Allelopathic interactions between wheat, selected crop species and the weed *Lolium multiflorum* x *perenne*

by

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I, Michael Ignatius Ferreira declare that the thesis/dissertation, which I hereby submit for the degree Ph D: Agronomy at the University of Pretoria, is my own work, except where acknowledged, and has not previously been submitted by me for a degree at this or any other tertiary institution.

SIGNATURE: .....…………………………..

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ABSTRACT

No information is available on the role of allelopathy in crop rotation systems of the Western Cape Province of South Africa, where more than 100 000 ha are under threat from herbicide-resistant rye grass. A study which investigated the use of allelopathic properties for the suppression of rye grass hybrid type *(Lolium multiflorum* x *perenne)* was undertaken. These objectives were accomplished by: a) exploring the use of allelopathic properties of crop residues for rye grass suppression; b) evaluation of the role of allelopathy from seeds, seedlings, roots and above-ground plant material of rotational crops; c) assessing the distribution of genetic and morphological variability of rye grass and d) determining the interactions among micro-organisms and allelopathic root leachates from rotational crops and rye grass. In the field trials, growth inhibitory or stimulatory effects were observed on crops exposed to the residues of others. Medic suppressed the weed type rye grass. The radicle length of rye grass was inhibited by seed leachates from wheat and lupine. Growth inhibition from lupine seed and seedling leachates was evident in rye grass radicle length and cumulative germination percentage. Morphologically, 50% of the total number of specimens was classified as rigid rye grass, 48% as the hybrid, namely *L. multiflorum* x *perenne* and 2% as perennial rye grass. The wide genetic and morphological variation detected in rye grass may be due to high genotypic plasticity and hybridisation for producing the weed type *L. multiflorum x perenne*. The faster growth rate of rye grass on Langgewens soil treated with barley root leachates was revealed by Principal Component Analysis (PCA) as a probable association with growth-promoting soil micro-organisms. Crop cultivars and weeds may modify the soil micro-organism populations to their advantage and to the disadvantage of other species by the release of root exudates that apparently differ in composition between plant species. The effect on microbial communities varied with source of exudates and between soils.

Allelopatiese wisselwerking tussen koring, gekose gewasspesies en die onkruid *Lolium multiflorum* x *perenne*

deur

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UITTREKSEL

Daar bestaan geen inligting oor die rol van allelopatie in wisselboustelsels van die Wes-Kaap Provinsie in Suid-Afrika, waar meer as 100 000 ha bedreig word deur raaigras met weerstand teen onkruiddoders, nie. ’n Studie wat die gebruik van allelopatiese eienskappe vir die onderdrukking van onkruidtipe hibriediese raaigras *(Lolium multiflorum* x *perenne)* ondersoek het, was onderneem. Hierdie doelwitte is bereik deur: a) ’n ondersoek na die gebruik van allelopatiese eienskappe van gewasreste vir raaigrasonderdrukking; b) evaluasie van die rol van die allelopatie van saad, saailinge, wortels en plantmateriaal van die bogrondse dele van wisselbougewasse; c) assessering

van die verspreiding van genetiese en morfologiese veranderlikheid van raaigras en d) bepaling van die wisselwerking tussen mikroörganismes en allelopatiese wortelloog van wisselbougewasse en raaigras. In die veldproewe is groei-inhiberende of stimulerende invloede op gewasse wat blootgestel was aan ander gewasreste, waargeneem. Medic het die onkruidtipe-raaigras onderdruk. Saadloog van koring en lupiene het die lengte van raaigras se kiemwortel geïnhibeer. Raaigras se groei is ook geïnhibeer deur lupiensaad en lupiensaailingloog, soos waargeneem kon word in kiemwortellengte en kumulatiewe ontkiemingspersentasie. Morfologies was 50% van die totale aantal plantmonsters geklassifiseer as raaigras *(Lolium rigidum)*, 48% as ‘n hibried, naamlik *L. multiflorum* x *perenne* en 2% as meerjarige raaigras. Die wye genetiese en morfologiese variasie wat vir raaigras waargeneem is, mag weens hoë genotipiese plastiesiteit en verbastering wees om die onkruidtipe *L. multiflorum x perenne* te vorm. Die vinniger groeitempo van raaigras op grond van Langgewens en wat met garsloog behandel was, is deur Prinsipiële Komponent Analise (PKA) onthul as ’n moontlike assosiasie met grond-mikroörganismes wat groei bevorder. Gewaskultivars en onkruide kan die grondmikroörganisme-populasies tot hul voordeel en tot die nadeel van ander spesies modifiseer, deur die vrystelling van wortelafskeidings waarvan die samestelling blykbaar tussen spesies verskil. Hierdie invloed op mikroörganisme-gemeenskappe het varieër met bron van afskeiding en tussen grondsoorte.

INTRODUCTION

A weed is a plant growing where it is not desired, or a plant out of place (Ashton & Monaco, 1991). Weeds are diverse in their habit and habitats throughout the world. Although they account for not more than 1% of the total plant species on earth, they cause great problems nevertheless to humankind by interfering in food production, health, economic stability, and welfare (Qasem & Foy, 2001). In agriculture, weeds are of concern because they compete with cultivated crop plants for growth factors (Vyvyan, 2002).

Economically, there is no doubt that herbicides and herbicide-resistant crops have drastically improved agricultural efficiency and yields. However, the broad application and/or sometimes the abuse of herbicides also created problems. The major problem is the evolution of weeds with resistance to herbicides which refers to the capacity of a plant to grow and reproduce under the dose of herbicide that is normally lethal to the species (Yuan *et al.*, 2007). Weed resistance to herbicides presents one of the greatest current economic challenges to agriculture (Baucom, 2009) with more than 346 biotypes of weed known to be resistant to herbicides (Heap, 2010).

Allelopathy was considered an alternative to herbicides and an aid for weed control by Fay and Duke (1977) who found that some *Avena* spp accessions contained an allelopathic agent that reduced annual weed growth and caused chlorosis, stunting and twisting when planted in close association. According to Hoffman *et al.* (1996) competitive hierarchies often form during early stages of plant growth, and therefore interference should be measured between germinating seeds and between seedlings. Typical field studies cannot separate the effects of competition from allelopathy since they happen simultaneously between roots and shoots. In view of this, artificial environments must be devised that remove any possibility of competition while allowing chemical exchange to take place (Smith *et al.,* 2001).

Knowledge about the genetic constitution of rye grass and its populations is increasingly becoming crucial, particularly given the extent of herbicide-resistance within the Western Cape. Data on this topic will further enhance our understanding of the genetics and evolution of herbicide-resistant weeds. Descriptive studies of patterns of genetic diversity in weedy populations can be an extremely important tool for helping to minimise the evolvement of resistance to herbicides (Madhou *et al.*, 2005).

McCalla and Norstadt (1974) showed that the water soluble substances in wheat residues reduced germination and growth of wheat seedlings. Wheat residues reduced yield of the subsequent wheat crop. This was attributed to the fact that wheat contains a number of phenolic acids. Kong (2008) confirmed that variation of the soil microbial populations and community structures could be distinguished by the allelopathic and non-allelopathic rice varieties tested. Furthermore, Sozeri and Ayhan (1998) found in pot experiments, that mixing straw, which was gathered after harvesting, with soil, decreased germination of wheat seeds and increase seedling mortality. The release of phytotoxins by plants, has been proposed as an alternative theory for the success of some invasive plants and they have long been suspected of using allelopathic mechanisms to rapidly displace native species (Bais *et al.,* 2003).

Herbicide resistant rye grass is a serious problem in Western Cape grain producing areas as it is threatening more than 100 000 ha of productive grain fields. Wheat fields have become so heavily infested that economic grain production will be impossible in certain areas in the foreseeable future, leading to huge production losses and less sustainable grain production. Therefore, system-oriented approaches to weed management that make better use of alternative weed management tactics need to be developed (Liebman & Davis, 2000; Barberi, 2002). Although residue management appears to be a key factor in residue-mediated weed suppression, very few studies have systematically compared the influence of different residue management methods on germination and establishment of crop and weed species (Kruidhof, 2008). Therefore, a hypothesis was formulated: the management of crop residues, which is normally regarded as a production constraint, could be used for suppression of herbicide-resistant weeds, thereby reducing input costs and promoting the sustainability of cropping systems. Locally, the concomitant responses of the crop species in such systems have to be considered as well.

No information is available on the role of allelopathy in crop rotation systems of the Western Cape Province, where 750 000 ha are subjected to crop rotation. Of this area, more than 100 000 ha are under threat from invasive herbicide-resistant rye grass. Because of the importance this could have on sustainability of small grain crop rotation systems in the Western Cape Province, a study with the following objectives, was undertaken:

1. Explore the possibility of using allelopathic properties of rotational crop residues for the suppression of weed establishment and then specifically that of herbicide-resistant rye grass.
2. Evaluate the possible role of allelopathy from seeds, seedlings, roots and above-ground plant material of rotational crops, under controlled conditions.
3. a) Assess the distribution of genetic variability of rye grass; b) determine its botanical classification by morphological analyses; c) determine the presence of the crown rot pathogen of barley and wheat on rye grass; and d) analyse soil samples from each collection point where rye grass were sampled to determine its preference for soil chemical properties.
4. Determine the interactions among allelopathic root leachates, from different crop cultivars and the weed type rye grass, their growth rate, and soil micro-organisms. Also assessed were the allelopathic effects of the afore-mentioned plant species on wheat and barley.