027	-.155	.463*	1
	Sig. (2-tailed)	.913	.585	.047	.780	.060	.889	.421	.011	
	N	29	29	29	29	29	29	29	29	29

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Portulaca oleracea, Study site = Natural soil area

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Crop = Portulacaria afra prostrata, Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	.506**	.712**	.401**	.721**	-.257	-.309*	.299*	-.008
	Sig. (2-tailed)		<,001	<,001	.003	<,001	.063	.024	.030	.956
	N	53	53	53	53	53	53	53	53	53
Soil temperature	Pearson Correlation	.506**	1	.282*	.900**	.902**	-.916**	.355**	.337*	-.178
	Sig. (2-tailed)	<,001		.041	<,001	<,001	<,001	.009	.013	.203
	N	53	53	53	53	53	53	53	53	53
Soil Saturation Extract EC	Pearson Correlation	.712**	.282*	1	-.003	.467**	.111	-.105	-.070	-.080
	Sig. (2-tailed)	<,001	.041		.985	<,001	.430	.454	.618	.570
	N	53	53	53	53	53	53	53	53	53
Local maximum temperature	Pearson Correlation	.401**	.900**	-.003	1	.709**	-.944**	.070	.167	-.024
	Sig. (2-tailed)	.003	<,001	.985		<,001	<,001	.618	.231	.865
	N	53	53	53	53	53	53	53	53	53
Local minimum temperature	Pearson Correlation	.721**	.902**	.467**	.709**	1	-.725**	.330*	.596**	-.113
	Sig. (2-tailed)	<,001	<,001	<,001	<,001		<,001	.016	<,001	.422
	N	53	53	53	53	53	53	53	53	53
Local relative humidity	Pearson Correlation	-.257	-.916**	.111	-.944**	-.725**	1	-.367**	-.334*	.204
	Sig. (2-tailed)	.063	<,001	.430	<,001	<,001		.007	.014	.144
	N	53	53	53	53	53	53	53	53	53
Precipitation	Pearson Correlation	-.309*	.355**	-.105	.070	.330*	-.367**	1	.503**	-.403**
	Sig. (2-tailed)	.024	.009	.454	.618	.016	.007		<,001	.003
	N	53	53	53	53	53	53	53	53	53
Daylength	Pearson Correlation	.299*	.337*	-.070	.167	.596**	-.334*	.503**	1	-.081
	Sig. (2-tailed)	.030	.013	.618	.231	<,001	.014	<,001		.566
	N	53	53	53	53	53	53	53	53	53
PItot	Pearson Correlation	-.008	-.178	-.080	-.024	-.113	.204	-.403**	-.081	1
	Sig. (2-tailed)	.956	.203	.570	.865	.422	.144	.003	.566	
	N	53	53	53	53	53	53	53	53	53

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Portulacaria afra prostrata, Study site = Eco green wall

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Crop = Portulacaria afra prostrata, Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.789**	.875**	-.608**	-.315*	.835**	-.464**	-.126	.320*
	Sig. (2-tailed)		<,001	<,001	<,001	.026	<,001	<,001	.382	.023
	N	50	50	50	50	50	50	50	50	50
Soil temperature	Pearson Correlation	-.789**	1	-.717**	.950**	.748**	-.952**	.157	.305*	-.031
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.276	.031	.832
	N	50	50	50	50	50	50	50	50	50
Soil Saturation Extract EC	Pearson Correlation	.875**	-.717**	1	-.647**	-.268	.826**	-.575**	-.472**	.021
	Sig. (2-tailed)	<,001	<,001		<,001	.059	<,001	<,001	<,001	.886
	N	50	50	50	50	50	50	50	50	50
Local maximum temperature	Pearson Correlation	-.608**	.950**	-.647**	1	.809**	-.927**	.086	.393**	.157
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	.554	.005	.276
	N	50	50	50	50	50	50	50	50	50
Local minimum temperature	Pearson Correlation	-.315*	.748**	-.268	.809**	1	-.687**	.177	.367**	.192
	Sig. (2-tailed)	.026	<,001	.059	<,001		<,001	.218	.009	.183
	N	50	50	50	50	50	50	50	50	50
Local relative humidity	Pearson Correlation	.835**	-.952**	.826**	-.927**	-.687**	1	-.332*	-.294*	.028
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001		.019	.039	.845
	N	50	50	50	50	50	50	50	50	50
Precipitation	Pearson Correlation	-.464**	.157	-.575**	.086	.177	-.332*	1	.461**	-.003
	Sig. (2-tailed)	<,001	.276	<,001	.554	.218	.019		<,001	.982
	N	50	50	50	50	50	50	50	50	50
Daylength	Pearson Correlation	-.126	.305*	-.472**	.393**	.367**	-.294*	.461**	1	.524**
	Sig. (2-tailed)	.382	.031	<,001	.005	.009	.039	<,001		<,001
	N	50	50	50	50	50	50	50	50	50
PItot	Pearson Correlation	.320*	-.031	.021	.157	.192	.028	-.003	.524**	1
	Sig. (2-tailed)	.023	.832	.886	.276	.183	.845	.982	<,001	
	N	50	50	50	50	50	50	50	50	50

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Portulacaria afra prostrata, Study site = Vicinity wall

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Crop = Portulacaria afra prostrata, Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.416**	.570**	-.201	-.231	.509**	.190	-.450**	.138
	Sig. (2-tailed)		.002	<,001	.146	.092	<,001	.168	<,001	.319
	N	54	54	54	54	54	54	54	54	54
Soil temperature	Pearson Correlation	-.416**	1	.174	.967**	.824**	-.831**	.685**	.513**	-.318*
	Sig. (2-tailed)	.002		.208	<,001	<,001	<,001	<,001	<,001	.019
	N	54	54	54	54	54	54	54	54	54
Soil Saturation Extract EC	Pearson Correlation	.570**	.174	1	.308*	.498**	-.070	.470**	-.637**	-.358**
	Sig. (2-tailed)	<,001	.208		.024	<,001	.613	<,001	<,001	.008
	N	54	54	54	54	54	54	54	54	54
Local maximum temperature	Pearson Correlation	-.201	.967**	.308*	1	.825**	-.759**	.838**	.434**	-.322*
	Sig. (2-tailed)	.146	<,001	.024		<,001	<,001	<,001	.001	.017
	N	54	54	54	54	54	54	54	54	54
Local minimum temperature	Pearson Correlation	-.231	.824**	.498**	.825**	1	-.492**	.602**	.070	-.634**
	Sig. (2-tailed)	.092	<,001	<,001	<,001		<,001	<,001	.614	<,001
	N	54	54	54	54	54	54	54	54	54
Local relative humidity	Pearson Correlation	.509**	-.831**	-.070	-.759**	-.492**	1	-.548**	-.405**	.054
	Sig. (2-tailed)	<,001	<,001	.613	<,001	<,001		<,001	.002	.697
	N	54	54	54	54	54	54	54	54	54
Precipitation	Pearson Correlation	.190	.685**	.470**	.838**	.602**	-.548**	1	.137	-.238
	Sig. (2-tailed)	.168	<,001	<,001	<,001	<,001	<,001		.324	.083
	N	54	54	54	54	54	54	54	54	54
Daylength	Pearson Correlation	-.450**	.513**	-.637**	.434**	.070	-.405**	.137	1	.228
	Sig. (2-tailed)	<,001	<,001	<,001	.001	.614	.002	.324		.097
	N	54	54	54	54	54	54	54	54	54
PItot	Pearson Correlation	.138	-.318*	-.358**	-.322*	-.634**	.054	-.238	.228	1
	Sig. (2-tailed)	.319	.019	.008	.017	<,001	.697	.083	.097	
	N	54	54	54	54	54	54	54	54	54

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Portulacaria afra prostrata, Study site = Natural soil area

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Crop = Spinacea oleracea, Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	.726**	.642**	.474**	.952**	-.499**	.758**	.731**	-.215
	Sig. (2-tailed)		<,001	<,001	.007	<,001	.004	<,001	<,001	.246
	N	31	31	31	31	31	31	31	31	31
Soil temperature	Pearson Correlation	.726**	1	.274	.934**	.896**	-.930**	.596**	.315	-.056
	Sig. (2-tailed)	<,001		.136	<,001	<,001	<,001	<,001	.085	.766
	N	31	31	31	31	31	31	31	31	31
Soil Saturation Extract EC	Pearson Correlation	.642**	.274	1	-.063	.489**	.092	.492**	.123	-.293
	Sig. (2-tailed)	<,001	.136		.735	.005	.621	.005	.509	.110
	N	31	31	31	31	31	31	31	31	31
Local maximum temperature	Pearson Correlation	.474**	.934**	-.063	1	.720**	-.985**	.357*	.184	.025
	Sig. (2-tailed)	.007	<,001	.735		<,001	<,001	.049	.321	.893
	N	31	31	31	31	31	31	31	31	31
Local minimum temperature	Pearson Correlation	.952**	.896**	.489**	.720**	1	-.732**	.706**	.634**	-.169
	Sig. (2-tailed)	<,001	<,001	.005	<,001		<,001	<,001	<,001	.363
	N	31	31	31	31	31	31	31	31	31
Local relative humidity	Pearson Correlation	-.499**	-.930**	.092	-.985**	-.732**	1	-.468**	-.263	-.076
	Sig. (2-tailed)	.004	<,001	.621	<,001	<,001		.008	.153	.684
	N	31	31	31	31	31	31	31	31	31
Precipitation	Pearson Correlation	.758**	.596**	.492**	.357*	.706**	-.468**	1	.523**	.055
	Sig. (2-tailed)	<,001	<,001	.005	.049	<,001	.008		.003	.768
	N	31	31	31	31	31	31	31	31	31
Daylength	Pearson Correlation	.731**	.315	.123	.184	.634**	-.263	.523**	1	-.101
	Sig. (2-tailed)	<,001	.085	.509	.321	<,001	.153	.003		.590
	N	31	31	31	31	31	31	31	31	31
PItot	Pearson Correlation	-.215	-.056	-.293	.025	-.169	-.076	.055	-.101	1
	Sig. (2-tailed)	.246	.766	.110	.893	.363	.684	.768	.590	
	N	31	31	31	31	31	31	31	31	31

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Spinacea oleracea, Study site = Eco green wall

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Crop = Spinacea oleracea, Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.835**	.898**	-.739**	-.428**	.889**	-.425**	-.299	.016
	Sig. (2-tailed)		<,001	<,001	<,001	.005	<,001	.005	.054	.922
	N	42	42	42	42	42	42	42	42	42
Soil temperature	Pearson Correlation	-.835**	1	-.761**	.978**	.805**	-.965**	.314*	.538**	.104
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.043	<,001	.512
	N	42	42	42	42	42	42	42	42	42
Soil Saturation Extract EC	Pearson Correlation	.898**	-.761**	1	-.733**	-.391*	.857**	-.592**	-.577**	.042
	Sig. (2-tailed)	<,001	<,001		<,001	.011	<,001	<,001	<,001	.789
	N	42	42	42	42	42	42	42	42	42
Local maximum temperature	Pearson Correlation	-.739**	.978**	-.733**	1	.854**	-.952**	.333*	.620**	.121
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	.031	<,001	.445
	N	42	42	42	42	42	42	42	42	42
Local minimum temperature	Pearson Correlation	-.428**	.805**	-.391*	.854**	1	-.746**	.408**	.617**	-.040
	Sig. (2-tailed)	.005	<,001	.011	<,001		<,001	.007	<,001	.801
	N	42	42	42	42	42	42	42	42	42
Local relative humidity	Pearson Correlation	.889**	-.965**	.857**	-.952**	-.746**	1	-.464**	-.519**	-.034
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001		.002	<,001	.831
	N	42	42	42	42	42	42	42	42	42
Precipitation	Pearson Correlation	-.425**	.314*	-.592**	.333*	.408**	-.464**	1	.605**	-.472**
	Sig. (2-tailed)	.005	.043	<,001	.031	.007	.002		<,001	.002
	N	42	42	42	42	42	42	42	42	42
Daylength	Pearson Correlation	-.299	.538**	-.577**	.620**	.617**	-.519**	.605**	1	-.108
	Sig. (2-tailed)	.054	<,001	<,001	<,001	<,001	<,001	<,001		.494
	N	42	42	42	42	42	42	42	42	42
PItot	Pearson Correlation	.016	.104	.042	.121	-.040	-.034	-.472**	-.108	1
	Sig. (2-tailed)	.922	.512	.789	.445	.801	.831	.002	.494	
	N	42	42	42	42	42	42	42	42	42

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Spinacea oleracea, Study site = Vicinity wall

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Crop = Spinacea oleracea, Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.381*	.471**	.528**	-.378*	.006	.296	-.176	.144
	Sig. (2-tailed)		.017	.002	<,001	.018	.970	.067	.285	.381
	N	39	39	39	39	39	39	39	39	39
Soil temperature	Pearson Correlation	-.381*	1	.501**	.471**	.935**	-.406*	.705**	-.241	-.451**
	Sig. (2-tailed)	.017		.001	.002	<,001	.010	<,001	.139	.004
	N	39	39	39	39	39	39	39	39	39
Soil Saturation Extract EC	Pearson Correlation	.471**	.501**	1	.861**	.424**	-.570**	.755**	-.777**	-.505**
	Sig. (2-tailed)	.002	.001		<,001	.007	<,001	<,001	<,001	.001
	N	39	39	39	39	39	39	39	39	39
Local maximum temperature	Pearson Correlation	.528**	.471**	.861**	1	.270	-.698**	.932**	-.512**	-.357*
	Sig. (2-tailed)	<,001	.002	<,001		.096	<,001	<,001	<,001	.026
	N	39	39	39	39	39	39	39	39	39
Local minimum temperature	Pearson Correlation	-.378*	.935**	.424**	.270	1	-.091	.526**	-.142	-.359*
	Sig. (2-tailed)	.018	<,001	.007	.096		.583	<,001	.390	.025
	N	39	39	39	39	39	39	39	39	39
Local relative humidity	Pearson Correlation	.006	-.406*	-.570**	-.698**	-.091	1	-.607**	.678**	.531**
	Sig. (2-tailed)	.970	.010	<,001	<,001	.583		<,001	<,001	<,001
	N	39	39	39	39	39	39	39	39	39
Precipitation	Pearson Correlation	.296	.705**	.755**	.932**	.526**	-.607**	1	-.307	-.330*
	Sig. (2-tailed)	.067	<,001	<,001	<,001	<,001	<,001		.057	.040
	N	39	39	39	39	39	39	39	39	39
Daylength	Pearson Correlation	-.176	-.241	-.777**	-.512**	-.142	.678**	-.307	1	.615**
	Sig. (2-tailed)	.285	.139	<,001	<,001	.390	<,001	.057		<,001
	N	39	39	39	39	39	39	39	39	39
PItot	Pearson Correlation	.144	-.451**	-.505**	-.357*	-.359*	.531**	-.330*	.615**	1
	Sig. (2-tailed)	.381	.004	.001	.026	.025	<,001	.040	<,001	
	N	39	39	39	39	39	39	39	39	39

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).
a. Crop = Spinacea oleracea, Study site = Natural soil area

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Crop = Vigna unguilata, Study site = Eco green wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	.310	.857**	.179	.643**	-.036	-.230	.528**	-.035
	Sig. (2-tailed)		.084	<,001	.327	<,001	.846	.206	.002	.848
	N	32	32	32	32	32	32	32	32	32
Soil temperature	Pearson Correlation	.310	1	.307	.886**	.887**	-.952**	.598**	.534**	.027
	Sig. (2-tailed)	.084		.088	<,001	<,001	<,001	<,001	.002	.885
	N	32	32	32	32	32	32	32	32	32
Soil Saturation Extract EC	Pearson Correlation	.857**	.307	1	.089	.547**	-.003	-.111	.320	.017
	Sig. (2-tailed)	<,001	.088		.627	.001	.989	.547	.075	.927
	N	32	32	32	32	32	32	32	32	32
Local maximum temperature	Pearson Correlation	.179	.886**	.089	1	.660**	-.908**	.282	.208	-.184
	Sig. (2-tailed)	.327	<,001	.627		<,001	<,001	.118	.253	.314
	N	32	32	32	32	32	32	32	32	32
Local minimum temperature	Pearson Correlation	.643**	.887**	.547**	.660**	1	-.741**	.516**	.810**	.116
	Sig. (2-tailed)	<,001	<,001	.001	<,001		<,001	.003	<,001	.527
	N	32	32	32	32	32	32	32	32	32
Local relative humidity	Pearson Correlation	-.036	-.952**	-.003	-.908**	-.741**	1	-.656**	-.425*	-.013
	Sig. (2-tailed)	.846	<,001	.989	<,001	<,001		<,001	.015	.944
	N	32	32	32	32	32	32	32	32	32
Precipitation	Pearson Correlation	-.230	.598**	-.111	.282	.516**	-.656**	1	.583**	.361*
	Sig. (2-tailed)	.206	<,001	.547	.118	.003	<,001		<,001	.042
	N	32	32	32	32	32	32	32	32	32
Daylength	Pearson Correlation	.528**	.534**	.320	.208	.810**	-.425*	.583**	1	.302
	Sig. (2-tailed)	.002	.002	.075	.253	<,001	.015	<,001		.093
	N	32	32	32	32	32	32	32	32	32
PItot	Pearson Correlation	-.035	.027	.017	-.184	.116	-.013	.361*	.302	1
	Sig. (2-tailed)	.848	.885	.927	.314	.527	.944	.042	.093	
	N	32	32	32	32	32	32	32	32	32

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Vigna unguilata, Study site = Eco green wall

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Crop = Vigna unguilata, Study site = Vicinity wall

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.758**	.896**	-.568**	-.279	.773**	-.434**	-.080	.365*
	Sig. (2-tailed)		<,001	<,001	<,001	.063	<,001	.003	.600	.014
	N	45	45	45	45	45	45	45	45	45
Soil temperature	Pearson Correlation	-.758**	1	-.719**	.951**	.773**	-.955**	.176	.373*	-.507**
	Sig. (2-tailed)	<,001		<,001	<,001	<,001	<,001	.247	.012	<,001
	N	45	45	45	45	45	45	45	45	45
Soil Saturation Extract EC	Pearson Correlation	.896**	-.719**	1	-.628**	-.301*	.785**	-.552**	-.364*	.410**
	Sig. (2-tailed)	<,001	<,001		<,001	.044	<,001	<,001	.014	.005
	N	45	45	45	45	45	45	45	45	45
Local maximum temperature	Pearson Correlation	-.568**	.951**	-.628**	1	.847**	-.930**	.104	.453**	-.520**
	Sig. (2-tailed)	<,001	<,001	<,001		<,001	<,001	.497	.002	<,001
	N	45	45	45	45	45	45	45	45	45
Local minimum temperature	Pearson Correlation	-.279	.773**	-.301*	.847**	1	-.748**	.225	.554**	-.492**
	Sig. (2-tailed)	.063	<,001	.044	<,001		<,001	.136	<,001	<,001
	N	45	45	45	45	45	45	45	45	45
Local relative humidity	Pearson Correlation	.773**	-.955**	.785**	-.930**	-.748**	1	-.342*	-.370*	.529**
	Sig. (2-tailed)	<,001	<,001	<,001	<,001	<,001		.022	.012	<,001
	N	45	45	45	45	45	45	45	45	45
Precipitation	Pearson Correlation	-.434**	.176	-.552**	.104	.225	-.342*	1	.487**	-.265
	Sig. (2-tailed)	.003	.247	<,001	.497	.136	.022		<,001	.079
	N	45	45	45	45	45	45	45	45	45
Daylength	Pearson Correlation	-.080	.373*	-.364*	.453**	.554**	-.370*	.487**	1	-.304*
	Sig. (2-tailed)	.600	.012	.014	.002	<,001	.012	<,001		.042
	N	45	45	45	45	45	45	45	45	45
PItot	Pearson Correlation	.365*	-.507**	.410**	-.520**	-.492**	.529**	-.265	-.304*	1
	Sig. (2-tailed)	.014	<,001	.005	<,001	<,001	<,001	.079	.042	
	N	45	45	45	45	45	45	45	45	45

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Vigna unguilata, Study site = Vicinity wall

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Crop = Vigna unguilata, Study site = Natural soil area

Correlations[a]

		Soil water content	Soil temperature	Soil Saturation Extract EC	Local maximum temperature	Local minimum temperature	Local relative humidity	Precipitation	Daylength	PItot
Soil water content	Pearson Correlation	1	-.546**	.491**	.232	-.689**	.062	-.004	-.408**	.249
	Sig. (2-tailed)		<,001	<,001	.139	<,001	.695	.978	.007	.112
	N	42	42	42	42	42	42	42	42	42
Soil temperature	Pearson Correlation	-.546**	1	.093	.664**	.913**	-.833**	.705**	.587**	.152
	Sig. (2-tailed)	<,001		.560	<,001	<,001	<,001	<,001	<,001	.336
	N	42	42	42	42	42	42	42	42	42
Soil Saturation Extract EC	Pearson Correlation	.491**	.093	1	.550**	.194	-.552**	.348*	-.605**	.101
	Sig. (2-tailed)	<,001	.560		<,001	.220	<,001	.024	<,001	.526
	N	42	42	42	42	42	42	42	42	42
Local maximum temperature	Pearson Correlation	.232	.664**	.550**	1	.453**	-.938**	.915**	.242	.461**
	Sig. (2-tailed)	.139	<,001	<,001		.003	<,001	<,001	.122	.002
	N	42	42	42	42	42	42	42	42	42
Local minimum temperature	Pearson Correlation	-.689**	.913**	.194	.453**	1	-.726**	.522**	.301	-.036
	Sig. (2-tailed)	<,001	<,001	.220	.003		<,001	<,001	.053	.820
	N	42	42	42	42	42	42	42	42	42
Local relative humidity	Pearson Correlation	.062	-.833**	-.552**	-.938**	-.726**	1	-.899**	-.226	-.333*
	Sig. (2-tailed)	.695	<,001	<,001	<,001	<,001		<,001	.150	.031
	N	42	42	42	42	42	42	42	42	42
Precipitation	Pearson Correlation	-.004	.705**	.348*	.915**	.522**	-.899**	1	.275	.498**
	Sig. (2-tailed)	.978	<,001	.024	<,001	<,001	<,001		.078	<,001
	N	42	42	42	42	42	42	42	42	42
Daylength	Pearson Correlation	-.408**	.587**	-.605**	.242	.301	-.226	.275	1	.151
	Sig. (2-tailed)	.007	<,001	<,001	.122	.053	.150	.078		.341
	N	42	42	42	42	42	42	42	42	42
PItot	Pearson Correlation	.249	.152	.101	.461**	-.036	-.333*	.498**	.151	1
	Sig. (2-tailed)	.112	.336	.526	.002	.820	.031	<,001	.341	
	N	42	42	42	42	42	42	42	42	42

**. Correlation is significant at the 0.01 level (2-tailed).
*. Correlation is significant at the 0.05 level (2-tailed).
a. Crop = Vigna unguilata, Study site = Natural soil area

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Appendix N: Examiners comments with candidate responses

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REBUTTAL TO NOVEMBER 30th, 2023 EXTERNAL EXAMINER COMMENTS AFTER THESIS EXAMINATION

EXTERNAL EXAMINER: DR A RUSSO

CANDIDATE/STUDENT: KAREN BOTES

PhD IN LANDSCAPE ARCHITECTURE (DEPARTMENT OF ARCHITECTURE).

	EXAMINER COMMENT	CORRECTION DONE (Highlighted in yellow in thesis document)
General	I am highly impressed with the thorough and well-executed research presented in this thesis. The study's identification of seven species suitable for household food production, based on both yield and plant stress performance, is a significant contribution to the field of urban agriculture and edible green infrastructure EGI. The use of a mixed-method methodology, including questionnaires and a six-month experimental study, adds depth to the research and provides a holistic understanding of the outdoor modular living wall systems (LWSs) with TAV. This study is not only a commendable contribution to the knowledge base surrounding modular LWSs and EGI but also a pioneering effort in bringing empirical evidence from the Global South into a predominantly Northern-centric discourse. In addition, the emphasis on the Global South in this study not only adds a significant dimension to the literature but also has implications for policy and practice in the context of urban agriculture and food security. Given the significance and originality of the findings, I strongly recommend considering the submission of this research to peer-reviewed journals.	Thank you, much appreciated.

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REBUTTAL TO NOVEMBER 30th, 2023 EXTERNAL EXAMINER COMMENTS AFTER THESIS EXAMINATION

EXTERNAL EXAMINER: DR M. ISAAC

CANDIDATE/STUDENT: KAREN BOTES

PhD IN LANDSCAPE ARCHITECTURE (DEPARTMENT OF ARCHITECTURE).

	EXAMINER COMMENT	CORRECTION DONE (Highlighted in yellow in thesis document)
General	1. The thesis titled "The performance of traditional African vegetables in urban outdoor modular living wall systems for food security in Gauteng, South Africa" investigates an extremely important and contemporary issue – how do we enhance urban agriculture under environmental stress? This area of research is burgeoning, given the rise in interest in re-localizing food production and enhancing urban green spaces for multiple ecosystem services including climate change mitigation. The candidate does an excellent job at expanding the scope of investigation on this topic, providing critical evidence on these understudied systems. The candidate also contributes a really novel approach by centering traditional vegetables, very new in the green infrastructure research arena - the candidate should be commended on undertaking this important research. The candidate provides a compelling argument for an approach to select the best crops and the use of these vegetables and their performance in stressed environments. My comments below are minor, mostly are areas for the candidate to consider when unpublished	Thank you, much appreciated.

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	research in the thesis moves forward to publication.	
	2. The candidate starts with reviewing the state of urban agriculture in food security and relates to SDGs. This is a very nice review and very interesting to read. While I find the use of SDGs to frame the outcomes of the research interesting, I'm not convinced it is fully needed. This is not a major issue by any stretch but rather I challenge the candidate to think about the usefulness of centering SDGs and whether the scale of work matches that of the SDGs.	Thank you. For the researcher, it was important to centre this study around the SDG targets, as edible green infrastructure as part of urban agriculture can contribute to at least twelve of the SDGs. Ultimately the contribution that edible green infrastructure projects, such as LWSs with TAV, can make to the SDG targets, adds to their performance. The scalability of EGI projects will only increase once their success in terms of performance through ecosystem services to contribute to SDG targets has been proven. Their success will enhance EGI integration into the urban fabric, increasing the impact and contribution to SDG targets over time. However, this comment is valuable, and the researcher will consider the impact on food security-related SDGs for future publications.
	3. For the research on traditional agriculture vegetables, the candidate used interviews to derived a list of TAVs, then presented a set of criteria to select those to include in the study. I do not see any issue with this approach per se but could the candidate explore the functional traits of these vegetables? While the criteria narrows down to those most stress tolerant crops, by measuring functional traits, the chemical, morphology and physical traits of a plant, could provide insight into the mechanisms by which these specific crops may perform better in these stressed systems. By doing this, crop selection procedures may be transferrable to other regions and other crops. I see chlorophyll florescence is listed as a measurement but what about root traits? Of other physiological traits such as water use efficiency?	Thank you. Functional traits, including the plant type, size and shape, root size and spread, water use, and sun and shade preferences were considered. However, I appreciate the suggestion to consider functional traits such as root physiology and water efficiency as selection criteria. This is valuable for future research and publications. This has been added as a potential research project (see Section 9.6 on page 295).
	4. While I agree that removing the least commonly listed crops makes sense, I am	The crops selected were based on literature. This study focused on popular crops, based on the availability of seeds and seedlings, their consumption and popular

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	curious as to why those species were listed. What is the role of rarity in contributing niche production in urban agriculture? Do rare crops reduce household expenses by growing relatively unavailable but culturally appropriate crops? And what about seed sources?	crops, for food security. Rare crops were therefore not considered for this study, as the focus was on contributing to sustainable development goals (SDGs) centred around food security. The comment relating to the role of crop rarity in contributing to niche production in UA and their cultural value is, however, valuable and noted. This is worth pursuing for future publications and added as a potential research project (see Section 9.6).
	5. I appreciate the soil measurements but how controlled are these substrates? i.e. are these manufactured (i.e. little difference between substrates)?	Thank you for the question. The soils for the LWSs were obtained from a manufactured source and the components mixed exactly However, the soil from the natural soil area (control area) differed. The soils of the control area were not tested. This concern is noted for future publications, and soil samples of all typologies should be tested. This has been added as a limitation to the study. Please refer to par. 3.5.2 on page 113; *The soil for the two LWS typologies was similar, but different from the soil in the natural soil area. This might have impacted the difference in the soil VWC, EC and temperature readings, and crop performance in the different typologies.*
	6. Also, your data suggests strong variability and highly sensitive in soil physical response (temp and water content) on ecogreen wall and vicinity wall in comparison to natural soil. This makes sense but I'm wondering what amendments could/are used to control extreme variability? Organic composts, mulches (that can be mixed to stay in place)? This high sensitivity is seemingly reflected in higher variable plant stress measures (figure 7.8) but not for all crops.	The importance of soil tests for the natural soil area and the control of the substrates to ensure more accurate soil VWC, temperature, and EC is acknowledged. Additional measures to keep the soil variables in the LWS typologies more consistent could have been taken and will be considered for future studies. This could include more regular soil tests, with the necessary fertilising implemented. In addition, the available water content will also be measured and has been included as necessary for future research studies in Section 9.6.
	7. How does the higher density of plants in the walls affect over crop physiology? What other biological parameters changed given this higher density? We see high yield per m^2 on the walls but I'm curious about long term performance given the high density. Root restrictions?	The higher density of plants is not expected to impact the crop physiology, as the crops will be harvested regularly. Should bigger species be left unmaintained and not harvested, though, their growth is expected to impact surrounding species. This was experienced with especially the *Coleus amboinicus* and *Asystasia gangetica*. The long-term effect of root restrictions and higher density on long-term performance, crop physiology and other biological parameters is listed as a future research project (see par. 9.6 on page 295).

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	8. I really appreciate the crop combination analysis – this is absolutely critical to understanding the success and performance in urban agriculture and in green infrastructure. Thoughts on what traits make these combinations significantly different?	Thank you for the comment. Physiological traits of significantly different combinations will be interesting to include in future research and publications. Traits that made crop combinations significant included the growth form, growth rate and plant sizes. These crops are aggressive growers. Although these crops have a sprawling habit, they remain compact. The most successful crops have a spread between 500 and 1000mm. Crops prefer the sun and are water-wise.
	9. A major conclusion is that LWS with larger soil volumes have high yields. How much more volume? What is the tipping point to achieve this significant increase?	This was stated in Section 9.2.3; *Pot sizes must have a capacity of at least 3 litres with a minimum soil depth of 200mm. A soil volume of 3 litres produces higher yields and resilience than smaller pots of 1.5 litres.* Different soil volumes could be investigated to discover the tipping point.
	10. Coleus amboinicus, Portulacaria afra prostrata, Spinacea oleracea, Mentha aquatica and Vigna unguilata all showed higher performance. I do think the background theory and discussion of mechanisms as to why these species showed this performance would be a benefit to the overall thesis. Exploring the underpinnings of why crops perform better over others will help policy and recommendations to generalize results more broadly.	Please see the comment relating to point 8. The comment is valuable and will be elaborated on in future publications; thank you.
	11. I congratulate the candidate and the advisory committee on their excellent research in this comprehensive thesis.	Thank you.

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EXTERNAL EXAMINER: DR M SARDESHPANDE
CANDIDATE/STUDENT: KAREN BOTES
PhD IN LANDSCAPE ARCHITECTURE (DEPARTMENT OF ARCHITECTURE).

REBUTTAL TO DECEMBER 12th, 2023 EXTERNAL EXAMINER COMMENTS AFTER THESIS EXAMINATION

EXAMINER COMMENT	CORRECTION DONE (Highlighted in yellow in thesis document)
GENERAL	
1. The thesis titled 'The performance of traditional African vegetables in urban outdoor modular living wall systems for food security in Gauteng, South Africa' is a commendable effort in interdisciplinary research. It attempts to span the domains of landscape architecture, plant biology, and food security. It is ostensibly one of very few studies of its kind, and is potentially a very timely and interesting contribution to urban systems. The rationale behind the experiments undertaken in the study is clear and thorough. However, the thesis as a whole needs more work to frame the research undertaken with regard to the literature, theory, methodology, and interpretation of findings.	I appreciate your time, effort, and thorough comments, which were insightful and invaluable in improving my thesis. Given the critique of framing the research concerning the literature, theory, methodology and interpretation of findings, these concerns have been addressed below. Please consider that the study was framed from a discipline's perspective, namely Landscape Architecture. Although the thesis topic spans disciplines, given it being a PhD in Landscape Architecture, the contribution was focused on improving food security and sustainability of urban environments through applied research that would be valuable in practice. Regarding concerns about the thesis structure, it is essential to note that my institution's faculty and department do not have a fixed structure for PhD theses, and this is left to the discretion of the student and her study leader. With the above in mind, I have addressed the examiner's concerns below.
2. The work is heavy on concepts (AOC, EGI, LWS, SDG, TAV, UA, VF), but does not sufficiently pull these together into a theoretical framing that shows how they interact. The approach, involving an emphasis on SDGs, is particularly deficient, as it does not investigate pathways or relationships, but simply	I have added a diagram (Figure 2.6) to explicitly illustrate the link between the different theoretical concepts in Section 2.5 on page 66. For the researcher, it was important to centre this study around the SDG targets, as edible green infrastructure as part of urban agriculture can contribute to at least twelve of the SDGs. Ultimately, the contribution that edible green infrastructure projects, such as LWSs with TAV, can make to the SDG targets adds to their performance. The success of EGI projects will enhance their integration into the urban fabric, increasing the impact and contribution to SDG targets over time.

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	alludes to linkages, at times with broad strokes and poorly chosen words.	
3.	The level of language (e.g. a study conducted… and reported) and lack of clarity in research framing demonstrates basic command over the literature and scientific writing. The synthesis of the literature and analyses is not commensurate with doctoral level research.	This concern is noted but has not been echoed by two other international examiners. However, the specific concerns listed below, have been addressed and amended as far as possible to satisfy the examiner.
4.	There are gaps in reporting methodology – for the literature review, questionnaires, and specific use of statistical tests on variables.	The specific concerns listed below have been addressed and amended.
5.	The appendices, which are integral to interpreting the findings, are not accessible in the thesis file.	This is rather unfortunate to hear, as the appendices in the thesis were linked electronically to each applicable appendix and submitted separately. Please contact the EBIT research office email address (kenneth.nkanyana@up.ac.za) if you cannot access these files since the candidate or her supervisor cannot communicate with the examiner directly.
6.	Many tables and some of the text are poorly formatted. There are several instances of duplication within the text, and between figures and text. There are too many tables and figures, some of which could be combined for better interpretation, and some omitted for brevity.	The specific concerns listed below have been addressed and amended. Please note that landscape architecture is a visual discipline and, by convention, makes use of visual representations of data wherever possible.
7.	There are instances of abbreviations (LWS, SA, SDG, VF, WRC) used without expansion at first mention.	Noted, thank you. The use of abbreviations (LWS, SA, SDG, VF and WRC) has been rectified to show the expansion at first mention.
8.	The thesis cites limited literature, and repeatedly cites its own products (outputs that arose out of the research constituting the thesis).	Regarding the concern about the limited literature referenced, please refer to Section 2.1.1 on page 25 of the thesis for the literature selection. A list of eight books and 115 peer-reviewed articles was selected and screened for this study. A final number of 51 journal articles was included in the core review. Additional sources were added as suggested below by the examiner.

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9. Ideally, the original research should be presented fully in the thesis, with a footnote where Section of it has been published independently.	Thank you. Footnotes were added where sections of the research have been published independently.
10. The reviewer proposed three references to be included in the literature review.	Thank you, the suggested references were added to the literature review (Sections 2.2.1 on page 25, 2.2.3ii on page 33 and v on page 36).
ABSTRACT	
11. Abstract (734 words) well exceeds a maximum of 350 words as is general convention, and specific outline in G50.3. Unless abbreviations and concepts such as SDGs are central to the thesis, avoid referring to them in the abstract. Abstracts generally do not report statistical tests and absolute values, but present the implications and inferences of the results.	The abstract has been altered to exclude the statistical results and shortened to 348 words. The use of abbreviations was limited to the two most central concepts of the thesis, LWSs and TAV.
12. Suggest clarifying in the Abstract that current low economic feasibility, low resilience and high maintenance are characteristics of living walls and not edible crops, both of which appear in the same sentence.	Noted, thank you. The sentence has been altered to read more clearly.
13. The 'postulates' in the Abstract is actually one point of investigation in the study, so suggest rephrasing to indicate that this was a research question. It is generally unclear what the overarching research question and sub-questions were in the Abstract as it currently stands. It reads like a list of studies without a central narrative linking them mutually, and to the wider context of urban agriculture or built environment.	Noted, thank you. The abstract has been amended accordingly.

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14. The Abstract should also summarise the contribution(s) the thesis makes to the urban landscape architecture knowledge and practice.	Noted, thank you. The study contributions have been added to the abstract.
15. Here and throughout, check for the spelling of Vigna unguiculata.	Noted, thank you. The spelling has been rectified throughout the document.
CHAPTER 1	
16. Page 3: Expand LWS at first mention.	Thank you. The text has been rectified to reflect living wall systems at first mention.
17. Page 4: A way to increase the economic feasibility of LWSs is to introduce edible crops(Mårtensson et al. 2016; Russo et al. 2017; Ling and Chiang 2018). This is an interesting statement, and could be unpacked with a sentence or two on the economic sense it makes.	To accomplish brevity in the first chapter, introducing edible crops to increase the economic feasibility of LWSs was unpacked in Section 2.3.2. on page 46.
18. Page 4: Expand VF at first mention.	Thank you. Rectified.
19. Page 5: Sustainable use of?	The word “agricultural” has been added to the sentence to read more clearly. The sentence refers to the sustainable use of TAV in agriculture, following the previous sentence that states the need for crops that can tolerate these conditions.
20. Page 6: Perhaps summarise the findings of the literature review in a couple of sentences rather than simply displaying a link to chapter 2. This builds the narrative and helps assimilate the diverse pieces as one cohesive body of work that the author can then claim expertise in.	Noted, thank you. I aimed to keep the introduction section succinct and prevent repetition in the thesis.
21. Page 6: LWSs with vegetables have aesthetic value for enhanced human well-being and deliver productive yields, which exceed gains of traditional agriculture in the case of some species, with improved accessibility for harvesting. This	Noted, thank you. The text in Section 1.1.5. has been amended to “Furthermore, LWSs with vegetables have aesthetic value for enhanced human well-being and deliver productive yields, which exceed conventional agriculture gains such as crop productivity in terms of biomass in the case of some species, with improved accessibility for harvesting” to provide clarity about the gains. The crop productivity in terms of biomass is unpacked in Section 3.4.3.

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sentence could also use some unpacking – what gains are exceeded, and how?	
22. Section 1.2. Focus area (i) seems very far removed from the study's subject in pages 7-10. It starts to add up only at objective (iii) of question (1) on page 11. Suggest rewording the focus to reflect that the study investigates the potential of LWS as a form of UA that can contribute to food security – or something along those lines.	Noted, thank you. The focus was reworded to make this link clear in Section 1.2.1.i. on page 7 and in Table 1.1. on page 8.
23. Page 7: Suggest unifying the text on the focus areas here with Figure 1.1. and Table 1.1.	Noted, thank you. Figure 1.1 and Table 1.1 explain the relation between the study's focus areas and the research questions.
24. Sections 1.2.2 and 1.2.3 seem to reiterate what has already been said in preceding sections, and deviate from the logical flow from the study research focus. Suggest editing.	Please note that these sections are standard components required for PhD theses in our Department and they do serve to reiterate the relevance and importance of the study: the focus of Section 1.2.2 is to motivate why the study is performed, and Section 1.2.3 explains how the findings affect the field.
25. Section 1.2.4 reads like a list of tasks undertaken, and would do much better to describe the research as a narrative and how it links to the wider picture. For example, how were objectives (ii) to (v) under question 4 different from (i) and (vi), and why and how were they contributing to answering the question? As it stands, there is a lot of repetition within the text, and between the text and figures. Some of the questions seem to be too specific or leading (e.g. factors affecting performance negatively, factors that hamper), and the objectives below them seem more balanced (e.g. criteria that are efficient, factors affecting	This is noted, however the numbered list was preferred here as being more effective to show the link to the broader picture. The questions, objectives and outcomes were all carefully considered and satisfied the expectations of the supervisor and two other international examiners. In response to the query about research question 4, please refer to Figure 1.2, which shows the relation between the questions, objectives, sub-objectives and outcomes guiding the research study.

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potential). Some of the objectives describe methods used, which should either be consistent across all questions, or be described separately later. Overall, research aims outline unbiased questions, and the objectives describe tasks undertaken to answer these questions. This section could use restructuring to address this.	I followed my study supervisor's recommendations, which included questions, objectives and outcomes for each focus area. Methods for objectives were not included in Section 1.2.4 but were explained in Chapter 3. Fig. 1.2. on page 13 shows the link between the questions, objectives, sub-objectives and outcomes guiding the research study.
26. Section 1.2.5 needs to describe how these outcomes were arrived at, either in text, or in Figure 1.2. The methods should be linked to the objectives and outcomes.	To address this comment and include the methods that are only described in chapter 3, Table 3.5 on page 95 has been altered to include the research objectives. The table depicts the alignment of the methods and variables with the research questions, objectives and outcomes.
27. Page 14: Check for colon consistency.	Noted and rectified, thank you.
28. Section 1.4 Page 14: What constitutes commercial and financial viability?	Thank you. A footnote was added to explain the meaning of commercial and financial viability.
29. Why have cereals, grains, and underground vegetables been excluded?	Thank you for the question, the delineation in Section 1.4.1. on page 15 has been altered to include the reasons for selecting TAV with upperground parts and excluding vegetables with underground edible parts, cereals and grains. Reasons for excluding underground vegetables have been elaborated in Section 5.3.2. on page 143.
30. Good to note limitations, but would benefit from additional information. For example, study results could apply to certain Koppen climate classifications; similarly, which systems with matching technologies can technical and efficiency recommendations apply to? Which species were incompatible with the system, and why? Null results often provide good scientific advances.	The suggestion is noted, and some have been addressed. Thank you. Note that this section mainly explains aspects that impacted the research. Additional information, as requested on these aspects, was therefore placed in relevant section of the thesis, e.g., different systems and their advantages and disadvantages (see Section 2.3.1 on pages 41 to 46). The TAV selection criteria are discussed in Section 3.4.3.ii. b.
CHAPTER 2	
31. Figures 2.1 to 2.5 simply reiterate the text in the Introduction and Chapter 2 itself.	Noted, thank you. As landscape architecture is a visually oriented profession, more visualization was included for prospective readers.

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	Figures ought to present novel insights from the research undertaken.	
32.	Section 2.1.1 There needs to be a Methods section here that tells readers about: i. what search strings were used for each 'focus area' or research question ii. what the 'relevance criteria' were for inclusion or exclusion of retrievals iii. retrieval overlaps or lack thereof across databases, search strings, SDGs iv. what to make of the fact that Scopus yielded zero retrievals v. what total number of retrievals was used – 115 or 51 articles, and why vi. whether all retrievals were coded and analysed together, or by 'focus area' vii. how the analyses link the three 'focus areas' under aforementioned 'framework' A figure combining all of the above, or at least v-vii would be helpful.	Thank you. Please note that this was not a systematic literature review and that articles were not coded. The review followed an integrative review methodology, which allows for the inclusion of experimental and non-experimental research to inform research, practice and policy. This is clarified in the first paragraph of Section 2.1.1. on page 23 to avoid confusion. Search strings were added in Section 2.1.1. on page 23. The following explanation was added in Section 2.1.1. on pages 23 to 24 to provide clarification on the examiner's queries; *The combination of keywords limited the results, with limited papers found due to the combination of keywords. The review list was extended with additional publications based on the keywords "traditional African vegetables" OR "African vegetables" OR "African orphan crops" OR "neglected crops" OR "African leafy vegetables" OR "indigenous leafy vegetables" OR "living walls" AND "food production", resulting in additional peer-reviewed publications from Scopus (n = 14), ScienceDirect (n = 249) and Google Scholar (n = 1510). A list of eight books and 115 articles were selected for this study after titles and abstracts of the peer-reviewed publications were scanned in terms of relevance. Relevance criteria included urban agriculture projects, outdoor living walls with edible plants, small-scale non-commercial food production, and modular walls involving a growth medium.* The penultimate paragraph in Section 2.1.1 states that a final number of 51 journal articles was included in the core review and that journal articles are categorised into urban agriculture, living walls, African vegetables, sustainable development goals and food security.
33.	Section 2.2 Please check for consistency in reporting numbers. Some have commas, some have points, and some have the literal word comma to denote decimals.	Noted; thank you. The reporting of numbers in Section 2.2 on pages 28 to 38 has been amended only to include commas to denote decimals.
34.	Section 2.2.2 claims to present the status quo and potential of UA to SDG2. However, most of subsections (i) to (iii) seem to talk about the state of SDGs in general, with only one or two references	Thank you, this is noted. I investigated the status quo and potential of the SDGs, starting with the broader picture and zooming in on UA's contribution to the SDGs. This has been clarified in the text. I decided, with my supervisor, to discuss the status quo and potential together, given the research outcome of determining

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to UA. Indeed, there is a lot of literature on the links between UA and these three sub-themes. However, if the references here are strictly results from the literature review, this should be made clear. Also, please distinguish between status quo and potential. It might help to make a single table or figure displaying this for all SDGs. An added feature could be 'research required' derived from the studies, identified from the gaps between status quo and potential.	the status of urban agriculture in terms of its contribution to household food security and related SDGs globally and SSA.
35. Page 32 paragraph 2 paraphrases Frayne et al. (2014). What further literature presents the aforementioned two conflicting viewpoints? What are these viewpoints? Paragraph 3 has an orphan sentence on informal food vendors. How does that link to urban food production?	Thank you for the comment. The two viewpoints are stated in Section 2.2.3.i. on page 32. The first viewpoint in the penultimate paragraph on page 32 is that UA holds limited food security and poverty benefits. In contrast, the second is that UA can address income and employment in the last paragraph of Section 2.2.3.i. on page 32. Four references were listed to support the second viewpoint. The last sentence in the last paragraph of Section 2.2.3.i on page 32 has been amended for clarity to demonstrate the link with the second viewpoint. Further literature supporting Frayne et al.'s viewpoint will be considered for future publications.
36. Section (ii) on SDG 3 ventures to social equity in the penultimate sentence, but shies away and ventures into efficiency and resilience, which doesn't really belong here.	Noted, thank you. The sentence was relocated to Section 2.2.2. iv. (Sustainable Agriculture) on page 31.
37. Section (iii) on SDG 5 has virtually nothing on urban food production, so would be good to justify this and perhaps highlight a research gap.	Noted, thank you. The motivation for addressing SDG5 has been included in Section 2.2.4. on page 38 for clarity.
38. Also, what is a 'poverty crop'?	For clarity, a footnote defining poverty crops was added to Section 2.2.3.iii on page 34.
39. Section (iv) on SDG 8 makes a good case for this thesis. What are the research	Thank you.

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	needs that can contribute to developing small-scale, low-technology UA with vegetables?	The need for empirical research to contribute to developing small-scale, low-technology UA with vegetables is described in Section 1.1.5 on page 6 and Section 2.5. on pages 66 to 68.
40.	Section (v) on SDG 11: please check census spelling.	Noted; thank you. The spelling of census has been corrected on page 35.
41.	It strikes the reader here, but applies to the entire results section: the text should be clear about which of the literature cited is from the review results, and which is more general discussion (e.g. IPCC, UN). For example, use words like 'The literature reviewed in this study posits that…' Given the scale, scope, and distribution of the reviewed literature, it would be best to leave out general references in this section and discuss them separately in the concluding remarks section.	Thank you for this valuable comment. However, please note that a systematic literature was not followed. Therefore, literature from the scoping review versus general literature was not distinguished in the discussion section. In general, the discussion section of a systematic review would also allow for the addition of additional sources in the discussion section, yet the suggestion provided is a valuable alternative for future reference.
42.	This section also provides a great opportunity to specifically highlight how UA can contribute explicitly to urban inclusivity, resilience, and sustainability. The text needs to be refined to bring this out rather than brushing on ecosystem services.	I have added the following sentences in Section 2.2.3. v. on page 36 to elaborate the relationship between edible green infrastructure and sustainable cities; *Urban agriculture provides ecosystem services, which are benefits from the natural environment provided to humans through providing provisioning, supporting, cultural and regulating services. Ecosystem services delivered by vegetation can mitigate urbanisation disadvantages, including food provision, climate change events, water management and air pollution (Perez and Perini, 2018), all contributing to sustainable cities and communities (See Fig. 2.6).* Also refer to the theoretical framework in Figure 2.6 on page 70, which illustrates how the study explores LWSs with TAV as edible green infrastructure, forming part of urban agriculture, which addresses sustainable development and the SDGs through ecosystem services.
43.	The use of the term 'traditional agriculture' may be debated, suggest replacing with 'conventional' or 'industrial'.	Noted; thank you. The term "traditional agriculture" was replaced with "conventional agriculture" on pages 6, 36, 38, 48, 68, 69 and 71.

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44. Section (vi) on SDG 12 needs to link the text to UA.	The word “urban” has been added to the last sentence to clarify the link with UA.
45. Section (vii) on SDG 13 has three orphan lines on resilient landscapes, carbon dioxide concentrations, and pests and disease. How does this relate to UA?	The three sentences in Section 2.2.3.vii. are linked, starting by explaining the link between climate change and UA, then relating climate change to the need for resilient landscapes, followed by the link between climate change and atmospheric CO_2 concentrations and their impact on pests and diseases. This has been made more explicit.
46. Section (vii) on SDG 15 makes a sweeping and unfounded statement on UA and land, emissions, wastes, and footprints. Please reword to say that this is a possibility under some scenarios. And outline what these scenarios are, and where the potential and need for research is.	This statement was made based on a cited reference (Cilliers, 2019). However, it is acknowledged that this viewpoint may not be supported unanimously, and the sentence in Section 2.2.3. viii. on page 37 has, therefore, been amended accordingly.
47. The concluding remarks need to be sharpened to highlight novel findings from this review, not just reiterate and confirm things. The comments on preceding sections should help develop this section.	The second paragraph of Section 2.2.4 on pages 38 and 39 has been amended to highlight novel findings related to living walls systems as a form of urban agriculture to contrbutes to food security and related SDGs
48. Section 2.4 It is unclear what the scope of this section of the review was – was it global or South Africa-specific? If the latter, please contextualise the local situation and scope.	The scope is South Africa-specific, as stated in the heading of Section 2.4. Based on this comment, par. 2.4 on page 50 has been altered to contextualise the local situation and scope as suggested.
49. There seems to be very limited literature cited here. How were the sub-sections arrived at? Was it an inductive or deductive approach?	Around 40 literature references relating to TAV and associated key terms were cited in Section 2.4. These references were regarded as sufficient to enable the researcher to investigate all aspects related to TAV and their potential contribution to addressing food security in South Africa. As this was an integrative review, the subsections were selected inductively to clarify key terms and answer the research questions. The researcher describes the context of each key term in Section 2.4 on pages 50 to 52, leading to the sub-sections of Section 2.4.

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50. The following text appears first in Chapter 1, and is repeated twice in Chapter 2: a limited scope of suitable food crops (tomatoes, grapes, lettuce species, strawberries, and grain crops), high start-up costs, high technology, highly skilled labour, possible robotics usage (Benke and Tomkins, 2017), and the economic scale outcompeting small-scale producers (Pinstrup-Andersen, 2018). Please edit or omit.	Noted, and the text was omitted; thank you.
51. Here and throughout the thesis, do not cite the same references for every sentence. If the source remains the same, cite the references at one prominent place where it is easily understood that what follows is extracted from the cited literature.	Thank you. Your advice was followed, and it is also noted for future writing.
52. Table 2.1: While this may be adapted from a previous publication, it would be useful to note references that conclusively support the yes/no entries for the continuous systems, in contrast to the more nuanced modular systems text.	Noted, references supporting the entries of the continuous system have been added to Table 2.1. on page 42.
53. Also, what were the criteria derived from? Is this an existing evaluation framework for LWS?	I developed the criteria based on a case study involving three recently implemented edible living walls in Gauteng to reflect on the challenges currently experienced by the designers and contractors and the future potential benefits, with a specific focus on system resilience, economic feasibility, and edible plant possibilities.
54. The following text is repeated in adjacent subsections in Chapter 2: The study found that the irrigation and rainwater's calcium oxide and pH levels could harm food crops, although the researchers did not consider this problematic (Riley et al.,	The repeated text was omitted. Thank you.

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2019). It is unclear from the article how the drip irrigation system was installed to determine the efficiency of watering, drainage and maintenance (Botes and Breed, 2022). Please edit or omit.	
55. LWS with edible crops are reported to not only enhance the environment, but consumption of vegetables and fruit by urban community gardeners was also found to be higher than non-community gardeners (He, 2015; Botes and Breed, 2022). How are these health risks?	This sentence has been relocated to Section 2.3.2. on page 46. Thank you.
56. The four selection criteria seem to appear arbitrarily rather than from a synthesis of the reviewed articles. Suggest better reintegration to indicate how they arise.	The selection criteria in Section 2.3.6 on page 49 include cost efficiency, resilience and maintenance, carbon footprint, resilience and maintenance, and health risks. These criteria have been synthesized from literature in Sections 2.3.2 (Cost efficiency), 2.3.3 (Low resilience and high maintenance), Section 2.3.4 (Health risks) and Section 2.3.5 (Carbon footprint). The text was checked to make sure that they have been keenly pronounced in each section.
57. Section 2.4.2. TAV are divided into different categories: are these categories, or criteria? Sounds more like the latter.	Noted, for the thesis, the researcher, with support from the supervisor, regarded self-propagation and human propagation as categories for the TAV.
58. This section freely oscillates between crops including grains (Mabhaudhi), vegetables including fruits (Towns and Shackleton) and dark green leafy vegetables, rendering nutrient comparisons invalid. Please justify why leafy vegetables are selected for the study, and use specific examples to make valid comparisons.	Section 2.4 commences by contextualising TAV in the bigger category of AOC in Section 2.4.1 on pages 52, which also includes grains and fruits. Section 2.4.2 on page 52 defines TAV and also confirms the study focus and justifies the selection of leafy vegetables. This is also described and justified in Section 1.1.5 on page 6, 1.4.1. on page 15.
59. Section 2.4.4. The global food system relies on only 30 crops to provide for the nutritional requirements of the human population, which makes food systems vulnerable to climate variability. This is a	Given climate change and the fact that these 30 crops provide for the global population's nutritional requirements, current food systems are vulnerable, especially in SSA, with its semi-arid climate conditions. This is confirmed by the four references cited in Section 2.4.4 on page 54. Most of these crops are not tolerant to hot, dry conditions.

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repeated and sweeping sentence, and can easily be debated – 30 crops is still a lot of diversity, and these crops will respond differently to different climate variability in different geographies. Suggest rephrasing.	
60. Section 2.4.7. Moreover, climatic factors and soil salinity and acidity, diseases, insects and weeds impact the productivity of AOC (Tadele, 2019; Botes and Breed, 2022). These factors affect most crops – do they affect AOC more? How does that compare to the claim that AOC are better adapted to local conditions?	Section 2.4.7. on page 61 states that these factors also affect AOC, similar to mainstream crops. The paragraph states that AOC and TAV are more tolerant to local climate conditions, have low maintenance requirements for irrigation and agrochemicals (Araya, 2014), and are more resistant to pathogens than exotic vegetables (Aworh, 2018).
61. Avoid citing unrelated literature (e.g. review on LWS in a section on TAV properties) and repeating a citation more than five times in a chapter unless absolutely necessary.	This suggestion is noted thank you.
62. The viewpoint of "poverty crops" is, however, challenged – this doesn't seem to be a valid counterpoint, as the previous sentence talks about urban youth, and the following example talks about a sample of 64 villagers.	The sentence in Section 2.4.7 has been amended accordingly; *The urbanised South African youth negatively perceive TAVs as old-fashioned and "poverty crops" (Vorster et al., 2008; Jansen van Rensburg et al., 2009; Shackleton et al., 2009). However, a survey conducted in 2011 on a sample group of 64 respondents in Nomathiya village, KwaZulu Natal showed that rural residents disagreed with the perception of TAVs as "poverty crops" (Thandeka et al., 2011).*
63. Subsections (i) and (iii) to (vii) say nothing about urban feasibility, when in fact a lot could be different about these properties in urban settings. For example, cold supply chains could enhance preparation and marketability, controlled or interstitial growing environments could talk to genetic traits and cultivation practice, and so on. Consider exploring	While the benefits of cold supply chains and controlled environments are acknowledged, the study focused on improving the growth and production of TAV in modular LWSs for household food production. These aspects could be considered for future studies and publications.

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this, as the focus of the thesis is on urban food production.	
64. Throughout this section, consider replacing 'policy documents' with 'policy', as policy includes guiding documents, dedicated programmes, fiscal budgets and mechanisms, and implementing bodies across institutions.	Noted; thank you. The term "policy documents" was replaced with "policy" on pages 61, 65 and 96.
65. Section 2.5 Table 2.3: Here and throughout, tables, figure, and their captions should be readable as standalone objects, complete with references, footnotes, and abbreviations. Please check that this applies to all tables and figures in the thesis. Here, specifically, the caption would read along the lines of 'Summary of studies on living wall systems productivity'.	Noted, thank you. The titles of Table 2.3 and other tables and figures in the thesis document have been changed according to the comment.
66. Please make text formatting consistent	Text formatting is consistent in tables in the thesis, except for tables where the text size was reduced to enable the entire table to fit onto the page.
67. Section 2.6 Conclusions should go beyond reiterating or repeating findings (e.g. list of LWS criteria) and summarise details or next steps derived from these findings. How can the research, policy, practice gaps be filled? Who can do this? What do they stand to gain from it?	Section 2.6 was revised to fill the identified research gaps and assist this study in identifying new insights into current issues pertaining to LWSs and TAV to improve their performance in providing household food security and related SDGs.
CHAPTER 3	
68. Section 3.1.4 (iii) mention which of the interventions (Eco Green Wall, Vicinity Wall) belonged to which grade of technology (leading, simple).	This has been done, thank you. The words "all-in-one high" have been added to describe the technology of the first intervention in Section 3.4.1.iii. on page 84. The second intervention is described as "a local system representing simple technology". The technology of each LWS typology is described in Sections 4.3.1 and 4.3.2. on pages 132 to 134.
69. Section 3.4.2 (i) and (ii) What Questions were asked in these questionnaires	Sections 3.4.3.ii.a and b. on pages 96 and 97 refer to the questionnaires in the thesis, included as Appendix A (Questionnaire regarding LWSs) and Appendix B

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related to LWS and TAV? This is neither explained in the section, referenced in text, nor available in the appendices.	(Questionnaire regarding TAV). Findings from the questions were reported in Section 4.2.2. (LWSs) and Section 5.3. (TAV). Please make sure to request appendices from the research office should they not be shared.
70. Section 3.4.2 (iii) You get to Experimental Design and still wonder what the research question and aims are. What is the experiment trying to establish?	The research question and aims are provided in chapter 1. Please see Section 1.2.1 on pages 7 and 8. The research aims and objectives are provided in Section 1.2.4. on pages 10 to 12; *This study aims to define the technical characteristics of modular LWSs as EGI in local urban conditions (Gauteng, South Africa) for improved performance and to determine which TAV could grow productively in modular LWS to improve local household food security.* Figure 1.2 on page 13 depicts the questions, objectives, sub-objectives and outcomes guiding the research study.
71. Section 3.4.2 Not sure why this is a separate section, and why information here is distinct from Section 3.4.3. Please edit and unify this to reflect: 1. Questions, 2. Methods, 3. Sampling strategy, 4. Design and variables, 5. Analyses	Please note that the subsections and order requested by the examiner is not conforming to the typical structure and order used in our Department. This might be due to disciplinary differences and backgrounds.
72. Table 3.5 and its related text probably belongs in the Introduction chapter. The research methods and how the variables relate to the conceptual framing and objectives still needs to be fleshed out.	The Introduction and Research design chapters followed guidelines provided by my study supervisor and conformed to departmental norms. The variables were listed and explained in Chapter 3 (Research Design). Section 3.4.3. on pages 93 to 114 and Table 3.5 on pages 95 demonstrate the relation between the variables and conceptual framing, research questions, objectives and outcomes.
73. Section 3.4 (ii) Questionnaires – why are the Data subsections not numbered?	The data subsections have been numbered on pages 96 and 97; thank you.
74. Data: LWS – third round of?	The word “consultation” has been added to Section 3.4.3.ii.b on page 99 for clarity. Thank you.
75. Data: TAV – how was the number nine arrived at?	An explanation is provided on page 92, Section 3.4.2.iii. *The experimental study was limited to nine TAV species, with one mainstream leafy dark green vegetable crop as control, to accommodate the study site's area and the researcher's capacity.*

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76. Table 3.7: Please check instrumentation record for Precipitation and Photoperiod	Noted, thank you. As these variables involved secondary data, the words "secondary data, instrumentation unconfirmed" were added to Table 3.7 on page 103.
77. Variables 1 and 2: Why were grazing, pests, and disease not recorded as distinct variables?	The results for biomass and plant stress (variables 12, 13 and 14) showed the impact of grazing, pests, and disease. Grazing was regarded as unlikely in urban areas, and the impact of pests and disease was expected to be low, based on literature and the researcher's own experience.
78. Good to see the meticulous methodology on biophysical variable monitoring, dry mass measurements, and plant stress evaluation. These sections read strikingly different from the preceding text.	Noted, thank you.
79. Page 111: Was the data distribution non-normal? If it was, then it would entail use of nonparametric Kruskal-Wallis Anova. If it was normal, you would use parametric Anova.	The data distribution was normal; therefore, the one-way ANOVA test was used as the statistician consulted during the study recommended. To clarify, the sentence in Section 3.4.3. iii. J. was amended to include; *For the biomass yield, data were tested for uniform distribution using the numerial method, the Shapiro-Wilk test before analysis, that showed that data came from a normally distributed population.*
80. Please check for consistency. Interesting that some of the analyses were done in Python and some on SPSS – any reason why?	The reason for the different software used for the plant stress analysis was added to Section 3.4.3.iii. j on page 114; *Software for the plant stress data differed from the biomass data analysis since different experts were engaged to assist the candidate (who has limited statistical analyses experience) with these aspects.*
81. It would be good to tabulate the variables, their distributions, and the statistical analyses, and if possible, their link to the experiment hypotheses or aims.	This suggestion is noted for future publications; thank you.
82. Section 3.5.2: "compromises had to be reached between the researcher and the Department of Facilities Management. Additional delays to the experimental study included obtaining funding for the construction of the systems, establishing vegetation and purchasing instruments	The only impact was a delay, and the experimental monitoring was not affected per se. The impact of the limitations of variables was explained in Section 3.5.2. on pages 115 to 116. The sentence has been omitted as suggested; thank you.

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to measure variables. The pandemic and associated lockdown periods impacted the commencement date of the construction of the LWSs with TAV and the obtaining of instruments." Did these compromises and delays affect the experimental design and monitoring? If so, elaborate here with variables affected. If not, suggest omission.	
83. "Moreover, initial flaws in the data measurement include faulty logger batteries, non-randomisation of crops, and no controls such as natural soil crops and commercial crops." Were measurements with faulty loggers, non-randomised samples, and no controls included in the study? If so, report here, and detail how differences were accounted for.	All limitations relating to the study were added as recommended by my study supervisor. Faulty measurements were not included in the study. The researcher only included data once all flaws and issues were addressed. For clarity, the sentence "These data were excluded from the analysis" was added to Section 3.5.2. on page 115.
CHAPTER 4	
84. Findings from the literature review should not be repeated here, and methodology should not overlap. Either report findings in the review, or split methodology for this chapter and report them here only. Cross-referencing is fine, but repetition is unnecessary.	I have replaced the literature review summary in Section 4.2.1 with cross-referencing to Section 2.3.6.
85. Section 4.2.2 (i) It is still unclear what questions were asked and hence what the responses mean. For example, 'cost-effectiveness and uncomplicated installation were crucial in selecting LWS' – for what purpose? For	Please refer to Appendix A for the Questionnaire regarding LWSs. Please do contact the research office should you not have access to the appendices. Section 4.2.1. i. on page 125, focused on the findings categorised into six main themes and, therefore, did not include the questions. Respondents reacted to question 9, referring to cost-effectiveness and uncomplicated installation: *Which qualities and technical specifications should*

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the respondents' own projects (which were presumably different from), household UA?	*green wall systems have to ensure the optimal growing conditions for urban farming with African Orphan Crops and indigenous leafy vegetables?* Respondents, therefore, referred to the qualities and technical specifications of LWS for UA.
86. Did recycled materials emerge from an open-ended question or a list of options?	Please refer to Appendix A for the Questionnaire regarding LWSs. The aspect of recycled materials emerged from an open-ended question. This was also explained in Section 3.4.3.ii. on page 98; *"Open-ended questions listing LWS qualities and specifications that would optimise growing conditions for urban food production were also obtained, including the size or dimensions of LWSs. Respondents were requested to list preferred systems and describe the maintenance required and challenges related to these systems."*
87. What measure is 'bigger capacity' relative to?	A footnote was added in Section 4.2.1. i. to explain the bigger capacity.
88. Compliments on the crisp and clear graphics in this chapter.	Thank you.
89. Section 4.4. What were the comparative differences to be observed across the three treatments?	For the comparative differences, please refer to Table 3.5: these are all the variables identified for monitoring to answer the research questions and objectives.
90. How do the LWS features compare across the variables where differences are being monitored?	The LWS technical characteristics (low technology, affordable, uncomplicated, lightweight, adjustable for different scale installations, locally produced from recycled / recyclable components to limit their carbon footprint) guided the selection of the typologies for the empirical research (refer to Section 3.4.3.ii.a on page 102). Variables were monitored and analysed during the empirical study (see Table 3.5 on page 95 and Section 3.4.3.iii on pages 102 to 114) for justification of the variables. The variables for the LWS performance are listed as Daily maximum and minimum temperatures, relative humidity, biomass (per LWS), plant stress (per LWS), Cost efficiency, resilience and maintenance in Table 3.5 (*Table 3.5: Methods and variables identified for monitoring to address the research questions, objectives and outcomes*).
91. How would the selected local modules compare to the non-local modules besides place of origin and costs?	They could be very similar, but non-local modules would have higher embodied energy and therefore would be considered less sustainable and less accessible. The study was delimited to the two locally produced selected typologies and briefly mentioned non-local LWSs, such as the Atlantis Growall and Mobilane, in Section 4.2.1. on pages 126 to 128.

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CHAPTER 5	
92. Interesting opening quote – would Baldermann et al. recommend commercialisation of NUS into cash crops? Is there more context to this?	Note that the opening quote was merely added because of the context of NUS's potential to diversify human diets in a more sustainable and resilient way, which coincides with the greater aims of the study.
93. Figure 5.2: Are leaves of the following species used as TAV? Ancylobotrys capensis, Cucumis sp. Diospyros autro-africana, Englerophytum magalismontanum, Lannea edulis, Parinari capensis, Rhoicissus sp. To my knowledge, their fruits are edible, so not sure how these species appeared in the list given the definition outlined at the beginning.	The 31 species listed were derived from literature. *Many species recommended by the expert panel were not suitable in terms of the selection criteria, as depicted in Table 5.1.* As none of these species mentioned here were included in the study, the edibility of the leaves has not been verified. The comment about the edibility of TAV's leaves is noted for future studies and publications; thank you.
94. Please correct the spelling of okra.	The spelling of okra has been corrected; thank you.
95. Also, how did large plants like Adansonia, Ancylobotrys, Englerophytum, Lannea, Parinari, and Rhoicissus figure in the list given criteria listed in Table 5.1?	The requests by experts to include large plants despite the criteria listed in Table 5.1. are explained in Sections 5.3.3 on page 143; *Many species recommended by the expert panel were not suitable in terms of the selection criteria, as depicted in Table 5.1.* and 5.4 on page 146; *Therefore, the TAV species, as shown in Figure 5.2 and selected by four respondents, were investigated for inclusion in the empirical study. These included Ancylobotrys capensis (Wild apricot), Centella asiatica (Pennywort), Cucumis zeyheri (wild cucumber), Corchorus confusus (jute plant), Gazania krebsiana (Gazania) and Hilliardiella oligocepala (bicoloured leave Vernonia). Selection between them was based on the selection criteria listed in Table 5.1 in section 5.3.2. Ancylobotrys capensis (wild apricot), which can grow up to 5 metres, was excluded based on size., namely that many species recommended by the expert panel were unsuitable for the selection criteria, as depicted in Table 5.1.*
96. Table 5.2: How do these species compare across the criteria listed in Table 5.1?	Please see previous comment.
97. Page 147: Check the spelling of Ancylobotrys.	Thank you. I noted and rectified it on page 147.

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98. Table 5.3: Given the SDG focus of the thesis, this table or the descriptions below could use additional information on nutritional value and agronomical value.	Please refer to the research focus in Section 1.1.5 on page 6. The research focuses on (1) How urban small-scale food production addresses household food security and interrelated United Nations Sustainable Development Goals (SDGs) in Sub-Saharan Africa. Therefore, the study did not include the nutritional and agronomical values of TAV crops, which are not well documented and would entail a study in itself. This could be considered for future research though, thank you.
99. Section 5.7: What new knowledge has this research generated based on the existing sources iterated in the conclusions?	The following paragraph relating to knowledge generated about this research was added to Section 5.7; *Although basic information relating to edible TAV is available from existing literature, information about their agronomical requirements, preparation, nutritional value and edible parts for consumption is limited. These knowledge gaps must be researched to enhance their use and performance in urban agriculture. Traditional knowledge would be valuable to future generations and research about TAV should be prioritised.*
CHAPTER 6	
100. "comparing data on soil water content, soil temperature and soil electrical conductivity, ambient temperature and RH, and the crops' survival and yield for both the LWS typologies to that of natural soil conditions as the control." How do these link to the theoretical framing in Figure 3.8?	The theoretical framing in Fig 3.8 on page 96 depicts the relationships between the independent variables (RH, temperature, precipitation and day length) and mediating variables (soil temp, VWC and EC) on biomass and plant stress. The outcome is described in Section 6.1 on page 155; *The outcome entails analysing the efficiency of the two selected LWS typologies in providing optimal growing conditions for TAV to address research objective 3. This outcome was achieved by comparing data on soil water content, soil temperature and soil electrical conductivity, ambient temperature and RH, and the crops' survival and yield for both the LWS typologies to that of natural soil conditions as the control.* Therefore, the study compared the above data for the LWS typologies to that of natural soil conditions as the control. See Section 6.1 on page 158; *Chapter 6 is divided into three parts. The first part provides the background by presenting the abiotic conditions applicable to the experimental study under which the LWSs and TAV crops performed. The second part entails the findings relating to the efficiency of the LWSs. The total crop yields for each LWS are compared to the control, the natural soil. Subsequently, the findings regarding the effects of crop positioning and other external factors impacting crop performance are presented. The third part entails the results relating to the performance of the TAV*

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	crops (see Figure 6.1). In the third part of the chapter, the crop leaf biomass results in the experimental study period are presented, followed by the crop performance in each typology.
101. Section 6.2 Figure 6.3: The legends overlap with the x axis on figures a and b, and the label is missing for figure c. The degree symbol is incorrectly encrypted on the y axis.	The formatting was rechecked to ensure no overlapping between the x-axis and the legend. Figure 6.4's label and y-axis were checked for correct encryption, as there is no Fig. 6.3c (see page 161).
102. "The aim was to determine if there were any external influences on the performance of the crops in addition to the 1) positioning of crops (see section 6.5, 2) the growth system typologies, comprising the LWSs and natural soil area (see section 6.6), and 3) crop species (see section 6.7)." This should be clearly stated as the aim of the experiments in the Introduction and Methods chapters.	Section 6.3 on page 168 states; *The aim was to determine if there were any external influences on the performance of the crops in addition to the 1) positioning of crops (see section 6.5, 2) the growth system typologies, comprising the LWSs and natural soil area (see section 6.6), and 3) crop species (see section 6.7).* The external influences were merely tested to ensure that crop positioning, typologies and crop species were the only determining variables and did not impact the biomass, and it was not an aim of the experiment. Table 3.7 on page 103 includes all variables measured to determine the impact on plant stress and biomass. This is also illustrated in Fig 3.8 on page 97. Section 3.4.3iii. explains each variable in the experiment.
103. Suggest using the terms relationships between external or biophysical variables and LWS attributes.	I am unclear about where this amendment is suggested. No changes were therefore made.
104. Suggest also mentioning here which statistical analyses were used to investigate which relationships.	Please refer to Section 3.4.3.iii.j for the statistical analyses. Section 6.3. on page 166 also states; *Correlation coefficient (r) values were determined by performing a Pearson pairwise correlation matrix method using Python software (ver. 3.11, 2021, Santa Clara, California, US).*
105. Section 6.3 Figure 6.11: What do the blue bars indicate? Is this the total biomass of all three typologies?	The blue bars in Fig 6.11 (*Charts illustrating the monthly fresh and dry leaf biomass yield of all three typologies for the experimental study period between 1 November 2021 and 30 April 2022*) on page 166 indicate the monthly fresh and dry leaf biomass yield of all three typologies for the experimental study period between 1 November 2021 and 30 April 2022 (Please see the title of the figure and the legend states weight in gram).
106. What does this help interpret?	Please see Section 6.3;

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	Figure 6.11 shows the monthly fresh and dry weight during the study period, with the biggest yields in March and April 2022. This is an important indicator of the significance of the typologies and crops on biomass and any external influences that might have impacted biomass.
107. Tables 6.8 and 6.9: Were all these r coefficients statistically significant (p>0.05)?	Tables 6.8 and 6.9 illustrate the Pearson pairwise correlation matrix results showing statistically significant correlations ($p < 0.001$) between the local minimum and maximum temperatures, local relative humidity, precipitation, daylength and crop performance based on fresh and dry biomass yield.
108. Also, what is the rationale for displaying coefficients between biophysical variables?	This information is essential to show the significance of the typologies and crops on biomass and any external influences that might have impacted biomass. The following text was added to Section 6.3 on page 166 to justify the correlations for the biophysical variables; *To ensure that the LWS typologies and TAV species as moderating variables were not affected by external influences, the correlation coefficient (r) values were determined by performing a Pearson pairwise correlation matrix method using Python software (ver. 3.11, 2021, Santa Clara, California, US).*
109. Tables 6.11 and 6.13 are repetitions of Table 6.6 and 6.7 respectively. Please edit or omit.	Tables 6.11 and 6.13 were omitted, thank you.
110. Tables 6.15 (now 6.13) and 6.16 (now 6.14): Is there a reason why linear regressions were used for soil properties and LWS aspect, but not for biophysical external factors? The model interpretation appears incorrect.	The researcher focused on the relationship between biomass yield with the soil properties, as; There were no statistically significant differences ($p > 0.05$) in daily maximum (T_{max}) and minimum temperatures (T_{min}), relative humidity (RH), precipitation (P), daylength (DF) and soil temperature (ST) across different crops, typologies and positioning of the crops on the walls. (See Section 6.3).
111. Soil EC is the only significant variable for both fresh and dry leaf mass. Please interpret relevant coefficient accordingly.	The following interpretation of the relevant coefficients in Tables 6.13 and 6.14 has been added to Section 6.3 on page 172; *However, the EC is expected to impact the crop performance in terms of yield (fresh leaf biomass yield $p < 0.001$; dry leaf biomass yield $p < 0.001$). For every increase of 45.069mS/m in the soil EC, one gram of fresh leaf mass was gained, assuming that the other variables remained constant. Moreover, for every gram of dry leaf biomass, there was an increase of 5.9834 mS/m in the soil EC.*
112. What was the goodness of fit of these models?	The goodness of fit was 11% (based on the r^2 value) which explains the variation most likely because of fewer variables included here. This shows that the model

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	could only account for 11% of the variation. The low values maybe attributed to the fewer variables included here.
113. Section 6.4 Section 6.4.1: These numbers would be better presented in a figure such as a bar graph.	Figure 6.12 presents the fresh monthly yield per m^2 of the three typologies, with the Eco Green Wall and the Vicinity Wall producing smaller fresh leaf yields than the natural soil.
114. Also, avoid using words like significant and correlations unless backed by results of a statistical test.	Noted, thank you. The word “significantly” has been omitted from Section 6.4.1.
115. Table 6.17: Interesting that the number of plants per metre square were quite different for the three treatments, and the benchmark remained the same. Could this table not be pivoted and combined with table 6.18? That would make for a more insightful table.	The plants per m^2 in each LWS typology differ due to pots' size, shape and positioning. The benchmark, which involves conventional agriculture, is a set yield based on average production rates for mixed-stand, small-scale traditional agriculture. Table 6.17 (now 6.15) on page 171 compares the typologies’ yield per area to the average conventional mixed-stand, small-scale agriculture production benchmark comparing the yield per area. In contrast, Table 6. 18 (now 6.16) on page 172 only compares the horizontal footprint of the two LWS typologies with the natural soil area, which is the control. The researcher prefers keeping the tables separate because the two tables have different captions and compare two different aspects.
116. What statistics is this sentence presenting? They seem to be incorrect: The Eco Green Wall and Vicinity Wall produced almost 50% and 14%, respectively, lower yields per square meter than the average conventional small-scale mixed-use agricultural production benchmark (Rabin et al., 2021 in Nagle et al., 2017).	The sentence in Section 6.4.1 on page 174; *The Eco Green Wall and Vicinity Wall produced almost 50% and 14%, respectively, lower yields per square meter than the average conventional small-scale mixed-use agricultural production benchmark (Rabin et al., 2021 in Nagle et al., 2017)* presents Table 6.15’s figures, comparing the yield/square meter per month (g) to the benchmark (average conventional small-scale agriculture production rate)(Rabin et al., 2012 in Nagle et al. 2017).
117. Figures 6.12 and 6.13 are redundant given the information in Tables 6.17 and 6.18.	The study included Figures 6.12 and 6.13 on pages 174 and 175 to visually present the performance of the three typologies per area and m^2 horizontal footprint. The tables provide additional information to assist the reader in understanding the calculations for each figure. However, the suggestion to omit Figures 6.12 and 6.13 is considered for future studies and publications; thank you.

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118. This sentence compares area benchmark with footprint benchmark – suggest contextualising or omitting: Considering the benchmark average fresh produce weight of 244g/m2 (Rabin et al., 2021 in Nagle et al., 2017), the typologies produced more than required considering footprint.	Please note this sentence refers to Table 6.16 (previously Table 6.18) on page 175 and refers explicitly to the footprint instead of the area.
119. Section 6.4.2 is a great addition, and should appear in the methodology chapter.	Thank you. Based on this comment, the following text was added to Section 3.4.3.iii.j. on page 112; *Findings related to productivity, installation, costs and maintenance were analysed based on observations and calculations by the researcher. Area and footprint findings were calculated based on the plant's monthly yield per square meter per typology. These were compared to a benchmark average of fresh produce weight of 244g/m^2)(Rabin et al., 2012 in Nagle et al. 2017). The benchmark is based on the average mixed-crop small-scale conventional production rates of 2.44 kg/m^2 at the Rutgers Agricultural Experiment Station.*
120. Table 6.19 has incomplete text.	Thank you, the incomplete text was rectified to include " January 2022".
121. Please mention the frequency of maintenance activities (daily/weekly/monthly).	Frequency was indicated as the number of times over the 6-month experimental period.
122. Suggest omitting text below table as it is redundant.	The text below the table has been omitted, as suggested. Thank you.
123. Section 6.5 Suggest combining Figures 6.14 to 6.20 into one composite for better context and brevity.	Thank you for the suggestion. The boxplots were created in Python, and the suggestion to combine boxplots will be discussed with the statistician for future publications as the statistician is no longer contracted.
124. Please also make the markers bolder and axis font larger for readability.	Thank you for the suggestion. The markers and axis fonts were created in Python and cannot be currently amended. However, this is noted for future studies and will be communicated to the statistician.
125. Section 6.5.4: What insights does a comparison between LWS rows and natural soil provide?	The comparison between the LWS rows and natural soil, which shows *the mean fresh mass yield difference between all positions in the LWSs and the natural soil was statistically significant* on page 180, provides the following insight (see Section 6.8 on page 202); *However, there were statistically significantly higher yields in the natural soil compared to the top, second and third rows in the LWSs. The soil volume explains*

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	the higher yields in the natural soil and the yields in the Vicinity Wall, with a soil volume double the volume of the Eco Green Wall containers.
126. Table 6.22 (now 6.20): Are these correlations or regression coefficients? Please correct the preceding text and provide appropriate statistics.	The heading of Table 6.22 (now 6.20) on page 178 has been amended to the following; *Table 6.20: Correlation coefficient between the positioning of crops and crop performance based on fresh and dry biomass yield*
127. Section 6.6 Not clear what value the box plots and tables are adding. The total quantities, monthly averages, and anova statistics suffice here. They could simply be tabulated.	The boxplots revealed the significant differences visually which is in sync with the landscape architectural disciplinary preference for visual representations. The suggestion is noted for future studies and publications; thank you.
128. Section 6.7 Was there a significant difference in crop biomass productivity across treatments?	Section 6.7 describes *which crop produced the biggest total leaf biomass yield in the experimental study period*. The difference in crop biomass productivity across the three typologies is discussed in Section 6.4.1. Section 6.8 on page 202 states; *LWSs are more effective in space-saving of a horizontal footprint than traditional soil-based food production on a household scale, as the natural soil area produced the lowest yield per m^2 considering footprint. The Vicinity Wall was the most productive, considering the horizontal footprint area occupied in terms of yield per m^2. The Vicinity Wall produced over four times the yield of the natural soil area, with the Eco Green Wall over three times more productive than the natural soil area.*
129. Section 6.8 Use one figure for each superlative. Highest = 1 value. How did these values compare to expected averages for Gauteng?	The discussion in Section 6.8 was amended to reflect one figure for each superlative, and available averages for Gauteng were added to Section 6.8.
130. Page 203: Please check wording comparing LWS footprint to natural soil area. Ensure correct comparison.	The researcher specifically referred to the horizontal footprint to compare LWSs and natural soil area yields in Section 6.9 on page 205; *LWSs offer a potential option for urban agriculture, as they are more effective in space-saving considering the horizontal footprint.*
131. Page 203: Good that the soil volume difference is acknowledged here. Is there	Noted, thank you. This study did not compare the soil volume and yield but could be considered in future research.

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a way to check for differences in yield per cubic metre square of soil?	
132. Table 6.31 is not conveying much, and if included, needs to be in the results, not the discussion. The table is attempting to report 'post-hoc test results' but providing typology names instead of statistical values. Please edit or omit.	Table 6.31 has been omitted, as suggested.
133. Page 205: Contributing to household food security sounds like a stretch at this point. Urban agriculture or food production or vertical farming may be more appropriate.	Section 6.9 on page 205 concludes that; *LWSs offer a potential option for urban agriculture, as they are more effective in space-saving considering the horizontal footprint. They use interstitial space, which would otherwise not have been used productively.* *Six TAV crops produced higher mean fresh and dry leaf biomass than the control crop in the LWSs, indicating their potential for vertical production for household food security.* This study focused on household-scale food security, considering the scale and typology of the LWSs. However, the contribution to urban agriculture and vertical farming are also important as acknowledged above.
134. Figure 6.33 is a useful graph that belongs in Section 6.7. See comment on biomass variance.	Please note that Figure 6.33 *(A comparison of the mean fresh leaf biomass of the ten crops in the three typologies)* shows the biomass of crops per typology. In contrast, Section 6.7 *(Which crop produced the biggest total leaf biomass yield in the experimental study period?)* describes the total crop biomass regardless of their position in a living wall typology or natural soil.
135. How does effort invested (Table 6.19) compare to footprint yield performance (Section 6.7)?	Tools, skills, and maintenance were not quantified, so the effort invested was not compared to footprint yield performance and therefore not reported on. However, the researcher will consider methods to quantify the effort and time into a financial cost for future publications.
136. Section 6.9 Which crops were better suited to which LWS?	Please see Figure 6.33: *A comparison of the mean fresh leaf biomass of the ten crops in the three typologies* on page 202 depicts the crops' yield per typology. Please refer to Section 7.3 on pages 223 to 266; *The performance of each crop [maximum quantum yield of photosystem II (Fv/Fm) and total plant performance (PI_{total})* for a discussion of the crops suited best for each LWS typology.
CHAPTER 7	

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137. "Photosynthesis affects biomass and plant performance (Salam et al., 2022). Photosynthetic efficiency is reduced when plants experience dry, hot extremes, diseases and lack of nutrients (Salam et al., 2022). Therefore, this study aimed to determine the maximum quantum yield of photosystem II (Fv/Fm) and total performance index (PItotal) differences in the nine TAV crops and the control crop to evaluate the possible tolerance to the conditions of the study area." This is an essential framing that needs to appear in the Abstract and the Introduction and Methods chapters (using different words).	This framing occurs in the abstract and the method chapters. The following text in the abstract refers to the plant stress and the chlorophyll fluorescence analysis; *Plant stress was measured by chlorophyll fluorescence analysis as the second performance indicator.* Please refer to Section 3.4.3.iii.h. on pages 109 to 112 for the description of the plant stress.
138. Section 7.2 These are some good results, but make for laborious reading in words. They could easily be neatly reported in one table displaying means and standard deviations, and Anova and t-test statistics with merged cells. The text could interpret these in three sentences – significant differences were observed in quantum yield and performance index across treatments, and stating which typology was highest for each variable.	This suggestion will be considered for future publications; thank you.
139. Tables 7.3 – 7.5: As with most pairwise tests in this thesis, these statistics add no value – have not or can not be interpreted meaningfully – so suggest omitting throughout.	Tables 7.3 to 7.5 included the post-hoc results of crop combinations in the three typologies that showed a statistically significant difference ($p<0.05$) in the maximum quantum yield. These tables were included in the thesis document in consultation with Professor Berner (NWU), who has specialised knowledge in plant stress data. However, this suggestion will be discussed with Professor Berner before writing future publications; thank you.

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140. Figures 7.2 to 7.7 could be combined into a composite to make for insightful comparison.	The Figures were provided separately for clarity. The suggestion to combine Figures 7.2, 7.4 and 7.6, which entails clustered bar charts comparing the mean maximum quantum yield of photosystem II (Fv/Fm) of all crops in the three typologies, will be considered for future publications; thank you. However, the combination of Figures 7.3, 7.5 and 7.7, which entail line charts comparing the mean maximum quantum yield of photosystem II (Fv/Fm) of all crops in the three typologies, will be highly complicated, impairing the reading and comprehension.
141. Section 7.3 See comments on Section 7.2 about displaying test statistics in one table and interpreting them in a few sentences. This applies to the correlation values as well. Suggest omitting Tables 7.7 to 7.27.	Section 7.3 and Tables 7.7 to 7.27 were included and formulated based on expert advice in the field of plant stress data. However, this suggestion will be considered for future publications; thank you.
142. Section 7.4 Please reference Tables 7.1 and 7.2 in section 7.4.1 instead of citing p-values.	The suggestion to reference Tables 7.1 and 7.2 has been referenced instead of the p-values in Section 7.4.1.
143. Also, keep terminology consistent throughout section when referring to quantum yield.	Thank you. The terminology referring to quantum yield was amended on pages 261 and 262.
144. The discussion does not present results, but draws inferences on them while referencing the results.	The discussion aims to highlight the significance of the results and their importance. Since few similar studies exist, a comparative discussion was not possible.
145. Please correct caption for Table 7.29 (now Table 7.31).	I am unclear about what must be corrected. No corrections were made.
146. Table 7.30 to 7.32 belong to the results, not the discussion.	Tables 7.30 to 7.32 were moved to Sections 7.2.2, 7.2.3 and 7.2.4.
147. What do the x indicate?	The “x”-symbol in Tables 7.30 (now Table 7.4), 7.31 (now Table 7.6) and 7.32 (now Table 7.8) indicates each crop's applicable category (Fv/Fm or PI_{total}). For clarity, the x-symbol has been removed in Tables 7.30, 7.31 and 7.31 on pages 264 to 266, and the applicable cells are only hatched grey to indicate the relevant category (Fv/Fm or PI_{total}) for each crop.
148. What was the significance level for these tests?	Refer to Section 3.4.3.iii.j. on page 114;

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	Significant differences were calculated at a threshold of p < 0.05 between all genotypes.
149. Are the rest of the results in the Appendices?	Yes, please refer to; *Appendix L: Statistical analysis results of correlation between maximum quantum yield in the typologies and all climate and soil variables;* and *Appendix M: Statistical analysis results of correlation between total performance index in the typologies and all climate and soil variables*
150. Interesting that correlations were mutually exclusive between quantum yield and performance index. It would be ideal to present quantum yield correlations and performance index correlations separately, even if it means repeating crop rows within the same table.	This is noted for future publications. The quantum yield and total performance index correlations were combined in Tables 7.30, 7.31 and 7.32 for brevity.
151. Please make captions consistent with Table 7.32 (do not present results in captions).	The captions for Tables 7.30 (now Table 7.4), 7.31 (now Table 7.6) and 7.32 (now Table 7.8) are consistent. I am unclear about what must be corrected.
152. Is there a reason correlations were preferred over regression models?	Correlations were selected over regression models as the study wanted to determine the strength of the relationship excluding all other factors between the plant species and climate and soil variables.
153. The second half of the discussion is well-rounded and draws valuable inferences.	Noted, thank you.
154. Section 7.5 The last sentence of the conclusion, however, should acknowledge the lifespan difference as a study design limitation. The researcher selected species with a much different lifespan and growth form than the rest.	This is noted. However, the shorter lifespan of *Portulaca oleracea* and *Amaranthus thunbergii* was included as a limitation in Section 1.4.2. on page 16. These species have a compact growth form and were, therefore, included in the study.
155. Section 8.2 How does performance index in LWS relate to food and nutrition security, human health and wellbeing, climate change adaptation, and employment?	To explain the link between the performance index in LWS and food security, please refer to Section 2.5 and Fig 2.6 on page 70 and Section 3.4.3.iii.h.; *Photosynthesis, which entails the absorption and conversion of light energy into chemical energy, is affected by environmental factors, including light, water, CO_2, nutrient availability and temperature [Salisbury and Ross,1992; Strasser and Tsmilli-Michael, 2001 in (Little and Rolando, 2003; Kalaji et al., 2014)].*

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	Photosynthesis is highly sensitive to stress caused by extreme temperatures and, therefore, is suppressed before other cellular functions are affected (Yamane et al., 1998). Plants exposed to high temperatures exhibit two opposite effects in the electron transport chain of photosynthesis (Tóth et al., 2007). During high-temperature periods, the photosystem I (PSI) is stimulated (as measured by the rate of P700+reduction) (Tóth et al., 2007; Martinazzo and Marcos, 2012). In contrast, photosystem II (PSII), and mainly the oxygen-evolving complex (OEC), is deactivated even at slightly elevated temperatures (Martinazzo and Marcos, 2012; Yamane et al., 1998), indicating that this process is susceptible to temperature stress (Martinazzo and Marcos, 2012; Pushpalatha et al., 2008). PSII, a protein complex that is the first link in the photosynthesis chain, uses light energy for electron extraction from water molecules (Barber, 2003). The JIP test, which analyses the polyphasic fluorescence transient (OJIP), is a fast and informative test widely used for analysing plant performance to indicate plant stress caused by environmental conditions (Bussotti et al., 2010). Photosynthetic parameters are efficient plant stress indicators [Salisbury and Ross,1992; Strasser and Tsmilli-Michael, 2001, (Little and Rolando, 2003; Kalaji et al., 2014)]. Therefore, measuring chlorophyll fluorescence with a portable fluorimeter has been reported as an effective measuring tool of chlorophyll fluorescence to indicate plant adaptation and stress (Little and Rolando, 2003; Kalaji et al., 2014). To explain the link between food and nutrition security, human health and wellbeing, climate change adaptation, and employment, please refer to Section 2.2.1 on pages 25 to 27.
CHAPTER 8	
156. How does it relate to rural communities? Please check the sentence for relevance, and temper your claims. This section needs to highlight which SDGs the footprint efficiency relates to, and how.	The following statement has been added to Section 8.2. on page 275; *South African rural and urban communities share commonalities, and food security, malnutrition and poverty are more prominent in urban than rural communities (Corinna and Francois, 2015).*
157. Section 8.3 Section 8.3.1: Apparently the cost of VW paid off, with higher yields and lower plant stress. What are the specific trade-offs suggested?	The following text was added to Section 8.3.1; *Suggested trade-offs would include the low-technology, simplistic components of the Eco Green Wall, which are easily assembled with minimal skills and tools required. However, the size of the pots of the Eco Green Wall would need to be doubled to 3-litre volumes, with a 200mm depth, as the Vicinity Wall's pots produced higher yields and added resilience.*

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158. Which features worked, and what cost-cutting is likely to minimise impacts on these features?	Features that worked and proposed improvements were added to Sections 8.3.1 to 8.3.6.
159. Irrigation and drainage come out of the blue here, as opposed to exposed soil surface and volumes that appear previously. How do these reflect on observed and potential soil property outcomes, for example?	Irrigation and drainage were discussed in Table 4.1 in Section 4.2.2. (page 130), and Sections 4.3.1 (page 133), 4.3.2 (page 134), 5.2.2. (page 140), 5.3.2. (page 143), 6.4.2. (page 175). Table 6.17 (previously 6.19) on page 176 compares the Eco Green and Vicinity Walls' installation and maintenance actions. Considerations relating to potential property outcomes have been added to Section 8.3.4; *The benefits of LWSs relating to their limited footprint also make LWSs a favourable option concerning the cost of land, compared to conventional soil-based food production. However, the aspect needs to address the crop requirements in terms of light availability. Moreover, the biophilic benefits of LWSs are also expected to increase perceived property values.*
160. Section 8.3.2 has no basis in the research undertaken. Please reconsider this Section	The suggestions relating to Section 8.3.2 *(Reduction of the carbon footprint, including reduced electricity and water requirements)* are noted. However, given the need for a comprehensive list of technical characteristics, it was essential to include characteristics such as harvested water, recycled/ recyclable components, reduced water usage through a drip irrigation system and selecting waterwise plant species.
161. Perhaps some analyses on electricity and irrigation inputs can speak to the energy and water use across typologies. Else, omit.	The following text relating to energy and water use was added to Section 8.3.5; *Moreover, the Eco Green wall, which does not require electricity, can function with basic watering such as a wick system. Systems fully reliant on electricity and water in terms of their design have limited applications for outdoor use in SSA, should the proposed location not have consistent electricity and water supply.*
162. Section 8.3.3: Perhaps also emphasise productivity by footprint remained high in addition to resilience.	The productivity by footprint is included in Section 8.3.4. on page 279.
163. And suggest some stress tests based on your findings and methods.	The following sentence has been added to Section 8.3.3; *Including additional stress variables and growth performance, such as the available water content would benefit future performance studies to improve the resilience of EGI.*

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164. Section 8.3.4: Are the benchmarks for vertical farming? How did this experiment compare to those benchmarks?	The benchmark is for conventional mixed-crop small-scale agriculture. The study focused on household food production, so vertical farming benchmarks were not considered applicable as it is mostly for commercial purposes, large scale, high intensity and high cost.
165. What social benefits?	Social benefits refer to ecosystem services, such as food provision and improving city environmental conditions, including real estate value, energy demand reduction (cost saving), durability (cost caving), and air quality improvement. Refer to Section 2.3.2. on page 46; *A cost-benefit analysis was conducted to determine the economic sustainability of LWS, comparing the installation, maintenance and disposal costs to the social benefits (including real estate value, energy demand reduction, durability and air quality improvement) over the life cycle of the analysed systems (Perini and Rosasco, 2013).* Refer to Section 8.3.1 on page 276; *These findings extend the conclusion that economic feasibility could be improved through cost-effective installation and maintenance and ensuring a broader use to increase social benefits through improving city environmental conditions (Perini and Rosasco, 2013; Bustami et al., 2018).*
166. Section 8.3.5 and 6: These are very poor sections. Either elaborate along the lines of comments on section 8.3.1, or omit.	These sections have been elaborated.
167. Section 8.4 What does the success of some of these crops mean for urban food systems?	The success of these TAV crops and their contribution to urban food systems are explained in Section 9.3 (Summary of study contributions) on pages 295 to 296.
168. What kinds of nutrients can people expect to become self-sufficient in?	The study focused on the production of TAV in LWS for food security. Although TAV's nutritional value was listed as beneficial in Section 1.1.4. and 2.4.2. the nutrient values of TAV crops were not the main focus of this research. Moreover, nutrients are a study field on its own and outside the expertise of landscape architecture. The nutrient value of TAV is listed for consideration in future research (Section 9.6. on page 299).
169. What skills, knowledge, and technical know-how are needed to grow these crops? What problems (grazing, pests, disease) could they encounter?	Both these aspects were recommended for future studies. Although low technology and skills were listed as recommended characteristics of LWSs, the study focused on improving the performance of producing TAV in outdoor modular LWSs for household food production, not the social aspects such as skills development and technical knowledge. The importance of skills, knowledge

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	and technical development to grow TAV in LWS for household production is noted and could be considered for future research. Refer to Section 9.6 on page 299. Problems relating to the cultivation of TAV, including grazing, pests and diseases, should also be considered for future research as part of their cultivation (refer to Section 9.6 on page 299).
170. Section 8.5 Appears like an arbitrary collection of sweeping statements and recommendations not derived from the veritable study we've been reading about so far.	The concern relating to Section 8.5. is noted, and I rechecked the conclusion for improvements. The conclusion (Section 8.5 on pages 282 to 283) describes the new insights contributed by the thesis to improve the performance of outdoor modular LWSs with TAV to contribute to local household food security as EGI in urban environments (Gauteng, South Africa). In response to focus area 1, it confirms urban small-scale food production's contribution to household food security and interrelated SDGs in SSA. In response to focus area 2 (the performance of outdoor modular LWSs as EGI improvements), measures to improve the performance of LWSs for the production of TAV are proposed. The recommended TAV crops are listed in response to focus area 3 (the performance of the selected TAV crops in modular LWSs.
171. Also, what happened to the theoretical framing in Figure 3.8?	The conceptual framework shown in Fig 3.8 depicts the relationship between the variables and was mainly considered to guide the data collection and analysis. The conclusion in Chapter 8 discusses the results, which are based on the data collection and analysis of these variables. Variables that formed part of the results (soil temperature, VWC and EC, ambient temperature, irrigation, plant stress, biomass) are discussed in Chapter 8.
CHAPTER 9	
172. A conclusion should not present statistics. The conclusion still follows the disjointed narrative evident from the abstract, and does not bring together the parts of the thesis to form one cohesive work. It simply reiterates the (unsynthesised) findings from the different chapters, and cites references to 'affirm, support and extend' without any original advances.	Statistics have been removed from the conclusion, and improvements have been made to the chapter as suggested.

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173. How can readers use the findings from this work? Who are these readers? What value does the knowledge generated in this thesis offer to the science of LWS, VF, and UA at large? The author needs to reflect on these questions and revise the thesis.	Section 9.4. and 9.5. on pages 296 to 299 provide implications for existing theory and implementation. The research outputs for this study provide practical recommendations and guidelines addressing the performance of both the system and the plants. These guidelines can contribute to previous studies and improve the performance of LWSs with TAV as EGI in urban environments (Section 9.4 on page 296). Readers include researchers and professionals in the industry, as well as NGOs. Section 9.3. on page 295 sets out the study contributions. The thesis has been revised to reflect on the above questions.

REBUTTAL TO FEBRUARY 5th, 2024 EXTERNAL EXAMINER COMMENTS AFTER THESIS EXAMINATION

1. The author has meticulously addressed most of the technical concerns raised in the first round of examination. Some minor discrepancies remain:	Noted; thank you.
2. P 24: While the detailed retrieval strategy has improved, it could still benefit from specifying exclusion criteria that determined the whittling down from 115 retrievals to 51 shortlisted articles.	This is noted for future reference, thank you.
3. P 97: Figure 3.8 has a misplaced arrow.	Thank you. The misplaced arrow was rectified.
4. P 113: Please reconcile the data distribution with the use of tests. To reiterate, if data distribution was non-normal, then it would entail use of nonparametric Kruskal-Wallis Anova. If it was normal, you would use parametric Anova. Also good practice to report Shapiro-Wilk test W.	Please refer to p 114, where the data distribution was elaborated; *For the biomass yield, data were tested for uniform distribution using the numerical method, the Shapiro-Wilk test before analysis, which showed that data came from a normally distributed population. Results were analysed by following a non-parametric procedure, the analysis of variance (ANOVA), to assess dependent variable changes according to independent variable values (Bevans, 2022).*
5. P 148: Please check caption for Table 5.3 for spelling.	Thank you. The caption was corrected as follows; *Table 5.3: Final traditional African vegetable selection for the experimental study*

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6. P 169 to 173: Tables 6.13 and 6.14 are not 'correlation coefficient tests', but linear regressions mentioned in Chapter 3. Please edit the text and captions for this.	Thank you. The text and captions were corrected as follows; *Table 6.13: Linear regression results of the soil water content, soil electrical conductivity and soil temperature in terms of fresh leaf mass* *Table 6.14: Linear regression results of the soil water content, soil electrical conductivity and soil temperature in terms of dry leaf mass*
7. R squared values are usually not sufficient to determine the goodness of fit of the entire model. Chi-squared tests attest to this, along with Akaike Information Criteria compared across models combining different variables. At the very least, the author should recognise that only nine or 10 percent of variation can be explained by the model, and so these results are not generalisable or significant. Provided this caveat, the model interpretation is correct.	Thank you. The following limitation was added to par. 1.4.2; *The goodness of fit of the linear regression results was based on the r2 value and not attested by Chi-squared tests and Akaike Information Criteria compared across models combining different variables. Therefore, only nine or 10 percent of variation can be explained by the model, and so these results are not generalisable or significant.*
8. P 174: This sentence is still very unclear – 50% and 14% of what? Please split for clarity.	Noted, thank you. The sentence was split for clarity; *The Eco Green Wall produced almost 50% lower yields per square meter than the average conventional small-scale mixed-use agricultural production benchmark (Rabin et al., 2021 in Nagle et al., 2017). The Vicinity Wall produced 14% lower yields than the benchmark.*
9. Overall: There are still sections of text that are a light grey in contrast to the black font throughout. They stand out at pages 72, 100, 108, 158, and in tables 3.5 and 3.6.	Noted, thank you. The mentioned text has been rechecked to ensure that the font colour is black.
10. Wishing the candidate the very best for imminent advances in their field of research and development.	Thank you.

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