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Effect of cultivation practices on *Lachenalia* cultivars for a potential cut flower

by

Carmen Marlene Koch

Submitted in partial fulfillment of the requirements
for the degree MSc (Agric) Horticulture
in the Faculty of Natural and Agricultural Science
University of Pretoria
PRETORIA

Supervisor:	Dr. E.S. du Toit
Co-supervisor:	Dr. J.G. Niederwieser

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SUMMARY

Trials were done on four *Lachenalia* cultivars (Romaud, Robyn, Rolina and Romelia) to improve flower quality and inflorescence stem length and to evaluate vase life, as these criteria are important for the cut flower grower. Flowering size bulbs were grown under five different shade nets (white 18%, green 40%, black 40%, black 55%, black 70%) and in the open as a control. Under each shade net, bulbs were planted at a low planting density of two bulb diameters apart (56 bulbs/m^2), as well as a high planting density of one bulb diameter apart (111 bulbs/m^2). The effect of the growth hormone gibberellic acid (GA_3) on plant growth was investigated to determine if longer stems could be obtained. The plants were treated with gibberellic acid at 10 ppm and 0 ppm, which was applied as a foliar spray and as a bulb dip treatment.

It is necessary to identify and describe specific flowering stages to be able to establish a standard rating system for *Lachenalia* vase life. The morphology of *Lachenalia* cultivar Romaud was described to determine the real succession of

opening flowers on the inflorescence. The stages of 'first flower', 'full flower' and '50% wilt' were described.

A high photosynthetically active radiation (PAR) measurement of 1250 $\mu.mol.m^{-2}.s^{-1}$ in the control, resulted in the shortest inflorescence stem length of 13 cm for all four cultivars compared to the rest of the shade nets. The longest inflorescence stem length of 24 cm was produced for cultivars Rolina and Romelia by a low PAR of 400 $\mu.mol.m^{-2}.s^{-1}$ under the black 70% shade net. The inflorescence stem length of all four *Lachenalia* cultivars tend to decrease to a minimum of 13 cm when average temperatures are 30ºC and higher and to a maximum of 24 cm when temperatures are in the range from 24 to 27ºC. A long vase life of 12 to 14 days for cultivar Rolina was observed under the green 40% and black 40% shade nets, compared to 10 to 11 days in the control. The green 40% shade produced a long vase life of 14 to 16 days for cultivar Romelia, compared to the 12 to 14 days in the control.

Planting density significantly increased inflorescence stem length by about 2.5 cm and vase life by 2 days at the high planting density compared to the low planting density for all four cultivars.

Inflorescence stem length for cultivars Romaud and Romelia increased significantly by 3 cm for both the GA_3 foliar spray and bulb dip treatments. The number of flowers per inflorescence decreased significantly by about 3 to 5 flowers for cultivar Romaud and Romelia when GA_3 was applied as a foliar spray or bulb dip treatment. A significant increase in vase life (2 days) of GA_3 treated plants was observed.

All four *Lachenalia* cultivars are suitable for cut flower production, as inflorescence stem lengths were either just below or above the 20 cm mark and vase life was longer than the five to six days required by the cut flower industry.

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EFFECT OF CULTIVATION PRACTICES ON *LACHENALIA* CULTIVARS FOR A POTENTIAL CUT FLOWER

by

Carmen Marlene Koch

Supervisor: **Dr. E.S. du Toit**
Co-supervisor: **Dr. J.G. Niederwieser**

ABSTRACT

South Africa is richly endowed with indigenous flora including *Lachenalia* which has shown a substantial market potential. The *Lachenalia* is presently established as a pot plant and due to its increasing popularity, the demand for a cut flower was recognized. Trials were done on four *Lachenalia* cultivars (Romaud, Robyn, Rolina and Romelia) to evaluate flower quality, inflorescence stem length and vase life, as these criteria are important for the commercial cut flower grower. Flowering size bulbs were grown under five different shade nets (white 18%, green 40%, black 40%, black 55%, black 70%) and in the open as a control. Under each shade net, bulbs were planted at two densities, namely a low planting density of two bulb diameters apart (56 bulbs/m^2) as well as a high planting density of one bulb diameter apart (111 bulbs/m^2) in 20 litre black plastic bags (30 cm diameter). The effect of the growth hormone gibberellic acid (GA_3) on plant growth was also investigated to determine if longer stems could be obtained. The plants were treated with gibberellic acid at 10 ppm and 0 ppm. The gibberellic acid was applied as a foliar spray and as a bulb dip treatment.

The complex morphology of the *Lachenalia* inflorescence complicated initial attempts to describe the stages of flowering. It is necessary to identify and

describe specific flowering stages to be able to establish a standard vase life rating system for *Lachenalia*. The morphology of *Lachenalia* cultivar Romaud was described to determine the real succession of opening flowers on the inflorescence.

A high photosynthetically active radiation (PAR) measurement of 1250 $\mu.mol.m^{-2}.s^{-1}$ in the control, resulted in the shortest inflorescence stem length of about 13 cm for all four cultivars compared to the rest of the shade net treatments. The longest inflorescence stem length of about 24 cm was produced for cultivars Rolina and Romelia by a low PAR of 400 $\mu.mol.m^{-2}.s^{-1}$ under the black 70% shade net. The inflorescence stem length of cultivars Romaud and Robyn under the black 70% shade net was about 20 cm and 17 cm respectively. Under the black 55% shade net, PAR levels of 450 $\mu.mol.m^{-2}.s^{-1}$ yielded inflorescence stem lengths of 19 cm for cultivar Romaud, 14 cm for cultivar Robyn and 22 cm for cultivars Rolina and Romelia. Intermediate PAR levels between 500 and 600 $\mu.mol.m^{-2}.s^{-1}$ under the white18%, green 40% and black 40% shade nets slightly retarded inflorescence stem lengths compared to the black 55% and black 70% shade net. Also, the inflorescence stem length of all four *Lachenalia* cultivars tend to decrease to a minimum of 13 cm when average temperatures are close to 30ºC and higher in the control and to a maximum of 24 cm under the black 70% shade net, when temperatures are in the range from 24ºC to 27ºC. PAR and temperature therefore both play a regulatory role in determining inflorescence stem length.

Planting density significantly increased inflorescence stem length by about 2.5 cm and vase life by 2 days at the high planting density compared to the low planting density for all four cultivars. At the high planting density, the mother bulb fresh mass, total daughter bulb fresh mass and the number of daughter bulbs decreased significantly compared to the low planting density for all four cultivars. Peduncle diameter and number of flowers were not affected by the planting density.

A vase life of 8 to 10 days was observed for cultivar Romaud in the control and all the shade net treatments. Cultivar Robyn had a vase life of 9 to 11 days, with no significant differences between the shade net treatments. The longest vase life of 12 to 14 days for cultivar Rolina was observed under the green 40% and black 40% shade nets, compared to 10 to 11 days in the control. The green 40% shade net also lead to a long vase life of 14 to 16 days for cultivar Romelia, compared to the 12 to 14 days in the control. After day 6 of vase life, the cut surface was covered with bacteria. Bacteria were also identified in the xylem vessels and are probably involved in the processes that inhibit water uptake. Fungal hyphae were observed in the parenchyma cells on the cut surface which together with the bateria, probably contribute towards the reduction of vase life.

The control of stem elongation by the application of gibberellic acid (GA_3) [10 ppm] was observed by measuring inflorescence stem length. Inflorescence stem length for cultivars Romaud and Romelia increased significantly by 3 cm for both the GA_3 foliar spray and bulb dip treatments. The number of flowers per inflorescence decreased significantly by about 3 to 5 flowers for cultivar Romaud and Romelia when GA_3 was applied as a foliar spray or bulb dip treatment. This is a negative attribute for cut flower quality, especially for cultivar Romaud as any reduction in flower number is easily noticed. A significant increase in vase life (2 days) of GA_3 treated plants was observed. Foliar spray and bulb dip treatments significantly decreased mother bulb fresh mass, total daughter bulb fresh mass and number of daughter bulbs for cultivars Romaud and Romelia. This is probably as a result of increased inflorescence demand of assimilates.

The difference in general plant growth between the four different *Lachenalia* cultivars is primarily determined genetically. In general, the average inflorescence stem length of cultivar Robyn is the shortest, followed by cultivar Romaud. The longest average inflorescence stem lengths being produced by cultivars Rolina and Romelia. All four *Lachenalia* cultivars are suitable for cut flower production, as inflorescence stem lengths were either just below or above

the 20 cm mark. Also, the vase life of all four *Lachenalia* cultivars was longer than the five to six days required by the cut flower industry.

The cut flower grower should make the ultimate choice on which shade net to use, depending on the cultivar he intends to grow and local climate conditions. Black 70% shade net may be suitable in areas of low solar altitudes, for example Pretoria, compared to Stellenbosch, which is an area of high solar altitude.

Follow up research will be required to evaluate the effect of environmental conditions to which the bulbs were exposed in the previous growing season and storage conditions on cut flower quality. By applying correct cultivation methods, quality attributes can be positively manipulated to increase the cut flower quality of *Lachenalia* cultivars for the local and overseas market.

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'God often sends his help by way of human hands'

CHAPTER 1

INTRODUCTION

South Africa has an extensive flora from which flowering plants with a commercial potential are frequently selected. South Africa has contributed relatively little to the number of commercial crops in the international flower bulb industry, despite its wealth of flower bulb species. A few exceptions however are *Zantedeschia*, *Ornithogalum*, *Gladiolus*, *Nerine* and *Freesia*. Some of the most well known bulbous plants sold on international markets originate from genetic material from South Africa, for example *Amaryllis*, *Begonia, Sandersonia* and *Watsonia*. There is a constant need for new and improved products in the international floriculture market and genera with potential for new crop development, either as cut flower or pot plant, for example *Bulbinella*, *Cyrtanthus, Eucomis*, *Veltheimia* gleditsch and *Tritonia* amongst others.

In the past, indigenous flowers were harvested in the natural habitat. Due to over exploitation, wild populations have become depleted. This results in many plant species being considered vulnerable, and being lost from their natural habitat. The cut flower industry in South Africa is therefore concentrating on the increased cultivation of indigenous flowers.

One of the latest selections by the ARC-Roodeplaat Vegetable and Ornamental Plant Institute is the indigenous *Lachenalia*, which is cultivated commercially as a pot plant. In recent years, interest has focused on using certain *Lachenalia* cultivars as cut flowers as some cultivars bear relatively long inflorescence stems and together with the colour and shape of the flowers, show potential as cut flowers. No published information is available on *Lachenalia* cut flower production and this study is aimed at looking at the fundamental aspects needed to provide a standard product of uniform quality for the cut flower industry. Quality is the key to success in all phases of the cut-flower industry and the

deciding factors that make a good quality cut flower include a long vase life, good colour, low cost of production, good stem length, adaptability to local climate and resistance to disease or insect damage (Greer, 2000).

Stem length is of prime interest for cut flower quality. There are no uniform grading standards laid down for *Lachenalia* cut flowers. This study is aimed at achieving maximum stem length for *Lachenalia* cut flower production and a minimum stem length of 20 cm was chosen to be generally acceptable for cut flower purposes. Stem lengths of 20cm to 30cm are the required norm for *Hyacinthus orientalis* cut flower production (Anon, 2003). A stem length of 20 cm and higher will therefore be graded as a good quality stem length suitable for *Lachenalia* cut flower purposes. The hypothesis of this study is that maximum *Lachenalia* stem length can be achieved by making use of different cultivation practices to produce a good quality *Lachenalia* cut flower.

Short and long stems have different commercial uses and the preferred stem length varies with consumer demand. Growers therefore need to be able to manipulate stem length to meet market requirements. In this study, stem length will be referred to as inflorescence stem length, which is the combination of peduncle and rachis length.

Stem length is normally controlled by manipulating cultivation practices (e.g. planting density), environmental conditions and by applying plant growth regulators. The interrelated effects of light and temperature, planting density, as well as the application of the growth regulator gibberellin under five different shade nets and in the open as a control, on *Lachenalia* growth and development will briefly be discussed.

1.1 Description and distribution

The genus *Lachenalia* is a small, tunicate bulbous plant belonging to the subclass Monocotyledonae and the family Hyacinthaceae and consists of approximately 110 species. It is endemic and occurs mostly in the winter-rainfall region of South Africa. Flowers may be tubular, urn-shaped or bell-shaped and arranged in a spike, subspicate or raceme on a fleshy stem (Duncan, 1988). The three inner perianth segments usually protrude beyond the outer three segments. A wide spectrum of flower colours such as red, yellow, blue, green or even variegated colours exist in the genus. A pleasant fragrance is observed in some species. Flowering can take place from April to December. Leaves are formed in a basal rosette and are often marked (Duncan, 1988). *Lachenalia* can be propagated vegetatively by bulblet production, from leaf cuttings, as well as by daughter bulb development from the mother bulb. When temperatures begin to fall during autumn, *Lachenalia* bulbs become active. Initially the roots emerge, followed by the sprouting leaves, which continue to grow until flowering in winter.

1.2 Light

1.2.1 Light Quality

Light quality has a significant effect on plant growth, development and productivity (Kendrick and Kronenberg, 1992). The red (R) / far-red (FR) photon flux (R/FR) ratio of the radiation environment has a strong effect on the growth and development of plants. Changing the R/FR ratio is an effective method to control plant elongation under daylight. Red light promotes stem elongation. When plants are grown in blue light, growth is shortened, hard, and dark in colour (Moe, 1990). For greenhouse production, the main effect of light quality seems to be on stem elongation.

1.2.2 Irradiance

Providing shade is an effective means of reducing irradiance. Under different shade nets, levels of irradiance are altered resulting in changes in plant morphology and anatomy. Generally, high irradiance levels decrease stem length while low irradiance levels are known to stimulate an increase in stem length (Mastalerz, 1987). In cut flowers, irradiance is especially important because of the effect it has on the rate of photosynthesis. Photosynthate levels in flower tissues will increase as irradiance levels increase, unless temperatures become excessive and cause a reduction in net photosynthesis. Most likely, greater amounts of photosynthates are found in flowers grown during periods of high irradiance than there are in flowers produced when light levels are low (Mastalerz, 1987).

1.3 Temperature

Temperature is an important factor affecting both growth and development of plants. Generally, higher temperature results in faster growth, but simultaneously reduction in quality can occur, for example, longer, thinner stems, and smaller flowers (Mastalerz, 1987). With *Hyacinthus* and *Tulipa* (Hartsema, 1961) and with *Ornithogalum arabicum* (Shoub *et al.*, 1971) there are two critical temperatures, one for optimal peduncle elongation (13ºC), and one for optimal flower initiation, which is between 17ºC and 20ºC.

Air and plant temperatures can be lowered by reducing the amount of solar radiant energy entering the greenhouse. Carbohydrates are conserved at lower day temperatures because of reduced leaf temperatures and respiration rates. If an increase in leaf temperature occurs, net photosynthesis may be decreased because greater amounts of carbohydrates are utilized in respiration than are produced from a higher rate of photosynthesis (Mastalerz, 1987). It is generally

accepted by growers and professionals, that cut flowers produced at high temperature are of inferior quality (Mastalerz, 1987).

1.4 Shading

The amount of shading needed by plants for optimum growth varies depending on local climate and the specific light requirements of different plants (Mastalerz, 1987). When light levels are too high, shading is possible. Shade net is designed for use in agriculture and horticulture to control growing conditions, manipulate growth patterns and protect crops from extreme environmental conditions caused by the sun, wind and hail.

According to Van Rensburg (2001), the advantages of using shade net are as follows:

- Photosynthesis is enhanced by manipulating the amount and quality of light transmitted through various densities of shade net.

- Shade nets are stabilized against ultra-violet (UV) rays to prevent degradation by sunlight under variant climatic conditions and may also protect plants from the harmful effects of UV rays. Also, UV absorbing shade nets reduce the populations of pests whose vision is limited to the UV portion of the spectrum.

- By moderating temperature extremes, evapotranspiration is reduced and thereby overall water consumption is reduced.

- Minimizes the risk of stomatal closure caused by heat stress.

- Reduces wind, hail, bird and insect damage to nursery crops.

1.5 Planting Density

Planting density can strongly influence the growth and bulb yield of a plant. The optimal planting density is the one giving optimal yield and quality for the commercial flower grower (De Hertogh *et al.*, 1983). If plants compete for light, an increase in planting density will produce an increase in plant height resulting in a longer stem, but flower quality may be reduced. The effects of increasing planting density on tulip bulbs and sandersonia tuber growth and development have been intensively studied (Clark and Burge, 1997; 2000; Rees and Turquand, 1969; Timmer and Van der Valk, 1973; Van der Valk and Timmer, 1974). After the optimum density has been reached, an increase in stem length may occur and the total number of harvested bulbs per plant decreases with increasing density. Increasing planting density also results in a decrease in mother bulb fresh mass for both sandersonia and tulip (Clark and Burge, 1997; 2000; Rees and Turquand, 1969; Timmer and Van der Valk, 1973; Van der Valk and Timmer, 1974). Roodbol and Hancke (1997) observed similar results for *Lachenalia* bulb production.

1.6 Gibberellic acid

Gibberellic acid (GA_3) is involved in the control of stem elongation. The application of GA_3 in certain treatments results in a general increase in plant height when applied to lilies (Kays *et al.*, 1971). According to Ginzburg (1974), GA_3 promotes inflorescence growth by directing assimilate movement towards the inflorescence at the expense of the corm in gladiolus. Also the keeping quality of potted lilies was enhanced by the application of gibberellic acid (Kelley and Schlamp, 1964) but the number of initiated flower buds was reduced (Kays *et al.*, 1971).

1.6 Vase life

Vase life is an important criterion of quality of cut flowers. The environmental conditions at which cut flowers are grown immediately before cutting have a marked effect on their vase life. As outdoor maximum temperatures increase the vase life of cut flowers decreases (Mastalerz, 1987). According to Knappenberger *et al.* (1955) high irradiance levels on the day previous to harvest increase plant temperatures and thereby the rate of respiration increases, as a result, sugar levels in the flowers at harvest are decreased, and their vase life is reduced. Flowers with the highest sugar content at the time of harvest have the longest vase life (Mastalerz, 1987).

To prolong cut flower vase life, pre-harvest environmental conditions must be optimal and post-harvest water relations within the stem must be improved. Cutting, general handling, and placement of the stem in the water after harvesting, creates favourable conditions for contamination of microorganisms, mainly bacteria, on cut surfaces and in the vase water (Larsen and Cromarty, 1967; Marousky, 1969). Burdett (1970) has shown that bacterial contamination of stems and of water in which cut flowers are placed, can block the xylem and cause early flower senescence, but the addition of a bacteriostatic agent leads to a significant increase in vase life. A minimum room temperature vase life of five to six days is required for commercial cultivars used for cut flower production (De Hertogh, 1977).

1.7 The aim of this study

To determine if certain *Lachenalia* cultivars, commercially grown as pot plants, have commercial value for a potential cut flower and how quality can be improved.

Specific objectives were:

- The complex morphology of the *Lachenalia* inflorescence complicates the description of stages of flowering. The morphology of cultivar Romaud was described to recognize and understand the succession of flowering on the inflorescence axis. This work is aimed at identifying and describing the important flowering stages, in order to acquire a uniform vase life rating system of *Lachenalia* for the cut flower industry.

- To examine the effect of varying photosynthetically active radiation (PAR) and light quality created by different shade nets on *Lachenalia* growth, especially inflorescence stem length, flower quality and vase life.

- To determine the effect of planting density on inflorescence stem length, vase life and number of flowers.

- To evaluate the effect of the growth hormone, gibberellic acid (GA_3) on inflorescence stem length, number of flowers and vase life.

- To determine the cause of vascular occlusions in the flower stem, which reduce the vase life of cut lachenalias.

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CHAPTER 2

DETERMINING THE MORPHOLOGY OF *LACHENALIA* cv. Romaud WITH THE AID OF THE FIBONACCI SEQUENCE TO DESCRIBE STAGES OF FLOWERING

2.1 Summary

Understanding the morphology of the *Lachenalia* inflorescence and identifying specific stages in the succession of flowering on the inflorescence axis, leads to a standardised rating system of its vase life, which as yet has not been established. Once this has been established, the cut flower industry and the researcher will be able to identify important flowering stages, to acquire a uniform rating system. The stage of 'first flower', 'full flower' and '50% wilt' on the inflorescence of *Lachenalia* cultivar Romaud was identified. When the first flower on a contact parastiche opened, a small opening in the folded outer perianth was observed. This stage was described as 'first flower'. The stage at which 80% of the flowers on the inflorescence were fully open, was described as 'full flower' and '50% wilt' was described as the stage when ½ of the 80% fully open flowers turned brown on the edges of the outer perianth and started to shrivel.

2.2 Introduction

The stage of harvest varies with each species and the stage at which the first flower opens is a critical factor in vase life. Flowers cut at an advanced stage of development will have a shorter vase life and flowers harvested when the flowers are tightly closed may never open. Specific stages of flower development have been described for many cut flowers and used as 'markers' to standardize the specific stages of vase life, in order to achieve a uniform rating for all cut flower

growers. This is the first step towards establishing a uniform rating system for *Lachenalia* and leaves space for improvement if found necessary.

The morphology of the *Lachenalia* inflorescence is complex, because it consists of numerous flowers arranged in several spirals or parastichies around a common axis compared to single stemmed flowers. This makes the identification of specific stages (first flower, full flower and 50% wilt) of vase life difficult. A clear understanding of the inflorescence morphology is therefore necessary to be able to recognize the flowering stages accurately.

The term phyllotaxis is concerned with the description of patterns in which certain organs such as leaves and flower buds are arranged on the plant stem or on the growing point of the shoot (Barlow and Carr, 1984). The flower succession on the inflorescence axis of the *Lachenalia* is also determined by these spiral forms.

The individual trumpet-shaped, lemon-yellow flowers on the hyacinth-type inflorescence of the *Lachenalia* cultivar Romaud liberate a sweet scent (Hancke and Coertze, 1988). It was assumed that an average inflorescence stem length of 15 to 20 cm and the abundant display of colourful flowers would meet the requirements of the cut flower industry. The initial choice was therefore made to describe the specific stages of cultivar Romaud for vase life evaluation.

Initial attempts to describe stages of flowering were complicated by the complex morphology of the *Lachenalia* inflorescence and this needed to be clarified. The morphology of the inflorescence of *Lachenalia* cultivar Romaud is described in order to understand and recognize the stage of 'first flower', 'full flower' and '50% wilt'.

The concept of 'contact parastichies' was explained by Cutter (1959). These contact parastichies are recognizable as running in opposite directions and each node with a flower bud in the axil of a bract is located at the intersection of two

contact parastichies. In general, the contact parastichies nearly always yield numbers, which are successive terms of the main Fibonacci series. The successive Fibonacci numbers being dependent on the overall size of the inflorescence e.g. 2 plus 3 for smaller inflorescences and 3 plus 5 for large inflorescences. In the monocotyledons there may be a variable number of contact parastichies, which may vary during development (Cutter, 1959).

2.3 Materials and Methods

Lachenalia bulbs of cultivar Romaud (4.5 cm in circumference and 1g each) were grown in pasteurized composted bark mixture, under 55% shade net (average PAR 390 $\mu.mol.m^{-2}.s^{-1}$). Irrigation in combination with the water-soluble hydroponic fertilizer mix was kept constant and applied three times daily (08h00, 12h00, 17h00), by drip irrigation system. Ten randomly selected primary inflorescences were cut at the base and harvested as soon as the first flower on the inflorescence opened. The harvested inflorescences were placed in sterilized water-filled glass vases and stored in controlled temperature rooms at 22°C. The cabinets provided a 12 hr photoperiod with a light intensity of ±100 $\mu mol.m^2.s^{-1}$ PAR at plant level to simulate office conditions. Lighting was provided by WHO fluorescent tubes. The inflorescences were monitored closely for approximately 5 days to observe the pattern of flowering of the individual flowers.

The number of clockwise (steep) and counterclockwise (gradual) parastichies were counted by looking directly into the center of the inflorescence apex. A basic plan was drawn according to Reyneke, Coetzer and Grobbelaar (1987), to illustrate the arrangement of the flowers on the rachis. A series of concentric circles was drawn, with every circle representing a node with a flower bud in the axil of a bract. The innermost circle represents the apical meristem, therefore the oldest flower (furthest away from the growth tip) is accordingly positioned on the

outermost circle. The positions of the flowers are indicated on the circles by black points (Figure 2.1).

The cut stem was placed in water after harvest and the flowers were traced by a solid line in order of their formation from the first flower opening, to determine a series of parastichies. The solid line therefore connects the oldest flower consecutively with the second-oldest flower, the second-oldest flower with the third-oldest flower for each individual parastiche. The number of clockwise and counterclockwise parastichies were then counted and expressed accordingly as a contact parastichy system.

2.4 Results and Discussion

Flowers of cultivar Romaud spiral around the stem as two sets of distinctly different spirals or parastichies. One goes diagonally from lower left to upper right (counterclockwise) and the other crosses it diagonally from lower right to upper left (clockwise). The flowers in each parastiche ascend the stem in order of decreasing age i.e. *Lachenalia* inflorescences show an acropetal order of flowering.

Counting the number of parastichies on the primary inflorescence, revealed 8 clockwise and 5 counterclockwise parastichies on the inflorescence. Hence a 5+8 contact parastichy system as shown in Figure 2.1 was determined. When comparing the two, the clockwise parastiche rises gradually and the counter-clockwise parastiche rises more steeply. Apart from being arranged in two sets of spirals (contact parastiches), the flower buds are also arranged in 13 straight lines (ortostiches) if viewed from the tip of the inflorescence. Starting with the oldest flower (1) on the lowest node (outer circle in Figure 2.1), moving in a clockwise direction, the second oldest flower (2), on the entire inflorescence is situated on node 2, about 5 x 360/13 degrees away from flower no. 1. This angle

is close to the fibonacci angle of 137.5º C (Richards, 1951). The angle between all successive flowers remains constant (5 x 360/13 = 138.46º). By applying this angle, it is possible to determine the real succession of opening flowers on the inflorescence. However, since the contact parastiches are more prominent and the age difference between the basal flowers on the five counter clockwise parastiches are virtually the same, it would be practical to follow the succession of flowers per parastiche.

Small and large inflorescences present different numbers of parastichies, but once the succession of flowers per parastiche is understood, the specific flowering stages can be easily recognized and a uniform rating system of vase life by visual observations will be possible.

The identification and recognition of the initial stage of flowering (first flower) on the *Lachenalia* inflorescence is important for cut flower growers, as this is the stage at which flowers have to be harvested, to ensure a long vase life. When the first flower on a contact parastiche opened, a small opening in the folded outer perianth was observed (Figure 2.2). This stage was described as 'first flower'. Within a few hours, the succeeding flowers on the remaining parastichies opened. Consecutively placed flowers in each spiral, then flowered progressively upwards towards the growth apex (Figure 2.3). The stage at which 80% of the flowers on the inflorescence were fully open (day 3), was described as 'full flower' (Figure 2.4). The last 20% of the flowers near the centre of the growth apex remain tubular in shape and never fully open. On day 5 of vase life, ½ of the 80% fully opened lemon-yellow coloured flowers turned brown on the edges of the outer perianth and started to shrivel, this stage was described as '50% wilt' (Figure 2.5).

2.5 Conclusion

Determining the flower succession on the inflorescence axis of the *Lachenalia* cultivar Romaud is the first step towards identifying specific flowering stages for *Lachenalia* in order to establish a uniform vase life rating system. The initial background needed to recognize and identify the specific flowering stages has been established and the basic terminology of 'first flower', 'full flower' and '50% wilt' will be referred to in the following chapters when describing vase life.

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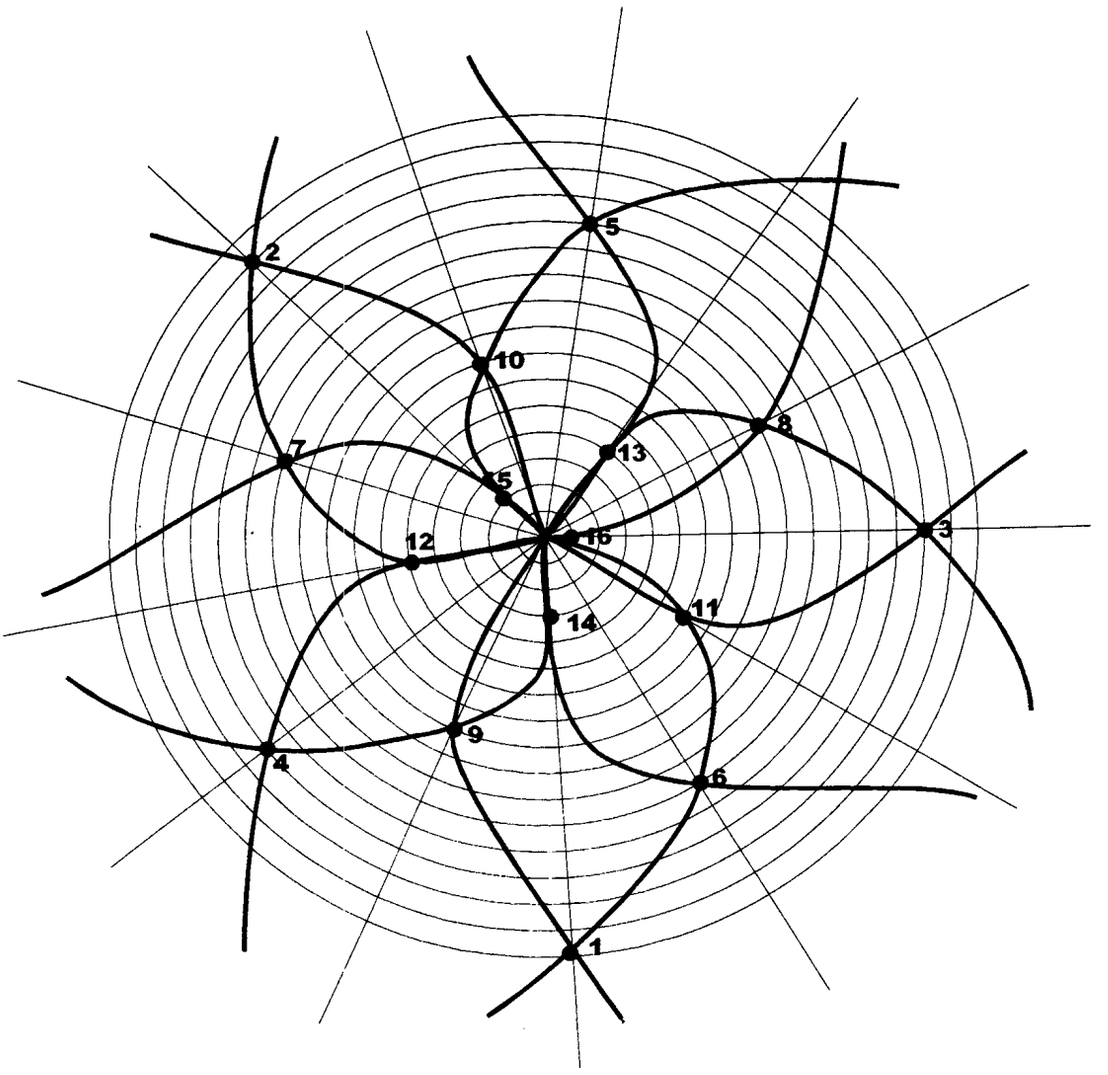

Figure 2.1 Schematic illustration of the inflorescence of *Lachenalia* cultivar Romaud, showing the spiral arrangement of the contact parastichies.

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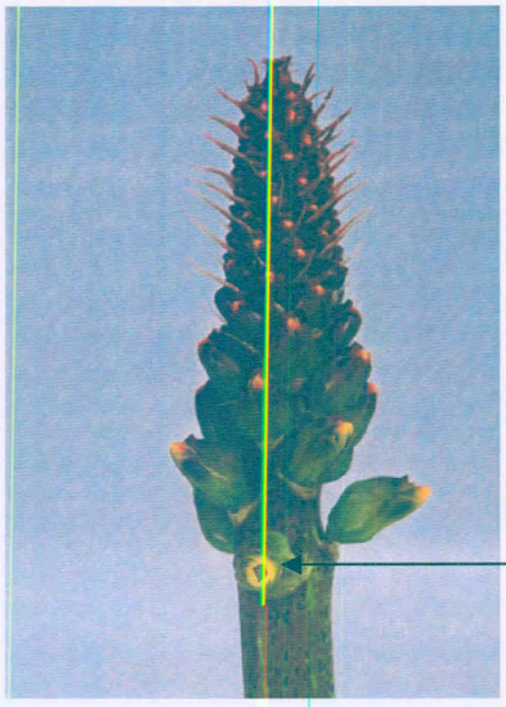

Figure 2.2 Photographical illustration of the stage of 'first flower' on the inflorescence of *Lachenalia* cultivar Romaud.

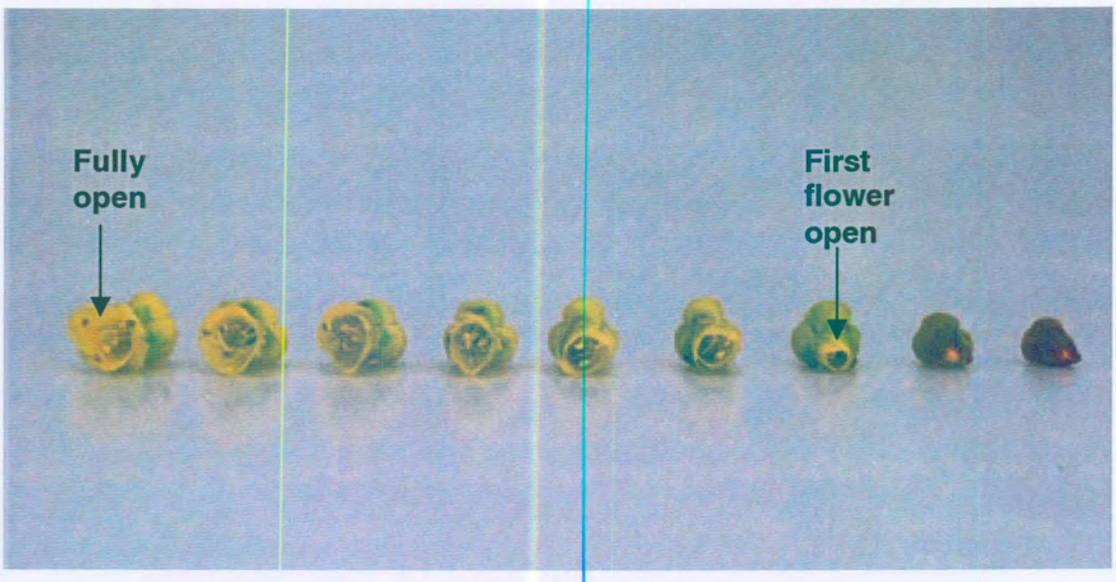

Figure 2.3 Photographical illustration of the order of flowering of a single parastiche on the inflorescence axis of *Lachenalia* cultivar Romaud.

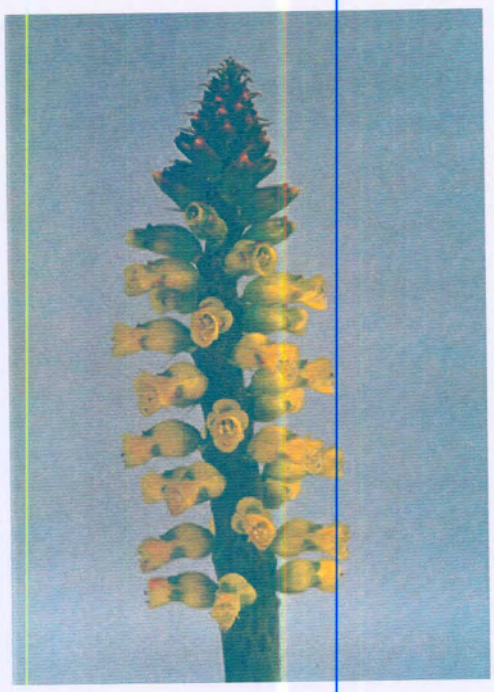

Figure 2.4 Photographical illustration of the stage when 'full flower' on the inflorescence of *Lachenalia* cultivar Romaud occurs.

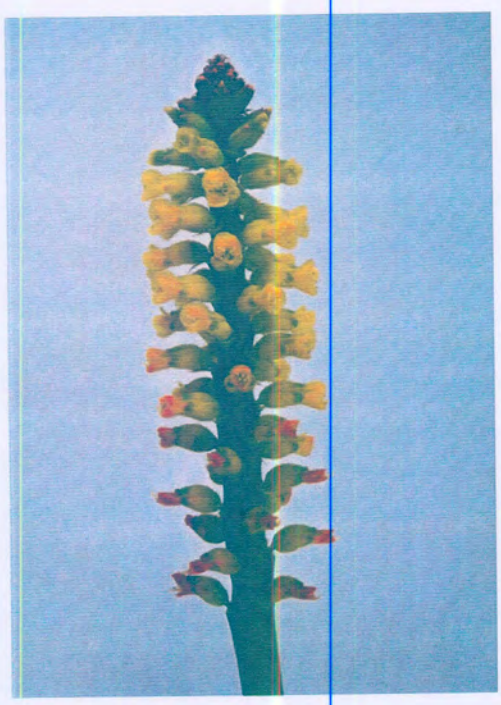

Figure 2.5 Photographical illustration of the stage when '50% wilt' on the inflorescence of *Lachenalia* cultivar Romaud occurs.

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CHAPTER 3

THE EFFECT OF PLANTING DENSITY AND DIFFERENT SHADE NETS ON PLANT GROWTH, WHICH INCLUDES BULB YIELD AND VASE LIFE OF FOUR *LACHENALIA* CULTIVARS

3.1 Summary

The regulation of stem elongation in plants is an important consideration in the floriculture industry. Long flower stems is an important criteria in determining the final quality and market value of cut flowers. By changing the spectral quality of the daylight in a greenhouse through the provision of appropriate shade nets, it is possible to alter the inflorescence stem length of *Lachenalia* cultivars. Four *Lachenalia* cultivars Romaud, Robyn, Rolina and Romelia were subjected to full sun (control), white 18%, green 40%, black 40%, black 55% and black 70% shade nets. Inflorescence stem length was higher under the green 40% shade net, (red light transmittance expressed as a percentage = 62%), compared to the black 40% shade net (red light transmittance = 60%).

A high photosynthetically active radiation (PAR) of 1250 $\mu.mol.m^{-2}.s^{-1}$ in the control, resulted in the shortest inflorescence stem length of about 13 cm for all four cultivars compared to the rest of the shade net treatments. The longest inflorescence stem length of about 24 cm was produced for cultivars Rolina and Romelia by a low PAR of 400 $\mu.mol.m^{-2}.s^{-1}$ at the low planting density under the black 70% shade net. The inflorescence stem length of cultivars Romaud and Robyn under the black 70% shade net was about 20 cm and 17 cm respectively. Under the black 55% shade net, PAR levels of 450 $\mu.mol.m^{-2}.s^{-1}$ yielded inflorescence stem lengths of 19 cm for cultivar Romaud, 14 cm for cultivar Robyn and 22 cm for cultivars Rolina and Romelia. Intermediate PAR levels between 500 and 600 $\mu.mol.m^{-2}.s^{-1}$ under the white18%, green 40% and black

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40% shade nets also increased inflorescence stem lengths compared to the control, however they were shorter than those under the black 55% and black 70% shade net. The inflorescence stem length of all four *Lachenalia* cultivars tend to decrease to a minimum of 13 cm when average temperatures are higher than 30ºC in the control and increase to a maximum of 24 cm under black 70% shade net, when temperatures were observed in the range from 24ºC to 27ºC.

Inflorescence stem length increased significantly by about 2.5 cm at the high planting density compared to the low planting density for all four cultivars. At the high planting density, vase life of all four *Lachenalia* cultivars increased significantly by 2 days compared to the low planting density. The mother bulb fresh mass, total daughter bulb fresh mass and the number of daughter bulbs decreased significantly at the high planting density compared to those planted at the low planting density for all four cultivars. Peduncle diameter and number of flowers were not affected by the planting density.

An acceptable vase life of 8 to 10 days was observed for cultivar Romaud in the control and under all the shade net treatments. The vase life of cultivar Robyn was between 9 and 11 days, with no significant differences between the shade net treatments. The longest vase life of 12 to 14 days and 14 to 16 days under the green 40% and black 40% shade nets was observed for cultivars Rolina and Romelia respectively, compared to 10 to 11 days and 12 to 14 days in the control. Thus the vase life of all four *Lachenalia* cultivars is suitable for cut flower purposes as the minimum requirement of vase life for cut flowers in general is 5 to 6 days as recommended by De Hertogh (1977). After day 6 of vase life, the cut surface of cultivar Romelia was covered with bacteria. Bacteria were also identified in the xylem vessels of cultivar Romelia and are probably involved in the processes that inhibit water uptake in cultivar Romelia and also the remaining cultivars. Fungal hyphae were observed in the parenchyma cells on the cut surface, which probably, together with the bacteria, contribute to a reduced vase life.

3.2 Introduction

Four *Lachenalia* cultivars, namely Romaud, Robyn, Rolina and Romelia were chosen to determine the effect of different cultivation practices on inflorescence stem length and vase life. Cultivar Romaud (Figure 3.1a) has a hyacinth-type inflorescence with closely spaced, trumpet shaped, lemon-yellow flowers, which are slightly fragrant (Hancke and Coertze, 1988). The bright red colour of cultivar Robyn (Figure 3.1b) contributes to the attractiveness of the inflorescence. The flowers on these inflorescences are pendulous and are borne horizontally. Cultivar Rolina (Figure 3.1c) changes its colour during flower development, from pink to a pale yellow flower with a purple tip and the inflorescence bears 45 to 60 multi-coloured pendulous flowers (Lubbinge *et al.*, 1983). Finally, cultivar Romelia (Figure 3.1d) has bright yellow, bell-shaped, pendulous flowers and an attractive inflorescence. In this trial, stem length will be referred to as inflorescence stem length, which is the combination of peduncle and rachis length.

Factors affecting growth and for which competition may occur among plants are, water, nutrients, light, oxygen and carbon dioxide. Increased competition for these factors occurs during the growth of plants under plant density stress; with the result that the allocation of assimilates between different plant structures becomes proportionally altered (Harper, 1977). Because of the sessile nature of established plants, there is a need for plants to accommodate continuously to a changing environment. Shade is one of the most common forms of stress, and thus light conditions are an important determinant of phenotypic plasticity (Grime, 1981). Local climate plays a primary role in causing variation in light, temperature and humidity from one habitat to another.

3.2.1 Light

Light is the source of energy for the process of photosynthesis, in which carbon is fixed into carbohydrates and ultimately all organic compounds of the plant. Three properties of light are known to be important for plant growth: irradiance or intensity (measured in foot-candles, lux or photon flux), quality or spectral composition (measured in wavelengths) and duration (measured in photoperiod) (Cathey and Campbell, 1980). Plants react in different ways to each of these factors. Light quality is involved in regulating stem length and optimum light intensity during growth of the crop is very important to vase life. Light intensity is of particular importance for *Lachenalia* cut flowers, as the natural habitat and commercial conditions differ, for example, the high light intensity conditions in the Highveld in South Africa compared to the low light intensity conditions in Europe.

3.2.1.1 Light Quality

Light is classified according to its wavelength in nanometers (nm). Visible or white light occurs between the wavelengths of 400 to 700 nm. Blue, green, yellow, orange and red light occur around wavelengths of 460, 510, 570, 610, and 655 nm, respectively. Far-red light (725 to 735 nm) has an influence on plants other than through photosynthesis (Nelson, 1998). The dramatic difference in spectral composition between sunlight and shade is most often expressed in terms of the absorption maximum of the pigment phytochrome: the ratio between the photon flux at 655-665 nm (red) and the photon flux at 725-735 nm (far-red) (R:FR) (Smith, 1982). Infrared light occurs at longer wavelengths and is not involved in plant processes. It is primarily the visible spectrum of light that is used in photosynthesis.

Maximum plant sensitivity for photosynthesis occurs at 675 nm. There are peaks in the blue and red bands where photosynthetic activity is higher. Red light is

necessary for photosynthesis and chlorophyll synthesis and promotes stem elongation, flowering, and anthocyanin formation amongst others (Moe, 1990). Blue light is also necessary for photosynthesis and chlorophyll synthesis and reduces stem length and dry weight. When plants are grown in red light, growth is soft and internodes are long, resulting in tall plants. When plants are grown in blue light, growth is shortened, hard, and dark in colour (Mastalerz, 1987).

3.2.1.2 Irradiance

Although photon flux is the most appropriate term to describe the amount of energy falling on a flat surface per unit time, irradiance is also widely accepted, according to Holmes (1984).

Solar irradiance at the earth's surface is determined by changes in positions of the sun, day length, cloudiness, altitude (in that there is less depletion of solar radiation by the atmosphere at higher altitudes), and the slope of the land surface (Hall, 2001).

The quality of solar radiation at the earth's surface can vary with latitude and altitude, especially with respect to variation in amounts of ultraviolet (UV) radiation. Ozone in the stratosphere absorbs UV and prevents all of the UV-C (wavelengths of 250 to 280 nm) and most of the UV-B (wavelengths of 280 to 320 nm) from reaching the earth's surface (Lamberts *et al.*, 1998). Due to differences in the path length of the stratosphere and atmosphere through which radiation passes, UV at the earth's surface is greatest at high altitudes and low latitudes. Most of the UV-A (wavelengths of 320 to 400 nm) reaches the earth's surface, but is less damaging to biological systems than UV-B and UV-C (Lamberts *et al.*, 1998).

Depletion of the stratospheric ozone layer is a major environmental problem in that the higher levels of UV can damage the DNA of plants, which can result in mutations. Physiological (Teramura *et al.*, 1991) and morphological effects may also be influenced by UV (Hall, 2001).

Irradiance, through its effect on photosynthesis, probably influences leaf development most significantly. Light utilized in photosynthesis is termed as photosynthetically active radiation (PAR) and comprises of the wavelengths from 400 to 700 nm (Nelson, 1998). The flux density of PAR photons (PFD) can be measured with sensors. The PAR reaching the plant, influences leaf and air temperatures and affects the rate of evapotranspiration. The increase in leaf temperature that results from the absorption of solar radiant energy has a major effect on transpiration, photosynthesis, respiration, and other metabolic processes (Mastalerz, 1987).

Flower initiation and bulb formation are controlled by exposure to radiant energy of a specific duration and quality. Irradiance and temperature determine the quantity of photosynthates available for plant growth. With temperatures at recommended levels, low irradiance limits photosynthesis and the supply of photosynthates; consequently, the total amount of fresh weight that can be produced is low. Leaves of plants grown in full sunlight are thicker and have a smaller area than those grown in the shade (Daubenmire, 1974). Generally, high irradiance decreases plant height but increases stem diameter. Plants grown in the shade or at reduced irradiance are taller, have thinner stems and a lower dry weight than plants exposed to full sunlight (Mastalerz, 1987).

Photosynthate levels in flower tissues will increase as irradiance increases, unless temperatures become excessive and cause a reduction in net photosynthesis. Most likely, greater amounts of photosynthates are found in flowers grown during periods of high irradiance than there are in flowers produced when irradiance levels are low (Mastalerz, 1987).

Changes have been observed in scape length, scape diameter (Wassink, 1965), and flower size of tulips. An increase in weight of the daughter bulbs has been correlated with irradiance (Wassink, 1965). According to Davies *et al.* (2002), irradiance can be used to manipulate flower stem length of *Sandersonia aurantiaca*, with the useful range being limited to photosynthetic photon fluxes of 460-700 µmol $m^{-2}s^{-1}$. Lilies subjected to low light intensities (50% or more) early in the growth cycle (emergence to flower bud initiation) causes a significant increase in flower bud abortion (Miller, 1992), but no abortion of florets was observed in shaded *Ornithogalum dubium* (Luria *et al.*, 2000).

3.2.2 Temperature

Plants respond to temperature at all stages of growth; consequently, temperatures should be maintained at optimum levels whenever possible. The effect of ambient temperature on plants is a major factor in geophyte growth (De Hertogh and Le Nard, 1993). The response of most plants to increases in temperature, in the range of 10ºC-35ºC, is to show an increase in growth rate, as the temperature rises to an optimum, followed by a decline (Sutcliffe, 1977). The longest flower stems for *Sandersonia aurantiaca* were produced at 21ºC and 24ºC, and a rise in temperature from 24ºC to 27ºC resulted in the shortest stems (Davies *et al.*, 2002). Kinet *et al.* (1985) observed that temperature affects flower development. At high temperatures flowers grow faster and their final size is smaller compared to low temperatures. According to Davies *et al.* (2002), flower number on the main stem of *Sandersonia aurantiaca* increased linearly with an increase in temperature up to 27ºC.

According to Du Toit (2002), the best temperature regimes for *Lachenalia* bulb production are the low and moderate temperature regime, which represent the cool and moderate winter climate in South Africa, for example the western and

south-western parts of the Cape province. It is in these climates where winter rainfall occurs, that *Lachenalia* species occur naturally.

Temperature also has a direct effect on the formation of carbohydrates in the photosynthetic process (Boodley, 1998). The rate of fixation of CO_2 rises with an increase in temperature. If there are no other limiting factors, such as the amounts of water, carbon dioxide, or light, the rate of photosynthesis and respiration increases as the temperature increases. It has been observed that translocation rates increase with temperatures between 20ºC and 30ºC (Hewitt and Curtis, 1948).

As the leaf temperature rises, the rate of transpiration also increases. If the change in environment results in an increase in leaf temperature, net photosynthesis may be decreased. This is because greater amounts of carbohydrates are utilized in respiration than are produced from a higher rate of photosynthesis. In addition to photosynthesis, respiration and transpiration, other growth processes that are affected by temperature include enzyme reactions, amino acid and protein synthesis, as well as carbohydrate conversions (Mastalerz, 1987). To ensure that photosynthesis exceeds respiration, plants are grown in cool temperatures at night to keep the respiration rate down and in warm temperatures by day to enhance photosynthesis. Generally, higher temperature results in faster growth, but with it a reduction in quality can occur. Longer, thinner stems, and smaller flowers may occur (Nelson, 1998). According to Du Toit (2002), inflorescence abortion occurs when *Lachenalia* bulbs of cultivar Ronina are exposed to a high temperature regime.

Although air is a poor conductor of heat and the transfer of heat between plant parts and the air is relatively slow, plant temperatures generally are similar to that of the air immediately surrounding them. An increase or decrease in air temperature usually results in a corresponding change in plant temperature, especially when the plant is exposed to moving air. The temperature of leaves

exposed to solar radiant energy may be 17ºC to 28ºC higher than air temperatures, but leaf temperatures from 6ºC to 21ºC higher than air temperatures are more common (Shull, 1936). Reducing the amount of solar radiant energy entering the greenhouse can lower air and leaf temperatures (Mastalerz, 1987).

3.2.3 Shading

Covering crops with shade net is a common practice used to achieve a number of objectives, which include the reduction of temperature inside the greenhouse and changing the incoming solar spectrum through the use of different coloured shade nets. Shade net also reduces wind speed by about 40%, thus extensive crop damage by wind is minimized (Tanny and Cohen, 2003).

Several factors such as the angle at which the incoming radiation strikes the shade net and the spectral composition of the incident radiation, influence the shading produced by shade net (Yates, 1986). With shade net, it is possible to regulate temperature as well as light quality and intensity to simulate optimum growing conditions for the specific requirements of various crops and plants. Shade nets are also used for the protection of plants against possible wind and rain damage.

The 'shade factor' is a measure of the fraction of incident radiation not transmitted by a material (Yates, 1986). The transmittance spectrum of incident radiation of different coloured shade nets and varying densities were monitored by Van Rensburg (2001) and expressed as a percentage.

	Blue light	Red light	Far-red light
White 18%:	87%	88%	88%
Green 40%:	84%	62%	66%
Black 40%:	60%	60%	60%
Black 55%:	49%	48%	48%
Black 70%:	28%	28%	29%

Greater availability and distribution of usable photosynthetically active radiation (PAR) upon crops is ensured by the use of certain colours of shade net. When comparing two shade nets with the same shade density but different colours, photosynthesis rates of plants growing under green shade net might be lower than those of similar plants grown under black shade net (Yates, 1986).

The use of shade net has to be suitable for the needs of the plant in the specific area. Which shade density used, depends on the crop requirements and the existing natural light intensity. A less-dense shade net (30% to 50%) may be necessary in cloudy climates. For most shade nets, the shade factor decreases with increasing solar altitude. Therefore in areas of low solar altitudes, for example, Pretoria, a shade net of higher density will be needed compared to an area of high solar altitude, for example, Stellenbosch, in order to produce similar growing environments.

Shade net manufacturers claim that shade nets are stabilized against ultra-violet rays to prevent degradation and to reduce the amount of UV rays transmitted. A rise in the depletion of the stratospheric ozone layer in recent years is a cause for concern, because increased levels of UV-B and UV-C reach the surface of the earth, which can lead to severe plant damage (Lamberts *et al.*, 1998). Thus shade net can possibly reduce the extent of the damage to plants caused by potential high levels of UV radiation. The use of UV absorbing screens have also been known to reduce the populations of pests whose vision is limited to the UV portion of the spectrum (Antigonous *et al.*, 1998).

Shade results in the elongation of flower stems, particularly in bulbous crops (Larson, 1992). For example, the addition of 55% shade cloth significantly increased the scape length of *Anemone coronaria* (Larson, 1992). According to Roodbol and Hancke (1997), cuttings of *Lachenalia* plants grown at a low light intensity produced more daughter bulbs.

3.2.4 Planting Density

It is known that the planting density can strongly influence the growth and bulb yield of a plant. Adjustments in the yield and quality of flower crops can be made by regulating planting density in relation to irradiance (Mastalerz, 1987). The optimal planting density is the one giving optimal yield and quality for the commercial flower grower (De Hertogh *et al.*, 1983). An increase in planting density increases competition for light between individual plants. Before interplant competition for light begins, an increase in planting density will result in higher yields without affecting quality. If plants start competing for light, however, an increase in planting density will produce a higher yield, but quality may be reduced (Mastalerz, 1987).

Quality and quantity must always be weighed in making a decision. The effects of increasing planting density on tulip growth and development have been intensively studied (Rees and Turquand, 1969; Timmer and Van der Valk, 1973; Van der Valk and Timmer, 1974) and the following observations were made. After the optimum density has been reached, the total number of harvested bulbs per plant decreased with increasing density. Increasing planting density also resulted in a decrease in mother bulb fresh mass (Rees and Turquand, 1969; Timmer and Van der Valk, 1973). Also an increase in scape length may have occured (Timmer and Van der Valk, 1973; Van der Valk and Timmer, 1974). Similar results were observed in *Sandersonia aurantiaca* tuber production, where tuber weight and secondary tubers decreased with an increase in planting

density (Clark and Burge, 1997; 2000). A maximum increase in *Lachenalia* bulb fresh weight has also been achieved by the widest spacing tested (Roodbol and Hancke, 1997).

3.2.5 Vase life

Vase life is the primary limiting character of cut flower quality. The vase life of cut flowers varies according to pre-harvest irradiance and temperature conditions in the greenhouse (Mastalerz, 1987). Temperature is the dominant environmental factor which affects the life of flowers after harvest. It influences the rates of respiration, water absorption, and transpiration – the physiological processes that play major roles in the vase life of cut flowers. At harvest, accumulation of photosynthates in cut flower tissues stops for all practical purposes. Respiration, however, continues in all of the tissues of the cut flower, producing changes in the metabolism of the flower that eventually lead to senescence (Mastalerz, 1987).

Fairchild and Holley (1959) found that an increase in maximum daily temperature led to a decrease in vase life of carnations. Knappenberger *et al.* (1955) who also worked with carnations concluded that high irradiances on the day before harvest increased plant temperatures resulting in a reduced vase life. It is possible to explain this effect on the basis of the sugar content of cut flower tissues. At high temperatures and irradiances there is a reduction in the sugar reserves within the plants in order to maintain the high rates of respiration. Consequently, sugar levels in the flowers at harvest decrease, and the vase life is reduced (Mastalerz, 1987).

Cutting, general handling, and the placement of the stem in water after harvesting, creates favourable conditions for contamination by microorganisms (mainly bacteria), on cut surfaces and in the vase water (Larsen and Cromarty,

1967; Marousky, 1969). General research available on cut flowers is on the development of an occlusion in the stems by microorganisms, which include fungi and bacteria (Burdett, 1970; Gilman and Steponkus, 1972; Marousky, 1969; Parups and Molnar, 1972). The development of this occlusion is correlated with an increase in the number of bacteria at the cut surface and inside the stems (Van Doorn *et al.*, 1991). According to Ford *et al.* (1961), water and soil-borne bacteria are most commonly associated with cut flower wilting. Similar blockage of vascular tissues has also been observed in *Iris* (Mayak and Halevy, 1971), *Chrysanthemum* and in *Gerbera* stems (Put, 1990).

A minimum room temperature vase life of 5 to 6 days is required for commercial cultivars used for cut flower production (De Hertogh, 1977). Similar grading standards are applied to *Lachenalia* for cut flower purposes. In Chapter 2 the cut flower stages were identified and described i.e. 'first flower', 'full flower' and '50% wilt' and will be used as a guideline to monitor *Lachenalia* vase life. Cultivar differences with respect to vase life are well recognized and the genetic potential of each cultivar will be determined to identify long-lasting cut *Lachenalia* cultivars for future use as potential cut flowers.

The objective of this trial was to determine the effect of five different shade nets and two planting densities on plant growth and vase life, with the ultimate aim of establishing a cultivation practice most suitable for cut flower production in the Pretoria region.

3.3 Materials and Methods

The trial was conducted on the experimental farm of the University of Pretoria (25°45'S, 28°16'E, alt. 1372 m) in a summer rainfall region and received an average of ca 670 mm a^{-1} rain during the trial period (March to August). The monthly average maximum was 26.6 °C (March), minimum average was 4.3 °C.

Flowering size bulbs (4.5 cm in circumference and ± 1g each) of four *Lachenalia* cultivars (Romaud, Robyn, Rolina and Romelia) were obtained from the ARC-Roodeplaat Vegetable and Ornamental Plant Institute, after approximately four months of storage at 25 °C. Bulbs were planted on 1 March, at a low planting density (56 bulbs/m^2) or at a high planting density (111 bulbs/m^2) of 5 bulbs or 10 bulbs per 20 litre black plastic bag (30 cm diameter). The growing tips of the bulbs were planted 3-4 cm below the surface of the planting medium. The planting medium used in the trial consisted of pasteurized composted bark mixture. The bulbs were grown under five different shade nets (white18%, green 40%, black 40%, black 55%, black 70%) and in the open as a control. The temperature was measured on a weekly basis. The photosynthetically active radiation (PAR) was measured every two weeks at 12h00 on a cloudless day. Irrigation in combination with the water-soluble hydroponic fertilizer mix was kept constant and applied three times daily (08h00, 12h00, 17h00), by drip irrigation system.

Ten randomly selected primary inflorescences, as well as ten randomly selected secondary inflorescences were cut at the base and harvested when the oldest flower on the primary as well as the secondary inflorescences opened. Secondary inflorescences yielded a significant reduction in inflorescence stem length and flower number which is not suitable for cut flower production, thus further measurements were not taken. Four randomly selected primary inflorescences were placed in each water-filled glass vase. Glass vases were sterilized before the experiment. The inflorescences were then held in the glass vases in controlled temperature rooms at 22°C. The cabinets provided a 12 hr photoperiod with a light intensity of ±100 $\mu mol.m^2.s^{-1}$ PAR at plant level to simulate office conditions. Lighting was provided by WHO fluorescent tubes.

The following parameters were observed:

- Date when the first (oldest) flower of the primary inflorescence opened (first flower)

- Date when 80% of the flowers on the primary inflorescence were fully open (full-flower)
- Date when ½ of the 80% fully open primary inflorescence flowers wilted (50% wilt)
- Number of open flowers per inflorescence at full flower
- Inflorescence stem length (peduncle and rachis) (mm) at harvest
- Length of peduncle (mm) at harvest
- Length of rachis (mm) at harvest
- Peduncle diameter (mm) at harvest

From the previous mentioned observations, the following calculations were made:

- Date of full flower, subtracted by the date of first flower (vase life)
- Date of 50% wilt, subtracted by the date of full flower (vase life).

To determine why water uptake in cut *Lachenalias* becomes inhibited, ten primary inflorescence flower stems of cultivar Romelia were randomly chosen and harvested at the base from under 55% shade net, as soon as the oldest flower on the inflorescence opened. The flower stems were kept dry and brought to the laboratory within 2 hours of cutting. The stems were then placed in the vase solution (tap water), one stem per vase. Vases were not sterilized prior to the experiment. The vases holding the stems were subjected to the same conditions as above during storage. After day 6, scanning electron microscopy observations were made to determine the presence of bacteria.

Scanning electron microscopy (SEM):

Longitudinal stem segments, 10 mm in length, were fixed in 2.5% glutaraldehyde in a 0.075M $NaPO_4$ buffer (pH 7.4) for two hours. Dehydration was done in a series of ethanol:water dilutions comprising of 30, 50, 70, 90 and 100% ethanol. The 100% ethanol was changed three times. After dehydration, the material was

dried to the critical point in a Polaron critical point drier. The dried samples were mounted on aluminium stubs and made conductive by exposing them to vapour from a 0.5% RuO_4 solution (Van der Merwe and Peacock, 1999). Specimens were viewed with a JOEL 840 scanning electron microscope operated at 5 kV and images were recorded digitally.

After senescence of the tertiary inflorescences, which stayed on the plant, the leaves were harvested and measurements were taken. Leaf area was measured with a LI-COR Model 3100 leaf area meter. The bulbs were harvested by hand to prevent losses of small daughter bulbs and sampled. The daughter bulbs were removed from the mother bulbs, counted and weighed. Mother bulb fresh mass was then measured.

The experimental layout was a randomized block design with four replications. Data were analysed using the PROC G.L.M. (General Linear Models) procedure in SAS (Statisical Analysis System) program. Analysis of Variance was performed and Tukey's studentized range test (Steele and Torrie, 1980) was applied to compare treatment means.

3.4 Results and Discussion

Average photosynthetically active radiation (PAR) measurements and average minimum and maximum temperatures taken under five different shade nets and in the open as a control are shown in Figure 3.2 and Figure 3.3 respectively.

Figure 3.4 illustrates that in the control, a high PAR of about 1250 $\mu.mol.m^{-2}.s^{-1}$ resulted in the shortest inflorescence stem length of about 13 cm for all four cultivars. Compared to the control, the longest inflorescence stem length of about 24 cm was produced for cultivars Rolina and Romelia by a low PAR of 400 $\mu.mol.m^{-2}.s^{-1}$ under the black 70% shade net. The inflorescence stem lengths of

cultivars Romaud and Robyn under the black 70% shade net were about 20 cm and 17 cm respectively. Under the black 55% shade net, PAR levels of 450 $\mu.mol.m^{-2}.s^{-1}$ yielded inflorescence stem lengths of 19 cm for cultivar Romaud, 14 cm for cultivar Robyn and 22 cm for cultivars Rolina and Romelia. Intermediate PAR levels between 500 and 600 $\mu.mol.m^{-2}.s^{-1}$ under the white18%, green 40% and black 40% shade nets slightly reduced inflorescence stem lengths compared to the black 55% and black 70% shade net. According to Einert and Box (1966), shade densities of 50% (black) and 75% (black) increase the average stem length of *Lilium longiflorum*.

According to Yates (1986), photosynthesis rates of plants growing under green shade net might be lower than those of similar plants grown under black shade net with the same shade density. This was not the case for *Lachenalia* because overall plant growth performed better under the green 40% shade net compared to the black 40% shade net. Red light enhances stem elongation in plants (Moe, 1990) and the amount of red light transmitted through the green 40% shade net (62%) was higher than transmitted through the black 40% shade net (60%) (Van Rensburg, 2001). This could explain why inflorescence stem length was higher under the green 40% shade net, compared to the black 40% shade net. Moe (1990) also observed that there are peaks in the blue and red bands where photosynthetic activity is higher. Under the black 70% shade net the peaks in the blue and red bands seemed to be at the optimum level required for optimum inflorescence stem growth, since the inflorescence stem length of cultivars Romaud and Rolina was significantly the highest under the black 70% shade net compared to the rest of the shade treatments and the control. Cultivars Robyn and Romelia showed interactions with the rest of the shade treatments, but inflorescence stem length was still the highest under the black 70% shade net.

Leaf length (Figure 3.5) and leaf area (Figure 3.6) of the four cultivars had the same response to the spectral distribution (light quality) under the different shade treatments as inflorescence stem length (Figure 3.4). Leaf length (Figure 3.5)

and leaf area (Figure 3.6) was always slightly higher under the green 40% shade net, than under the black 40% shade net. Probably due to the amount of red light transmitted through the respective shade nets as mentioned previously. Under the black 70% shade net, leaf length (Figure 3.5) and leaf area (Figure 3.6) was significantly higher for all four cultivars compared to the control.

Increase in stem length may most probably relate to changes in the concentrations of plant hormones, which are affected by light quality (Holmes and Smith, 1977; Smith, 1982). According to Reid *et al.* (1990), light-quality-controlled stem elongation may be mediated by gibberellins, as this plant growth regulator is involved in the control of stem elongation. Reid *et al.* (1968) demonstrated in several plant species that red light influences gibberellin metabolism. Lockhart (1961) showed that the inhibition of growth in full sunlight is removed by the application of gibberellic acid. He proposed that the gibberellin relieved the red-light inhibition of growth and that the differences in the light-response may be related to the endogenous gibberellin contents. The effect of gibberellic acid (GA_3) on *Lachenalia* bulb growth and yield will be mentioned in Chapter 5.

By comparing temperature under the different shade nets (Figure 3.3) to the growth response of inflorescence stem length (Figure 3.4), it can be seen that the inflorescence stem length of all four *Lachenalia* cultivars tends to decrease to a minimum of 13 cm when average temperatures are over 30ºC in the control and increase to a maximum of 24 cm under the black 70% shade net, when temperatures are in the range from 24ºC to 27ºC.

The prevailing temperature regimes under the black 40% and black 55% shade nets were similar (Figure 3.3). The average increase in inflorescence stem length of about 2 cm for cultivars Romaud, Rolina and Romelia under the black 55% shade net compared to those under the black 40% shade net (Figure 3.4), was probably because of reduced PAR levels (Figure 3.2). Hence, increased

competition for light probably resulted in an overall increase in inflorescence stem length under the black 55% shade net. The slight increase in inflorescence stem length under the green 40% shade net compared to the black 40% shade net could be attributed mainly due to differences in the spectral distribution, as mentioned previously, because prevailing temperature regimes under the two shade nets were similar.

According to Kinet *et al.* (1985), high temperatures reduce final flower size compared to low temperatures. In Figure 3.7 the single flowers were visibly smaller in the control where high average temperatures of 30ºC and over prevailed, compared to the flowers grown at reduced temperatures under the low-density shade nets. Light intensity could also have an effect on flower size, although further research is required to confirm this. According to Catley *et al.* (2002), lantern-shaped *Sandersonia* flowers on short pedicels are most desirable by the commercial flower industry. When the ratio of the widest to the narrowest diameters of a flower, termed the ratio of hips to waist, is 1.5 or greater, the shape of the flower becomes more lantern-shaped. *Sandersonia* flower shape and pedicel length were strongly influenced by temperature and irradiance, with absolute mean temperatures having the greatest effect. The lower the mean temperature, the more lantern-shaped the flowers are. Further studies to determine the effect of irradiance and temperature on *Lachenalia* flower shape and pedicel length are required.

When plants are exposed to high levels of irradiance, leaf temperature rises and net photosynthesis may decrease, because greater amounts of carbohydrates are utilized in respiration than are produced from a higher rate of photosynthesis (Mastalerz, 1987). This leads to a reduction of photosynthates available for general plant growth and thus plant height is reduced. Leaf length (Figure 3.5) and leaf area (Figure 3.6) was reduced to a large extent at a high PAR level of 1250 $\mu.mol.m^{-2}.s^{-1}$ (control) compared to the rest of the shade net treatments, probably due to reduced rates of photosynthesis caused by high leaf

temperatures. Leaf length and leaf area per plant was greatest at 25ºC - 30ºC and PAR levels of 400-600 $\mu.mol.m^{-2}.s^{-1}$ under the green 40% and black 70% shade nets.

Leaf area may also play a regulatory role in determining the final bulb size. If a larger leaf area is available on the plant, an increased supply of carbohydrates is produced to be stored in the bulb and the use of reserve carbohydrates will be less. This in turn leads to the development of a larger bulb. The importance of leaf area on tuber growth was highlighted by Clark and Reyngoud (1997), who found that *Sandersonia* tuber size was greater for stems left with three leaves than stems left with only one leaf on.

According to Mastalerz (1987), a high irradiance decreases plant height but increases stem diameter. Also plants grown in the shade or at reduced irradiance are taller and have thinner stems. The different levels of shading did not significantly affect the number of flowers or peduncle diameter for *Lachenalia*. This is probably because the number of flowers produced is determined by the previous growing season and that the peduncle diameter of *Lachenalia* cultivars is cultivar dependent.

According to Du Toit (2002), inflorescence abortion occurs when *Lachenalia* bulbs are exposed to a high temperature regime. In this trial, flower abortion was observed in the control (Figure 3.8). Average temperatures ranged from 31°C to 36°C in the control and may have led to the abortion of some of the inflorescences. De Hertogh and Le Nard (1993) support the concept that high temperature regimes have a negative effect on inflorescence quality.

Low temperatures are necessary to accumulate carbohydrates for growth (Mastalerz, 1987). According to Hewitt and Curtis (1948), translocation rates increase with temperatures ranging between 20ºC and 30ºC. Maximum daily temperatures under the white 18%, green 40%, black 40%, black 55% and black

70% shade nets, were between 20ºC and 30ºC (Figure 3.3). These temperatures probably stimulated transport of assimilates, thereby promoting growth and development of the sinks, i.e. flower stems and bulbs.

In the control, mother bulb fresh mass (Figure 3.9) and total daughter bulb fresh mass (Figure 3.10), for all four cultivars, decreased to a large extent when compared to the rest of the shade nets. Du Toit (2002) observed that the fresh mass of bulbs exposed to high temperature was reduced when compared with bulbs exposed to low and medium temperatures. The number of daughter bulbs produced, varied between the different shade net treatments (Figure 3.11). According to Du Toit (2002), no significant differences were found between the number of daughter bulbs formed by mother bulbs exposed to the low, medium and high temperature regimes. However

Creating low irradiance by providing shade is an effective means of increasing stem length, but shading from neighbouring plants at high planting density results in an additional response from plants. Plants normally react to mutual shading by increasing their height. Roodbol and Hancke (1997) have observed that cuttings of *Lachenalia* plants grown at a low light intensity produced more daughter bulbs.

Competition for light and root-volume as a result of high-density planting has been known to cause flower abortion in geophytes due to a shortage of nutrients and carbohydrates (De Hertogh and Le Nard, 1993). A shortage of nutrients could possibly not have been a determining factor in *Lachenalia* growth and development under high-density planting, due to a daily supply of nutrients supplied via the fertigation system.

A definite response to low and high planting densities was observed for all four *Lachenalia* cultivars. Inflorescence stem length increased significantly by about 2.5 cm at the high planting density compared to the low planting density for all

four cultivars (Figure 3.4). A significant increase in leaf length (Figure 3.5) and leaf area (Figure 3.6) at the high planting density was also observed for all four cultivars. This growth response is as a result of increased competition for light. As the supply of excess photosynthates produced by the leaves is utilized for increased leaf and stem growth (Mastalerz, 1987), fewer assimilates possibly become available for transport to the mother and daughter bulbs. This may result in a decrease in mother bulb fresh mass (Figure 3.9) and total daughter bulb fresh mass (Figure 3.10) at the high planting density compared to those of the low planting density.

According to Timmer and Van der Valk (1973) and Rees and Turquand (1969), the planting density of tulips has a distinct effect on the number of daughter bulbs produced during the growing season. The number of daughter bulbs produced decreased with increasing planting density. Also in *Sandersonia aurantiaca* tuber production, tuber weights and secondary tubers decreased with increasing planting density (Clark and Burge, 1997; 2000). Similar observations were made for *Lachenalia* cultivars in this trial (Figure 3.11). The difference in the number of daughter bulbs produced between the four cultivars is primarily genetic. The planting density did not significantly affect the number of flowers, because this is most probably determined by conditions during the previous growing season and the dormancy period. The peduncle diameter of *Lachenalia* cultivars could also be cultivar dependent.

Figure 3.12 illustrates that a vase life of 8 to 10 days was observed for cultivar Romaud in the control and under all the shade net treatments. Cultivar Robyn had a vase life of 9 to 11 days, with no significant differences between the shade net treatments. The longest significant vase life of 12 to 14 days and 14 to 16 days under the green 40% and black 40% shade nets was observed for cultivars Rolina and Romelia respectively, compared to 10 to 11 days and 12 to 14 days in the control.

At the high planting density, vase life of all four *Lachenalia* cultivars increased significantly by 2 days compared to the low planting density (Figure 3.12). According to Mastalerz (1987), increased competition for light occurs at a high planting density. The excess supply of photosynthates produced by the leaves is utilized for increased leaf and stem growth. Also an increased supply of assimilates results in a higher level of available sugar in the cut flower tissues which probably resulted in an increased vase life at the high planting density compared to the low planting density.

According to Fairchild and Holley (1959) and Knappenberger *et al.* (1955), who worked with carnations, an increase in maximum daily temperature and high irradiances on the day previous to harvest, leads to a decrease in vase life. It is possible to explain this effect based on the sugar content of cut flower tissues. At high temperatures and irradiances there is a reduction in the sugar reserves within the plants and as a result, sugar levels in the flowers at harvest are decreased (Boodley, 1998). Respiration, however, continues in all of the tissues of the cut flower, producing changes in the metabolism of the flower that eventually lead to early flower senescence, thus resulting in a reduced vase life (Mastalerz, 1987).

The prevailing conditions shortly before harvest have a decided effect on the vase life. The vase life of all four cultivars was the shortest for flowers harvested from the control. This is because PAR levels were in the range of 1250 $\mu.mol.m^{-2}.s^{-1}$ (Figure 3.2) and maximum daily temperatures were about 31°C (Figure 3.3) on the day before harvest. These high temperature and irradiance conditions probably led to a vast reduction in the sugar reserves within the plants and hence a reduced vase life. The longest vase life for cultivars Rolina and Romelia was observed under the green 40% and black 40% shade nets. Temperature and irradiance levels were lower under these shade nets, therefore respiration rates were probably reduced and a greater amount of photosynthates may have been present in cut flower tissues to increase vase life. When counting the number of

days from flowering to first flower i.e. when inflorescence stems are ready to be harvested, no significant difference between the different shade treatments was observed.

A film of bacteria was visible on the cut surface of *Lachenalia* stems with the aid of scanning electron microscope studies, when stems were held in water for 6 days (Figure 3.13 a and b). Bacteria were also observed in the phloem and xylem vessels (Figure 3.13 c and d). The bacteria are embedded in a layer containing granular material. Fungal hyphae were scattered throughout the parenchyma of cut surface cells (Figure 3.14 a and b), which probably contribute to a reduced vase life. The bacteria were mainly restricted to the basal part of the stem, which is similar to the observation made by Van Doorn (1995). According to Van Doorn *et al.* (1991), bacteria are apparently unable to pass through the inter-vessel pits, and therefore remain in the pits that have been opened physically, e.g. by cutting.

Aarts (1957) confirmed the presence of slimy accumulations of bacteria on the cut surface of flower stems which act directly on cut flowers by physically blocking the pores in the pit membranes e.g. living and dead bacteria, bacterial slime and indirectly by producing substances that are absorbed by the flowers e.g. degradation products from dead bacteria. Together with these observations, the presence of bacteria inside the xylem vessels of *Lachenalia* cultivar Romelia, may at least partially explain why water uptake in cut lachenalias becomes inhibited leading to a reduced vase life.

3.5 Conclusion

From this study, recommendations can be made about the temperature and irradiance environment required for producing high quality inflorescence stems for cut lachenalia flower production. The longest inflorescence stems of 24 cm

was produced for cultivars Rolina and Romelia by a low PAR of 400 $\mu.mol.m^{-2}.s^{-1}$ and temperatures ranging between 20ºC and 30ºC under the black 70% shade net. The second best inflorescence stem length of 22cm for cultivars Rolina and Romelia was produced under the green 40% shade net. At temperatures higher than 30ºC there is a high risk of flower abortion. The best results for increased inflorescence stem length was obtained at the high planting density under black 70% shade net for cultivar Romelia, with a vase life of 14 to 16 days.

The cut flower grower should make the ultimate choice on which shade net to use, depending on the cultivar he intends to grow and local climate conditions. Black 70% shade net may be suitable for cut lachenalia flower production in the Pretoria region, but a lower shade density of 55% will most probably be best suited for cut lachenalia flower production in Stellenbosch. This is mainly because of a reduction in irradiance levels reaching the surface of the earth.

For the commercial *Lachenalia* cut flower grower, postharvest characteristics resulting in a short vase life must be controlled. The main prerequisite for a long vase life is an undisturbed water uptake. Bacteria were observed in the xylem vessels of *Lachenalia* cultivar Romelia, which could possibly be involved in the obstruction processes inhibiting water uptake. To increase vase life, the addition of a bacteriostatic agent to the vase water should be considered.

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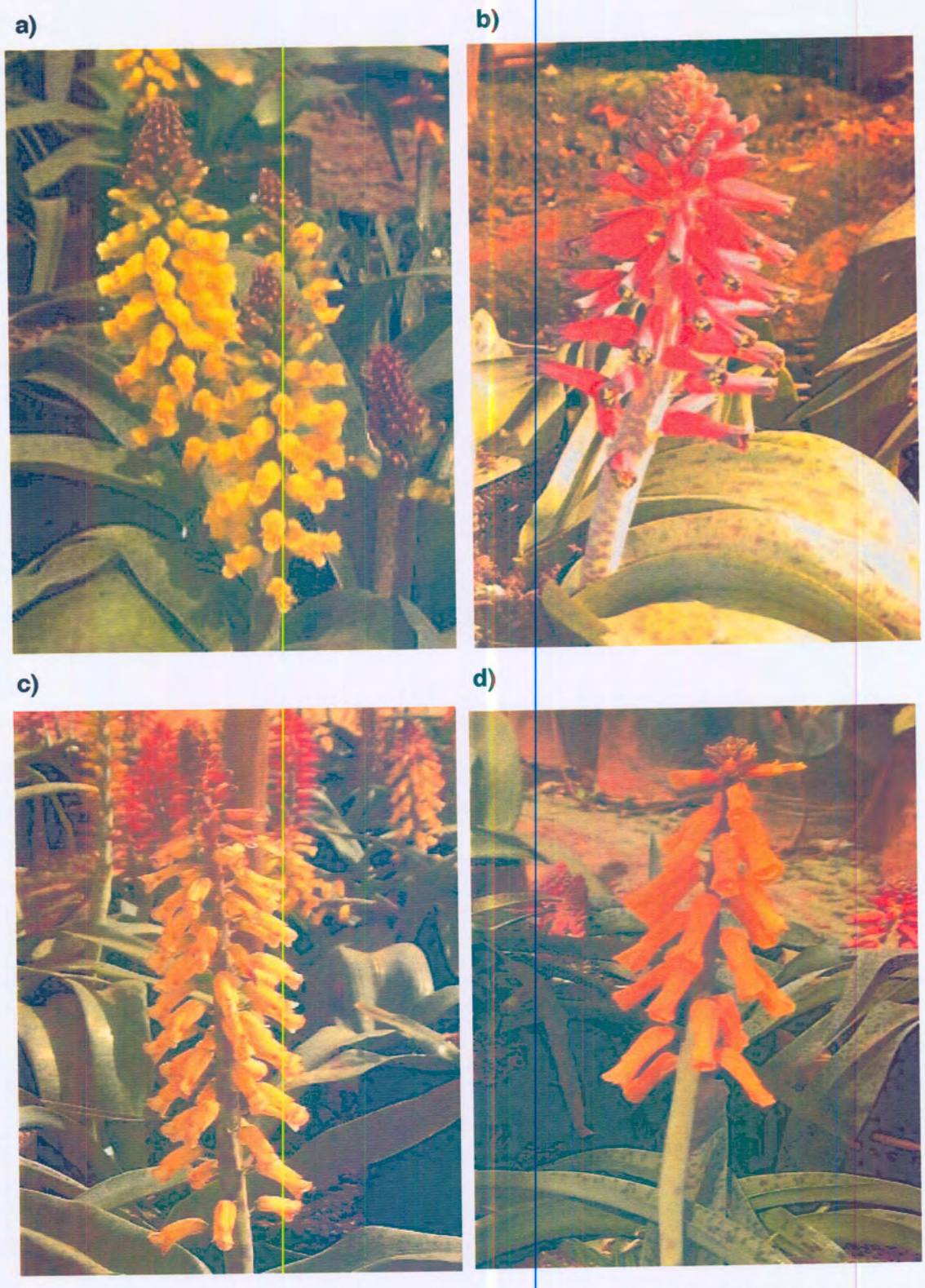

Figure 3.1 Photographical illustration of cultivar Romaud (a), Robyn (b), Rolina (c) and Romelia (d).

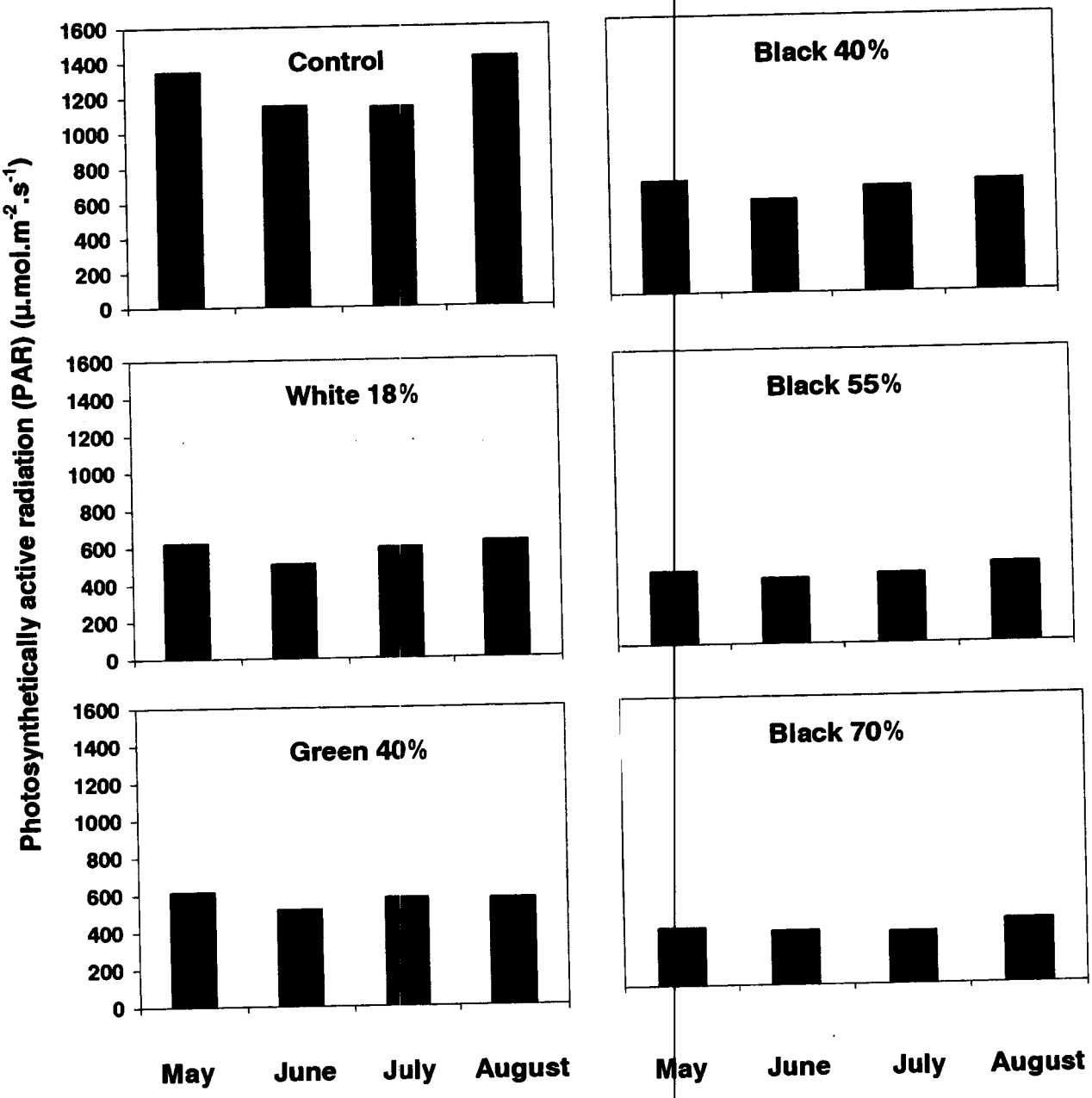

Figure 3.2 Average photosynthetic active radiation (PAR) measurements taken under five different shade nets and in the open as a control in the first season.

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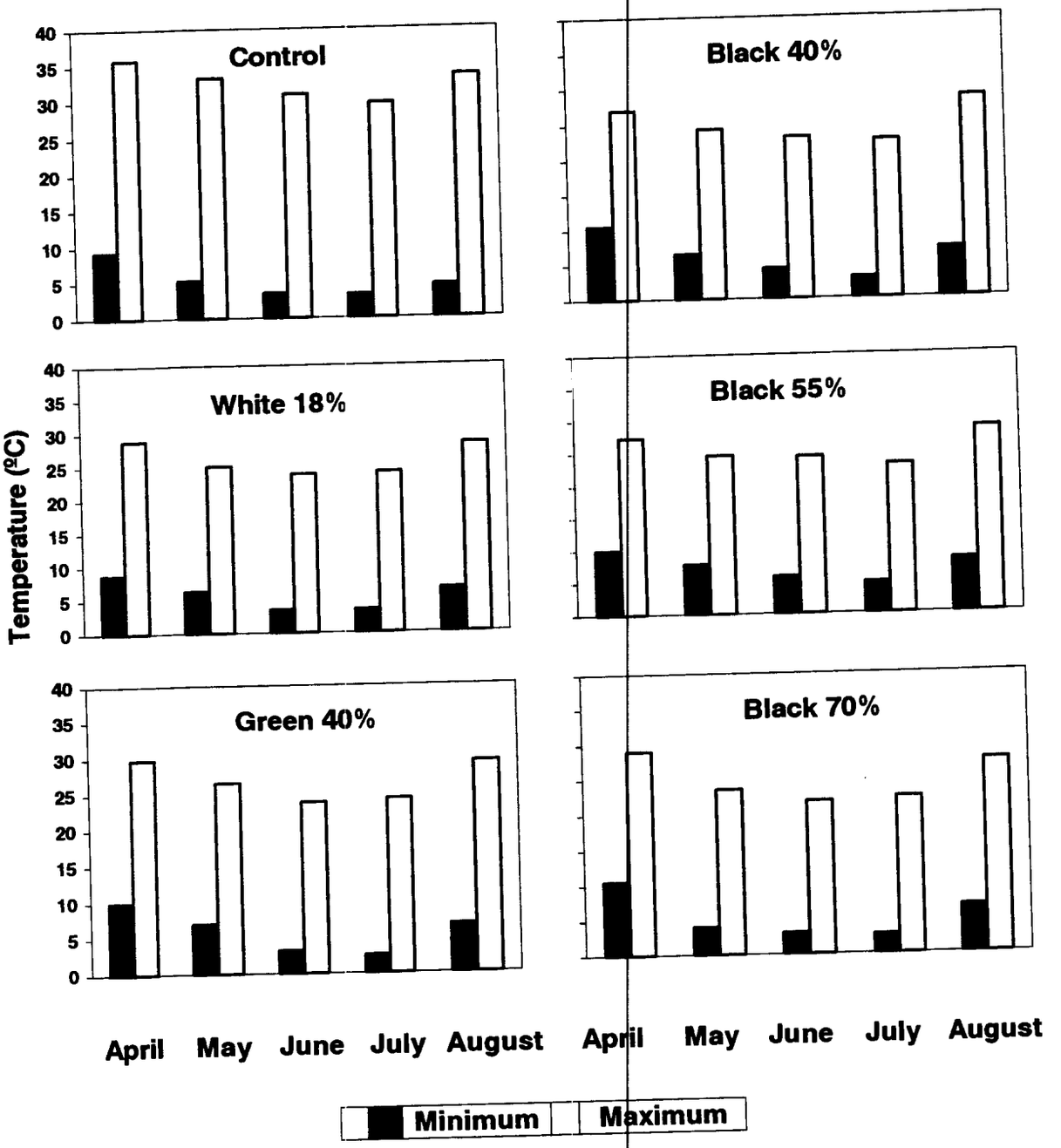

Figure 3.3 Average minimum and maximum temperature measurements taken under five different shade nets and in the open as a control in the first season.

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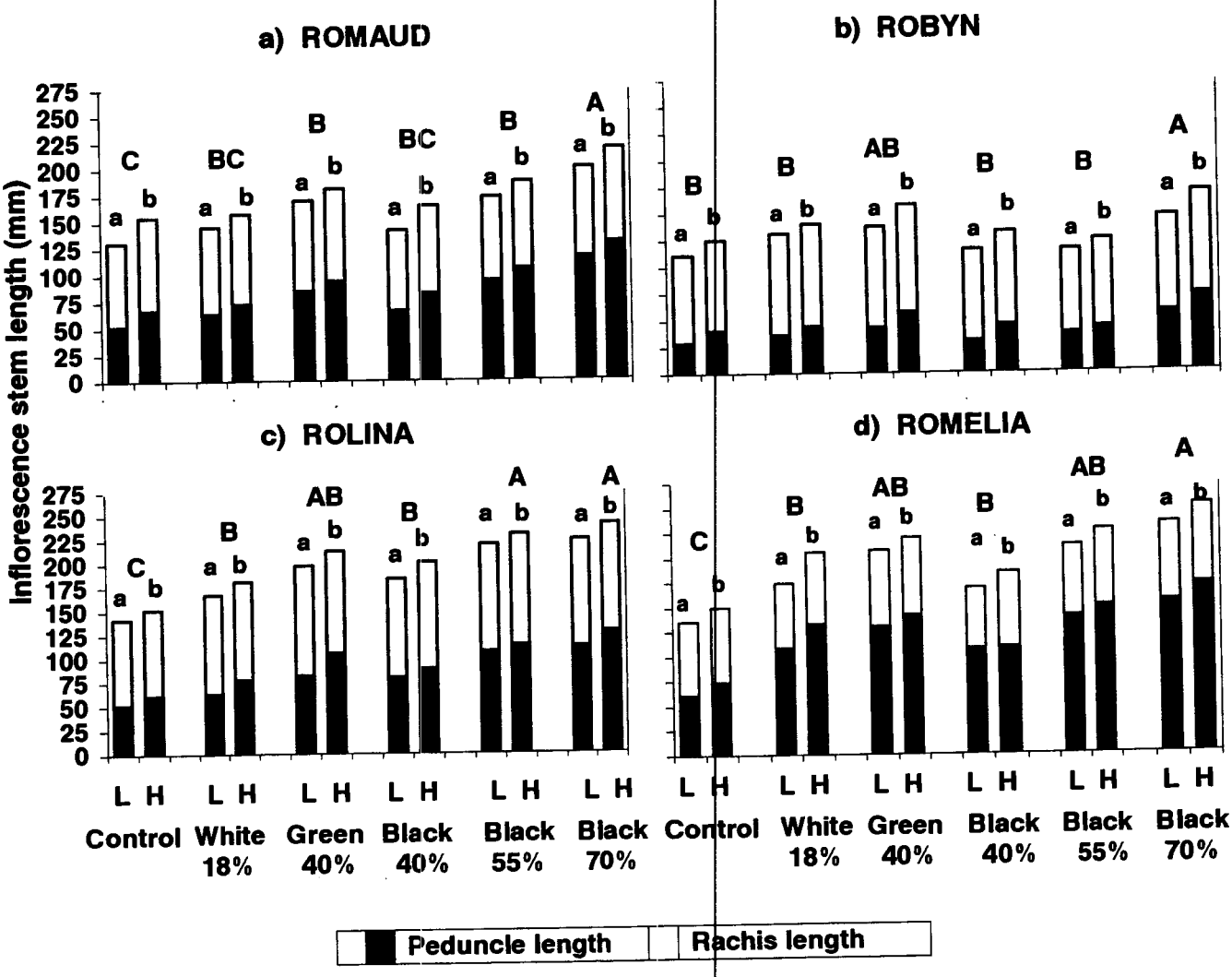

L = Low planting density H = High planting density

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 3.4 Effect of a low and high planting density on inflorescence stem length of four *Lachenalia* cultivars grown under five different shade nets and in the open as a control.

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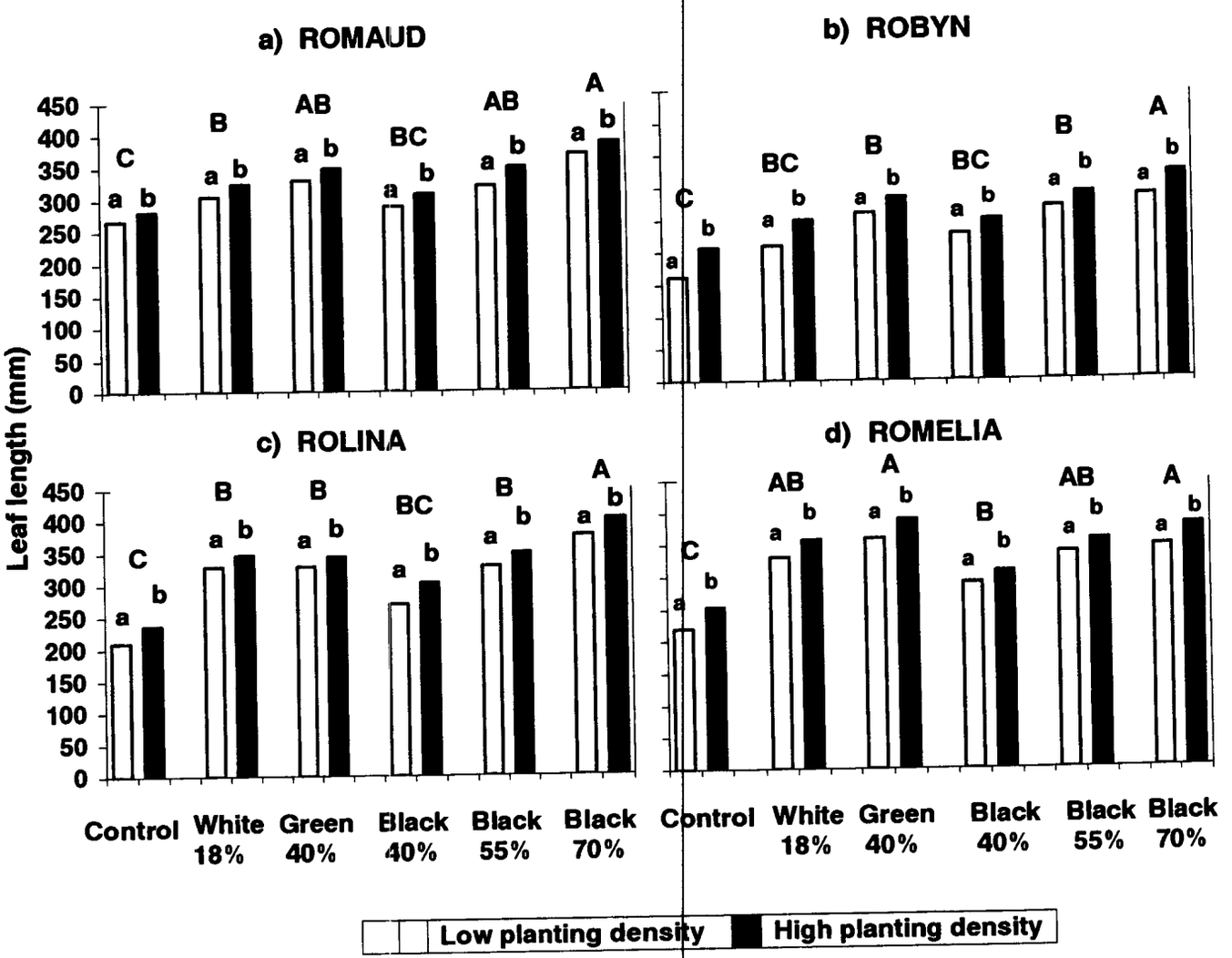

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 3.5 Effect of a low and high planting density on leaf length of four *Lachenalia* cultivars grown under five different shade nets and in the open as a control.

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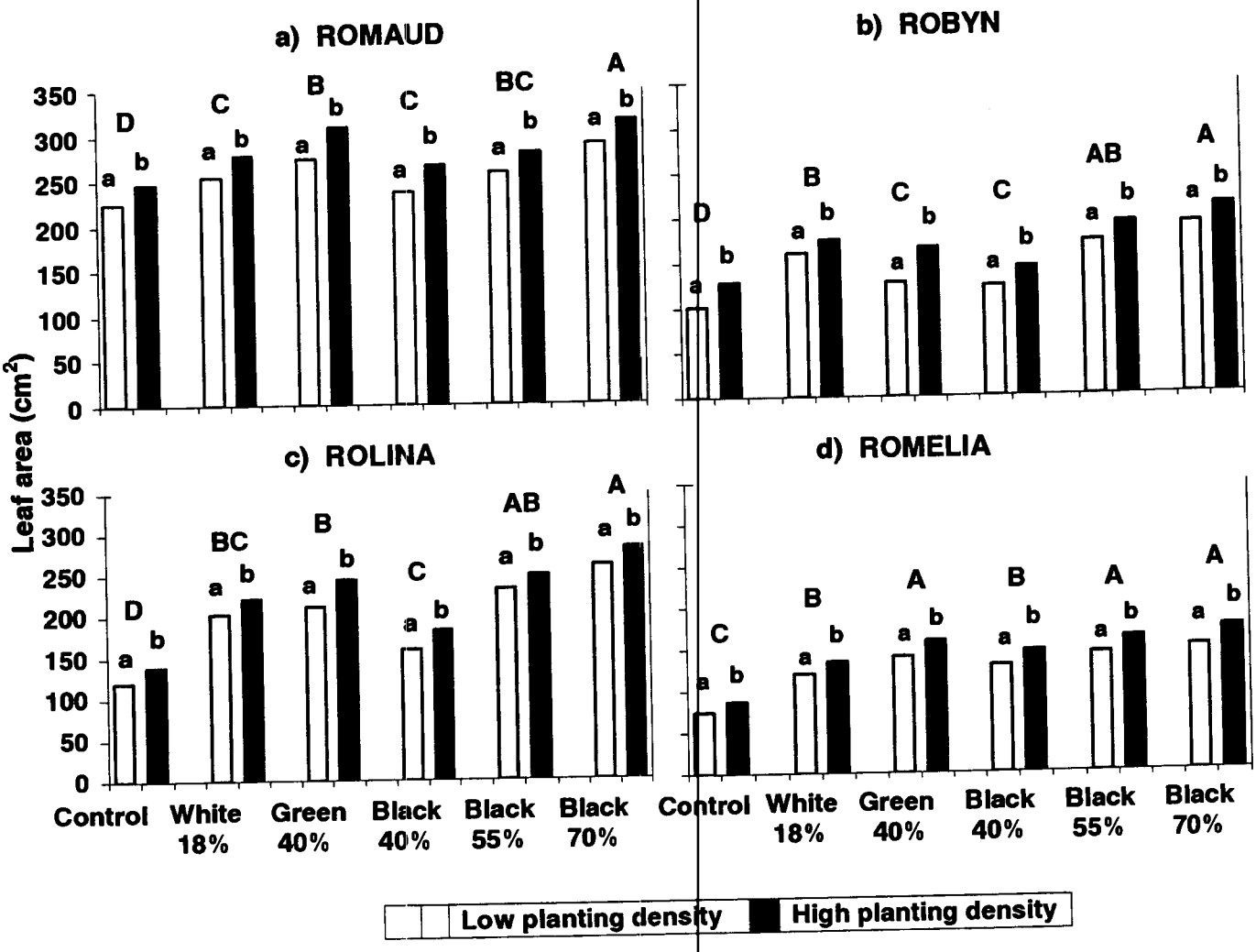

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 3.6 Effect of a low and high planting density on leaf area of four *Lachenalia* cultivars grown under five different shade nets and in the open as a control.

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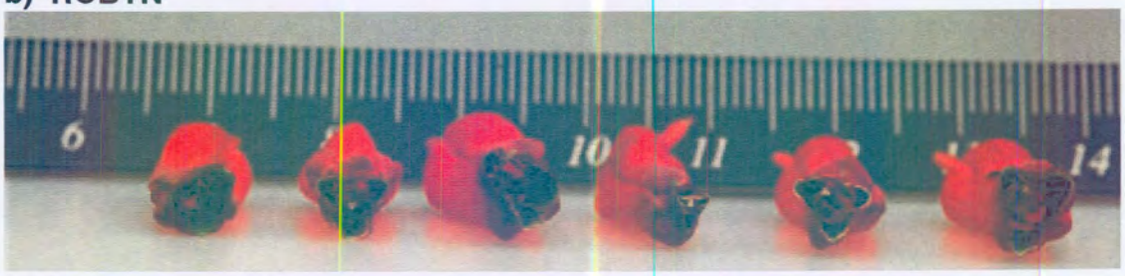
a) ROMAUD

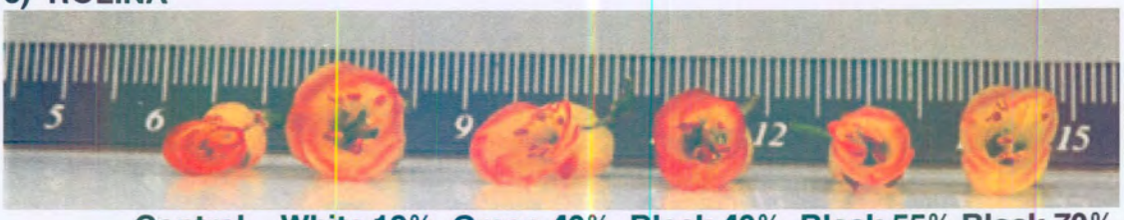
Control White 18% Green 40% Black 40% Black 55% Black 70%

b) ROBYN



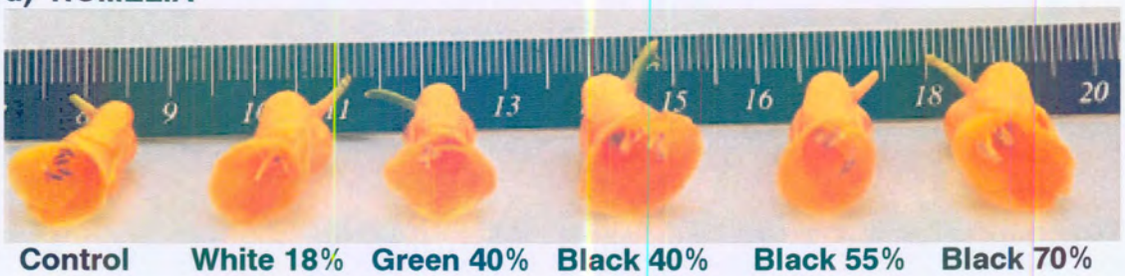
Control White 18% Green 40% Black 40% Black 55% Black 70%

c) ROLINA



Control White 18% Green 40% Black 40% Black 55% Black 70%

d) ROMELIA



Control White 18% Green 40% Black 40% Black 55% Black 70%

Figure 3.7 Photographical illustration of the effect of different temperature regimes and possibly light intensities under five different shade nets and in the open as a control, on the flower appearance of *Lachenalia* cultivars Romaud (a), Robyn (b), Rolina (c) and Romelia (d).

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Figure 3.8 Photographical illustration of inflorescence deformities in *Lachenalia* cultivar Romaud.

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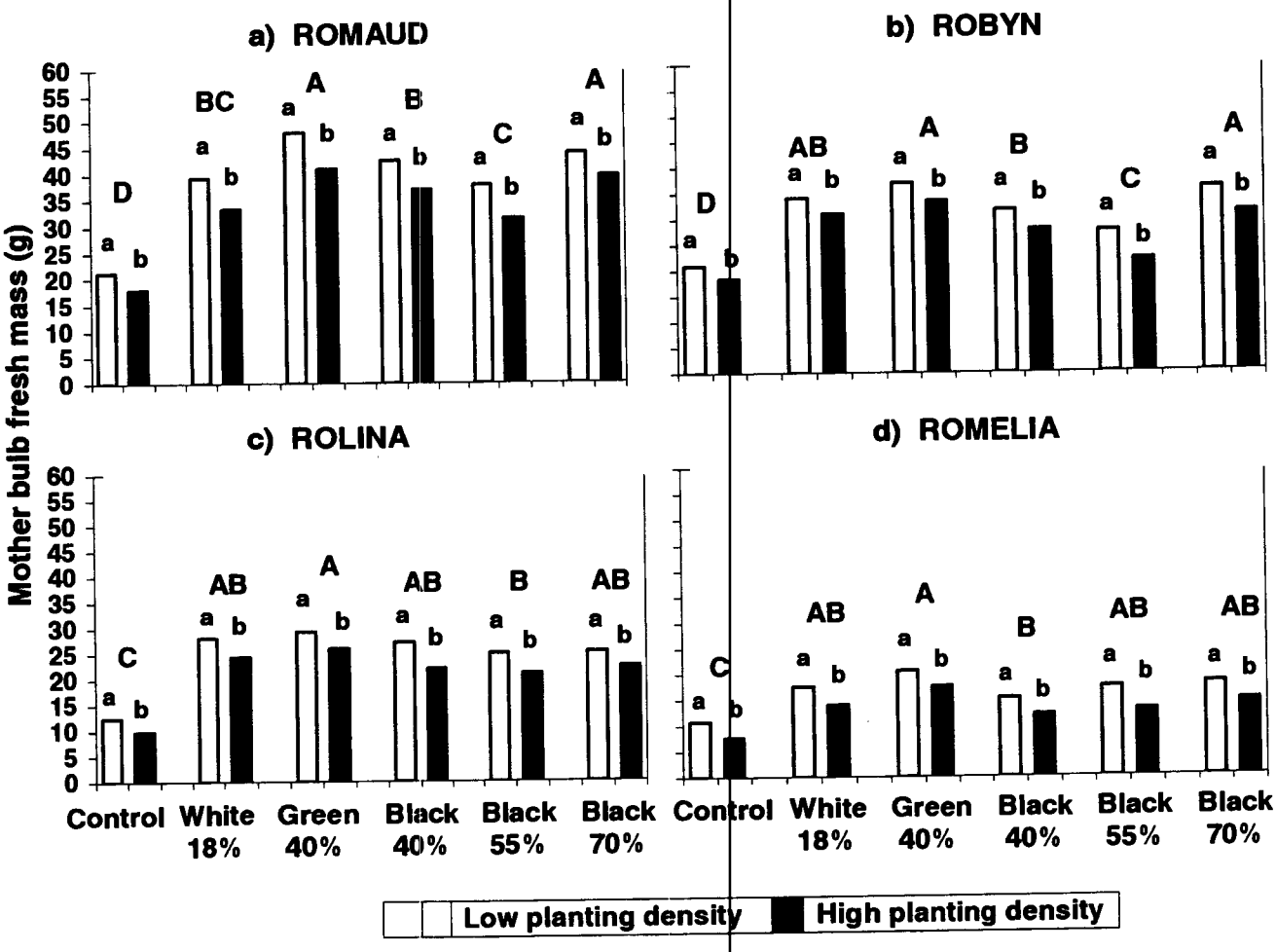

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 3.9 Effect of a low and high planting density on mother bulb fresh mass of four *Lachenalia* cultivars grown under five different shade nets and in the open as a control.

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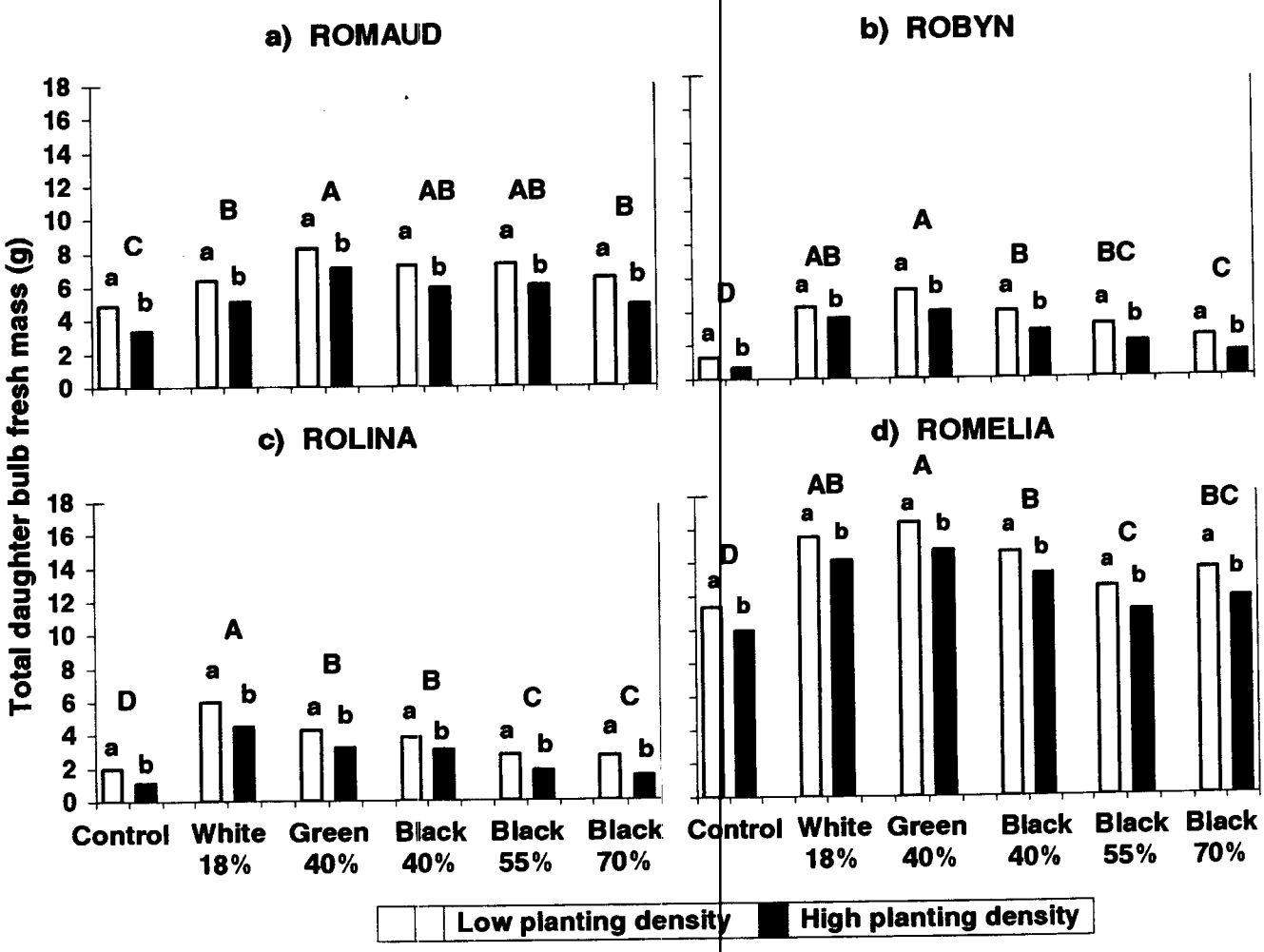

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 3.10 Effect of a low and high planting density on total daughter bulb fresh mass of four *Lachenalia* cultivars grown under five different shade nets and in the open as a control.

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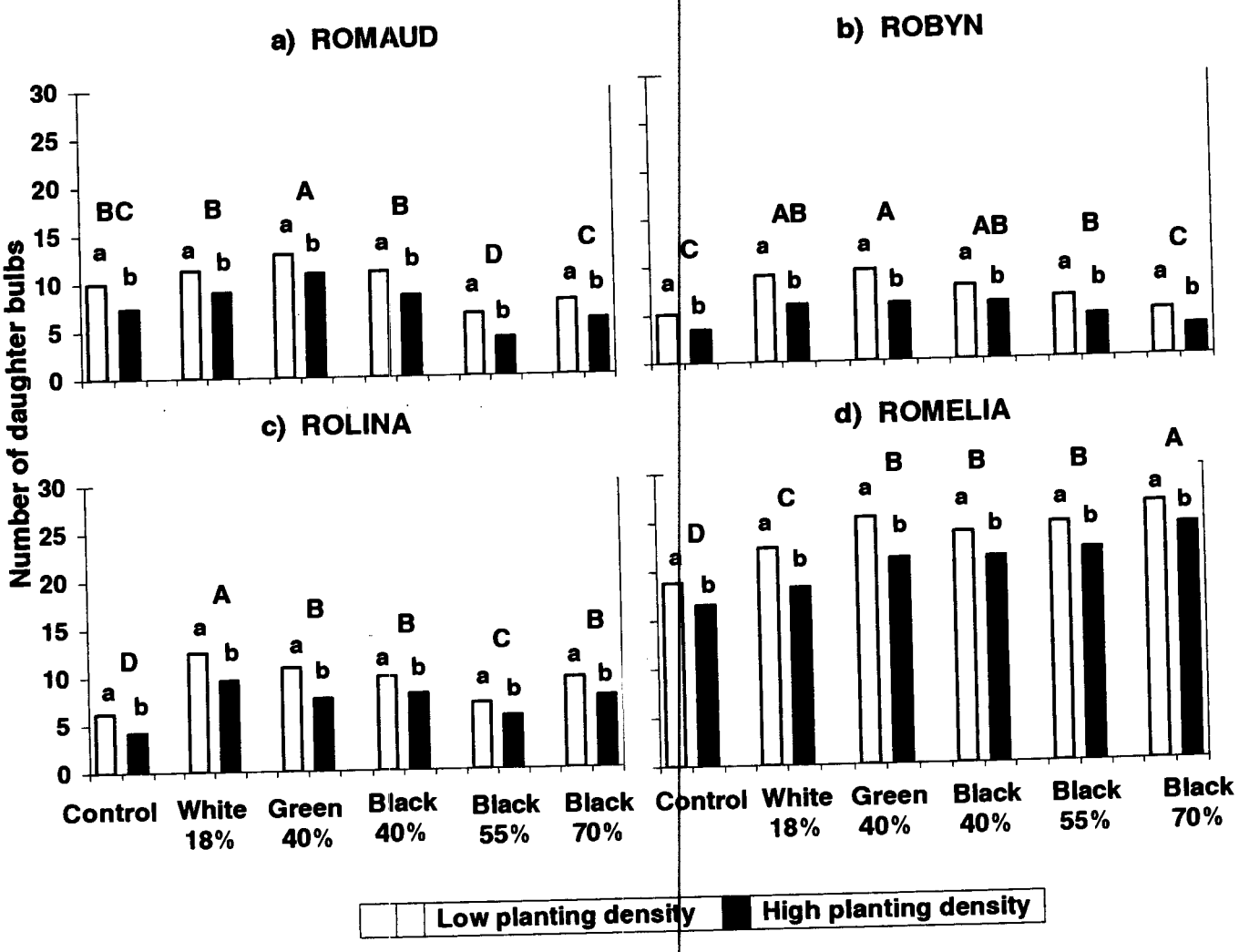

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 3.11 Effect of a low and high planting density on number of daughter bulbs of four *Lachenalia* cultivars grown under five different shade nets and in the open as a control.

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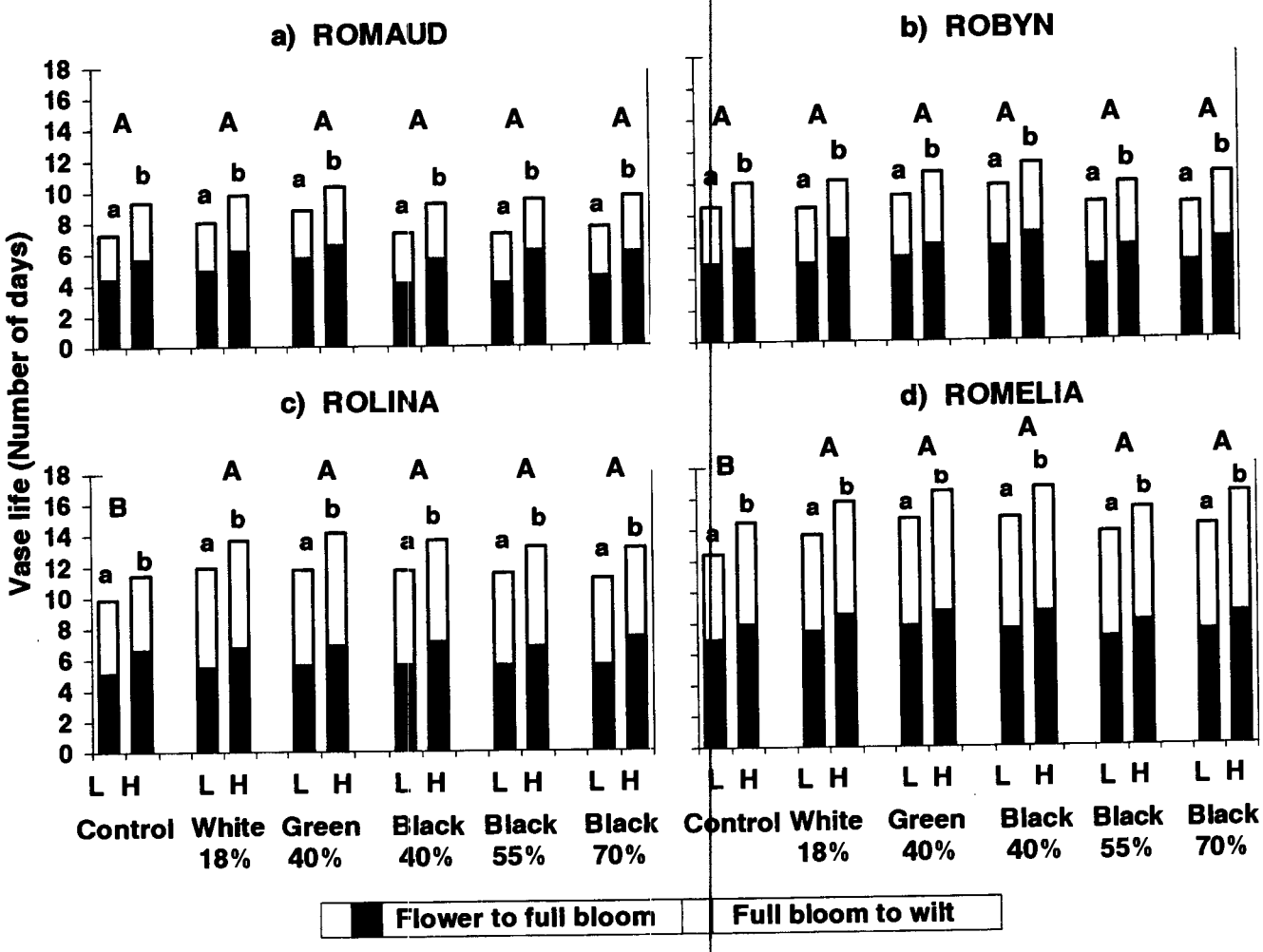

L = Low planting density H = High planting density

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 3.12 Effect of a low and high planting density on the vase life of four *Lachenalia* cultivars grown under five different shade nets and in the open as a control.

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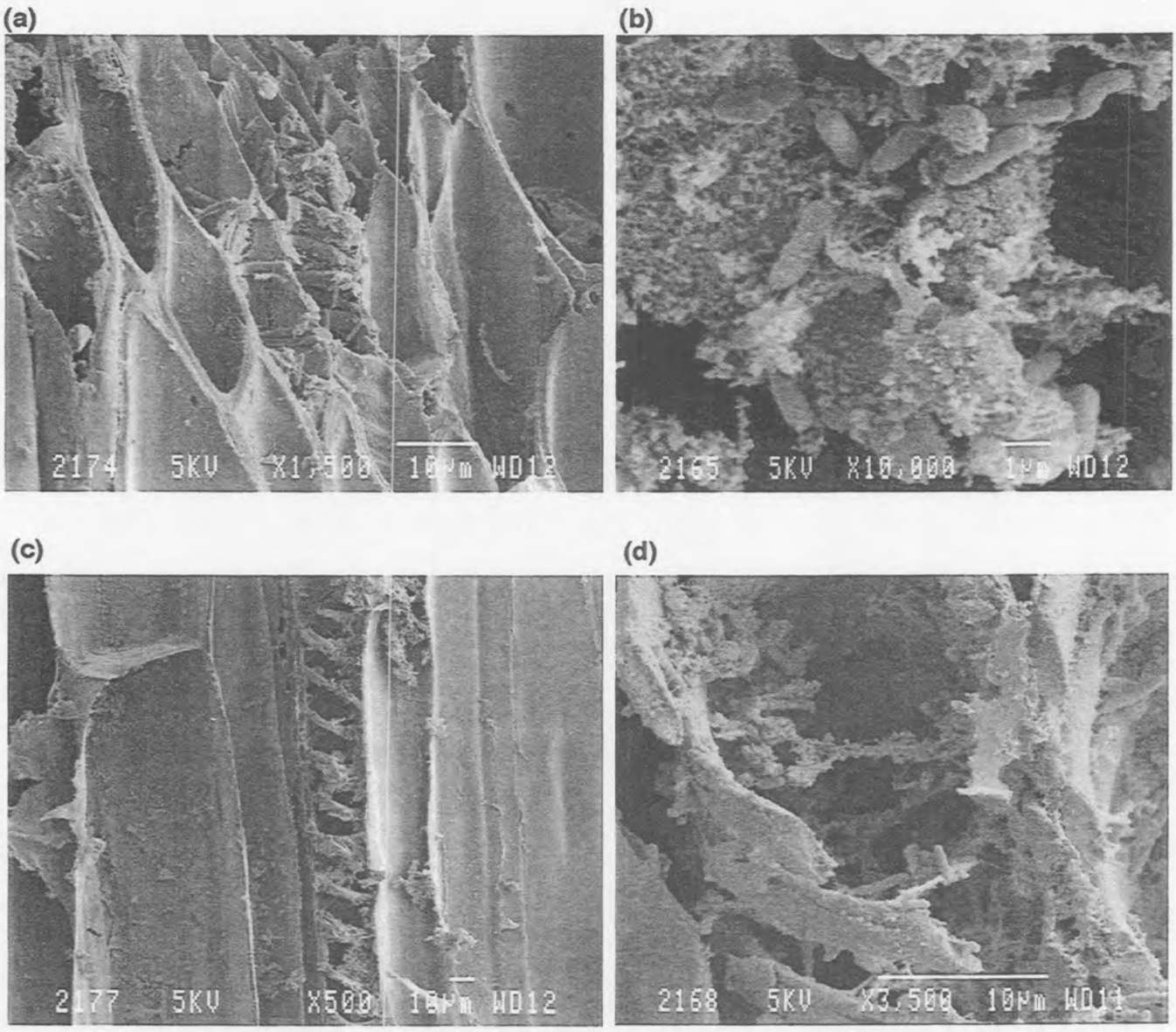

Figure 3.13 (a) – (d). Scanning electron micrographs of critical point dried surfaces near the base of the stem of *Lachenalia* cultivar Romelia. (a), (b) Detail of the cut surface of a stem held in water for 6 days. (c), (d) Bacteria in a xylem vessel of a stem held in water for 6 days. Scale bar = 10 µm

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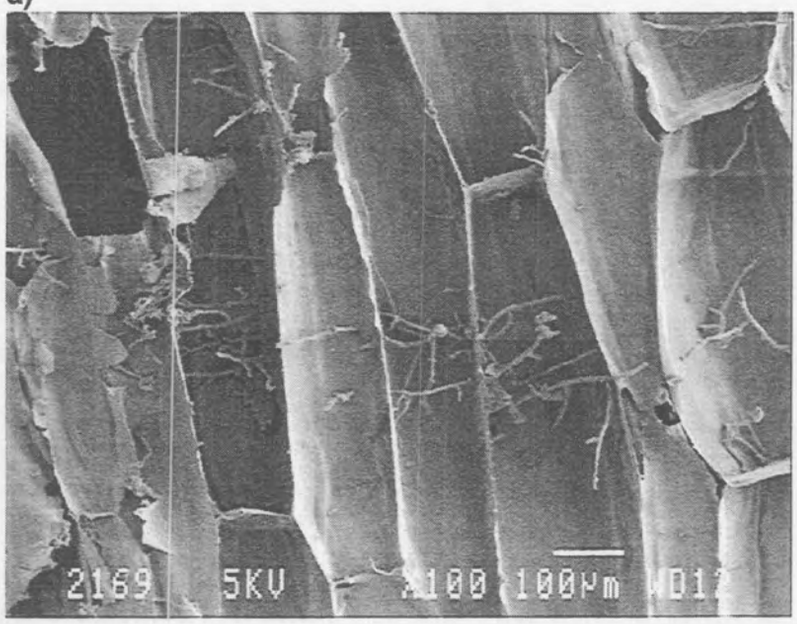
a)



b)

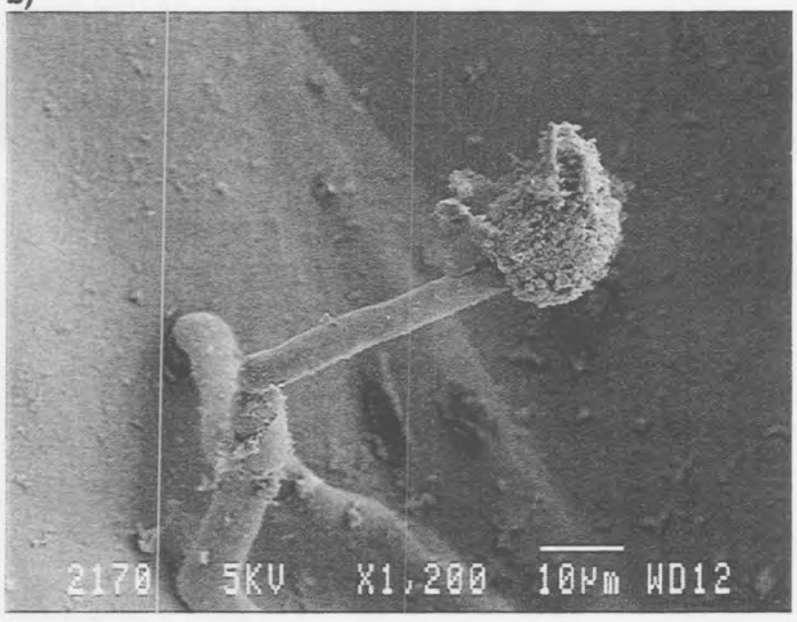


Figure 3.14 (a) Fungal hyphae-like material in parenchyma cells from a stem of *Lachenalia* cultivar Romelia, held in water for 6 days. Bar = 100 µm (b) High magnification of fungal hyphae. Scale bar = 10 µm

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CHAPTER 4

THE EFFECT OF HIGH AND LOW IRRADIANCE ON LEAF ANATOMY OF *LACHENALIA* cvs Romaud AND Romelia

4.1 Summary

Lachenalia cultivars Romaud and Romelia, which were chosen because they are early flowering cultivars compared to cultivars Robyn and Rolina, were exposed to full sunlight and 40% shade. Leaf structure was examined by light-, transmission- and scanning electron microscopy. Visual observations determined that leaves exposed to full sunlight illustrated a higher chloroplast number, a higher number of stomata and greater wax development than leaves exposed to 40% shade. There was no difference in the *Lachenalia* leaf structure between the black 40% and green 40% shade nets. Leaves exposed to 40% shade had more organized thylakoids/granum than those of leaves exposed to full sunlight.

4.2 Introduction

Plant growth is affected by environmental variation in light, temperature, water availability, minerals and other factors. Extreme variation in any of these factors may lead to stress. Light conditions are an important determinant of phenotypic plasticity. The photosynthetic apparatus tends to adjust to the specific environment so that the available light energy is utilized most efficiently. Difference in the morphology and anatomy of leaves grown at different irradiances are good examples of such plasticity (Wild and Wolf, 1980).

The modification of leaf anatomy and morphology as a response to light has been reported for various species (Bjorkman and Holmgren, 1963). Wassink *et al.* (1956) demonstrated that the adaptability to irradiance is obtained only during the growth period of the leaf; after the leaf has matured there is no further adaptation. Full sunlight (high irradiance) and shade (low irradiance) are the two extremes, where the basic growth responses of leaves are best seen (Baker *et al.*, 1985). Leaves exposed to full sunlight are often characterized by a higher stomata density (Wild and Wolf, 1980) and higher chloroplast numbers (Esau, 1965). Low irradiance increases the number of thylakoids/granum in chloroplasts in order to maximize solar energy absorption (Ballantine and Forde, 1970; Boardman, 1977; Lichtenthaler *et al.*, 1981).

The objective of this study was to visually observe differences in the leaf anatomy of *Lachenalia* cultivars Romaud and Romelia exposed to full sunlight and 40% shade.

4.3 Materials and Methods

Fresh leaf material from *Lachenalia* cultivars Romaud and Romelia was collected on the Hatfield experimental farm of the University of Pretoria. The plants were grown at a monthly average maximum of 26.6 °C (March) and a minimum average of 4.3 °C. Irrigation in combination with the water-soluble hydroponic fertilizer mix was kept constant and applied three times daily (08h00, 12h00, 17h00), by a drip irrigation system. Mature leaves were randomly selected from the plants grown in full sunlight and 40% shade after the tertiary inflorescences had senesced.

Light transmitting microscopy (LTM):

Sections of 1mm by 1mm, excised from the middle of the adaxial side of the lamina between the mid rib and leaf margin were fixed in 2.5% glutaraldehyde in a 0.075M $NaPO_4$ buffer (pH 7.4) for two hours. Glutaraldehyde fixation was followed by three rinses (10 minutes each) in the same buffer. Post-fixation was done with 1% aqueous OsO_4 for two hours. OsO_4 was removed with three rinses (10 minutes each) of distilled water. Dehydration was done in a series of ethanol:water dilutions comprising of 30, 50, 70, 90 and 100% ethanol. The 100% ethanol was changed three times. After dehydration the material was infiltrated and embedded in LR White medium grade resin. Sections of 0.5 – 1.0 µm were made with glass knives using a Reichert Ultracut E ultramicrotome and stained for 20 seconds at 60°C in 0.5% Toluidine blue O dissolved in 0.5% Na_2CO_3 in distilled water. The sections were mounted in immersion oil and viewed with a Nikon Optiphot light microscope using transmitted light. Images were recorded digitally using a Nikon DXM 1200 digital camera.

Transmission electron microscopy (TEM):

Leaf material for transmission electron microscopy was fixed in 2.5% glutaraldehyde in a 0.075M $NaPO_4$ buffer (pH 7.4) for two hours. Glutaraldehyde fixation was followed by three rinses (10 minutes each) in the same buffer. Post-fixation was done with 1% aqueous OsO_4 for two hours. OsO_4 was removed with three rinses (10 minutes each) of distilled water. Dehydration was done as for light microscopy. After dehydration the material was infiltrated and embedded in Quetol epoxy resin (Van der Merwe and Coetzee, 1992) and polymerized in an oven at 60°C for 39 hours. Ultra-thin cross sections were made with a Reichert Jung Ultracut E microtome and contrasted with 4% uranyl acetate and lead citrate (Reynolds, 1963). Sections were studied with the aid of a Philips EM 301 TEM.

Scanning electron microscopy (SEM):

Sections of 3mm by 3mm, excised from the middle of the adaxial side of the lamina between the mid rib and leaf margin were fixed in glutaraldehyde and dehydrated as for TEM. After dehydration the material was dried to the critical point in a Polaron critical point drier. The dried samples were mounted on aluminium stubs made conductive by exposing them to vapour from a 0.5% RuO_4 solution (Van der Merwe & Peacock, 1999). Specimens were viewed with a JOEL 840 scanning electron microscope operated at 5 kV and images were recorded digitally.

4.4 Results and Discussion

There was no difference in the *Lachenalia* leaf structure between the black 40% and green 40% shade nets. According to Wild and Wolf (1980), light intensity has a strong effect on the size and number of chloroplasts. Also, a greater number of chloroplasts per palisade cell are observed in leaves exposed to full sunlight. Similar observations were made for *Lachenalia* leaves exposed to high irradiance (full sunlight) (Figure 4.1a) compared to 40% shade-grown leaves (Figure 4.1b). When irradiance levels are high, chloroplasts are usually aligned along the radial (side) walls of the cells imbedded in the peripheral cytoplasm, becoming shaded by each other against light damage (Figure 4.1a). When irradiance levels are low, chloroplasts are distributed along the walls to maximize light absorption (Figure 4.1b). The orientation movement of chloroplasts allows the plant to adjust its photosynthetic processes to changes in the environmental light (Seitz 1987). Ecologically, chloroplast movements are important to increase light absorption when irradiances are so high that they might cause photo-destructive effects (Salisbury and Ross, 1992).

TEM micrographs showing leaf chloroplast ultrastructure of full sunlight-grown and 40% shade-grown leaves of *Lachenalia* cultivars Romaud and Romelia, indicate that full sunlight-grown leaves have fewer thylakoids/granum which tend to be disrupted (Figure 4.2a (i); 4.2b (i)) compared to the increased and more organized thylakoids/granum (Figure 4.2a (ii); 4.2b (ii)) of 40 % shade-grown leaves. These adaptations allow the *Lachenalia* leaves to optimise its use of the limited radiant energy available in reduced irradiance environments. These observations are similar to Lichtenthaler *et al.* (1981) who compared sun and shade leaves of beech (*Fagus sylvatica*).

A cross-sectional view of the guard cells of stomata exposed to full sunlight during growth of *Lachenalia* (Figure 4.3a), indicate that the guard cells of plants grown in full sun are more rectangular in shape and those of the 40% shade-grown leaves (Figure 4.3b) have a sigmoidal shape. The size of the stomatal pore for the full sunlight-grown leaves is smaller than that of the 40% shade-grown leaves. This is to regulate the loss of water vapour to transpiration.

According to Cutter (1979), a decrease in light intensity results in a lower stomatal frequency. Visual observations from scanning electron micrographs of both *Lachenalia* cultivar Romaud (Figure 4.4a) and Romelia (Figure 4.4b) indicated that the decrease in light intensity from full sunlight (Figure 4.4(i)) to 40% shade (Figure 4.4(ii)) resulted in a reduced number of the elliptical stomata on the adaxial leaf surface. This is probably because reduced rates of transpiration occured in shaded areas and thus fewer stomata are required to regulate transpiration rates compared to leaves exposed to full sunlight. There was no apparent difference in the size of individual stomata between the full sunlight and 40% shade treatments. Stomata of many monocotyledons such as Liliaceae, normally occur in rows parallel to the length of the leaf (Clegg and Cox, 1978).

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Wax development is affected by light intensity (Cutter, 1979). Visual observations in *Lachenalia* indicated that the development of wax projections is greater in leaves exposed to full sunlight (Figure 4.5a), compared to 40% shade-grown leaves (Figure 4.5b). The increased development of wax projections in leaves exposed to full sun present many light-scattering surfaces to reduce the high levels of incidence radiation reaching the leaves. The layer of this wax should be taken into consideration when planning to apply spraying treatments, as this surface wax resists wetting by sprays. Preferably a wetting agent should be included in the spray mixture.

4.5 Conclusion

Lachenalia cultivars Romaud and Romelia amongst others, adapt to sun and shade conditions by anatomical modifications. These modifications enable the plants to utilize the prevailing environmental conditions to their optimum capacity. The orientation movement of chloroplasts, the presence of high or low number of chloroplasts and the number of thylakoids/granum amongst others, allows the plant to adjust its photosynthetic processes to changes in the environmental light in order to achieve maximum growth responses. This results in varying changes in plant shape and form such as increased flower stem growth. It is therefore important for the grower to consider the effect of different shade densities on plant growth so as to create optimum conditions for *Lachenalia* cut flower production.

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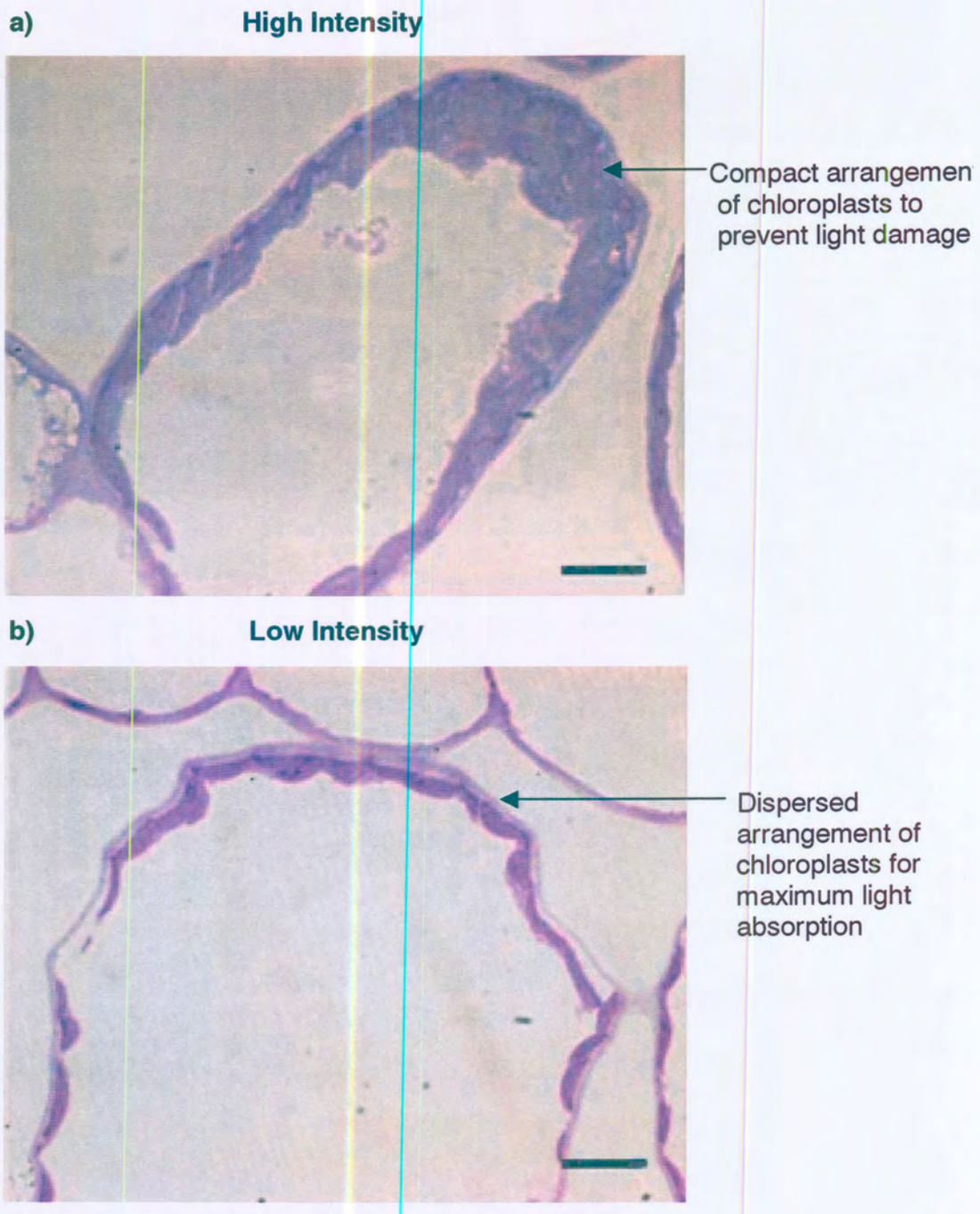

Figure 4.1 Light micrographs of transverse sections of leaves of *Lachenalia* cultivar Romelia illustrating chloroplast orientation of full sun-grown leaves (a); scale bar = 100 μm, and 40% shade-grown leaves (b); scale bars = 100 μm.

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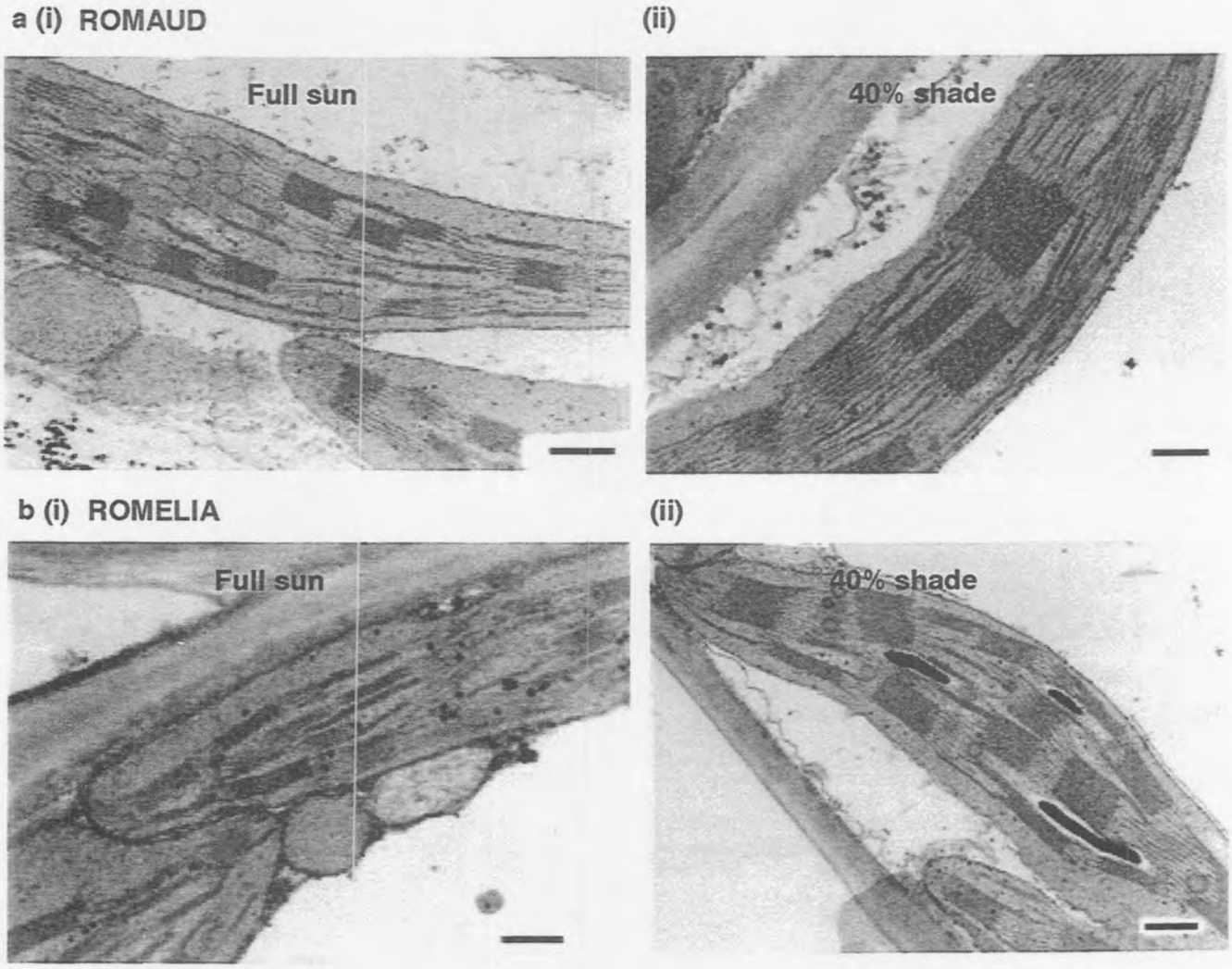

Figure 4.2 TEM micrographs of cultivar Romaud (a) and cultivar Romelia (b) showing leaf chloroplast ultrastructure in full sun-grown (i) and 40% shade-grown (ii) leaves; scale bars = 10 μm.

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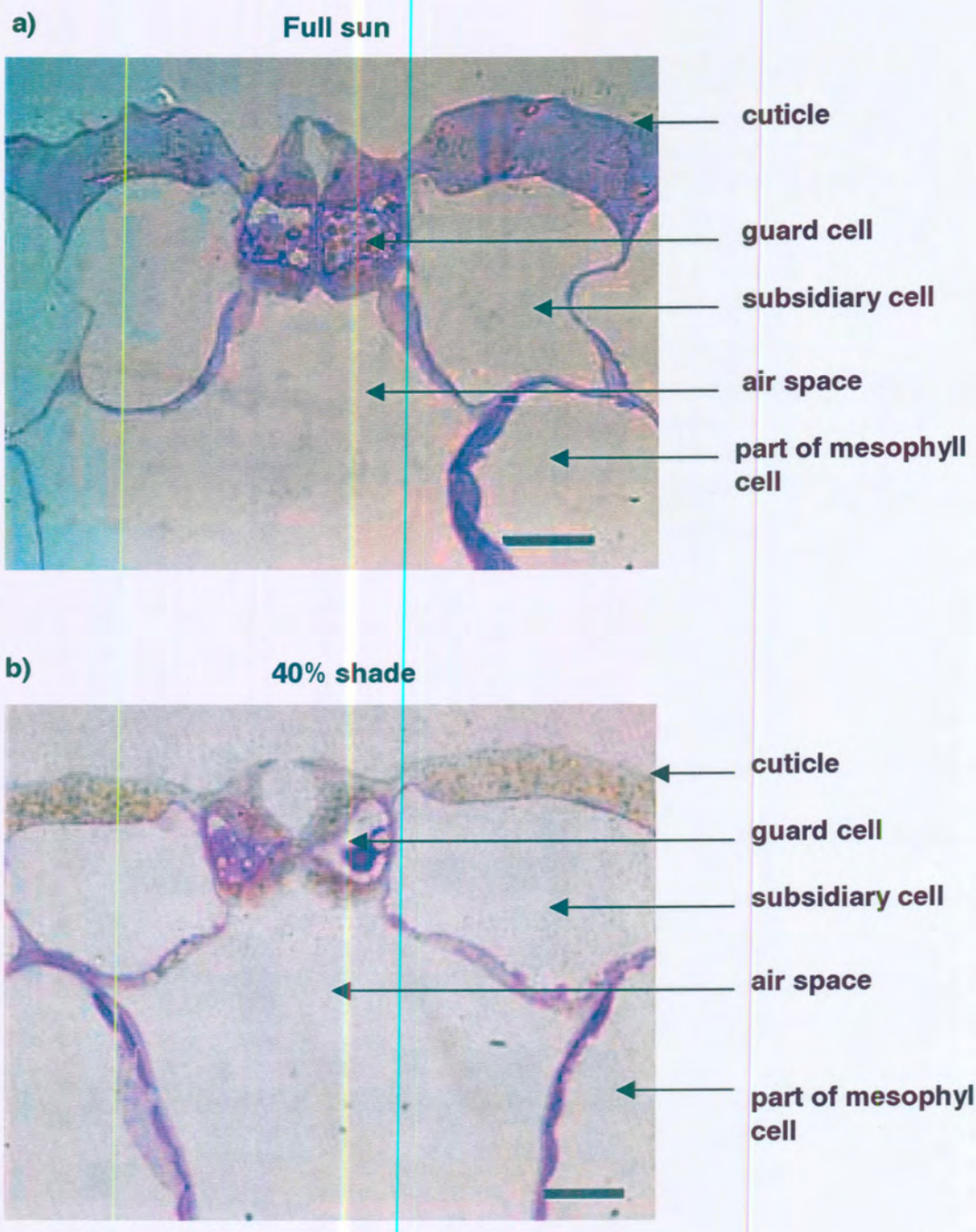

Figure 4.3 Light micrographs of transverse sections of *Lachenalia* cultivar Romelia leaves, illustrating details of cuticle, subsidiary cells and guard cells, in full sun-grown (a) and 40% shade-grown (b) leaves; scale bars = 100 μm.

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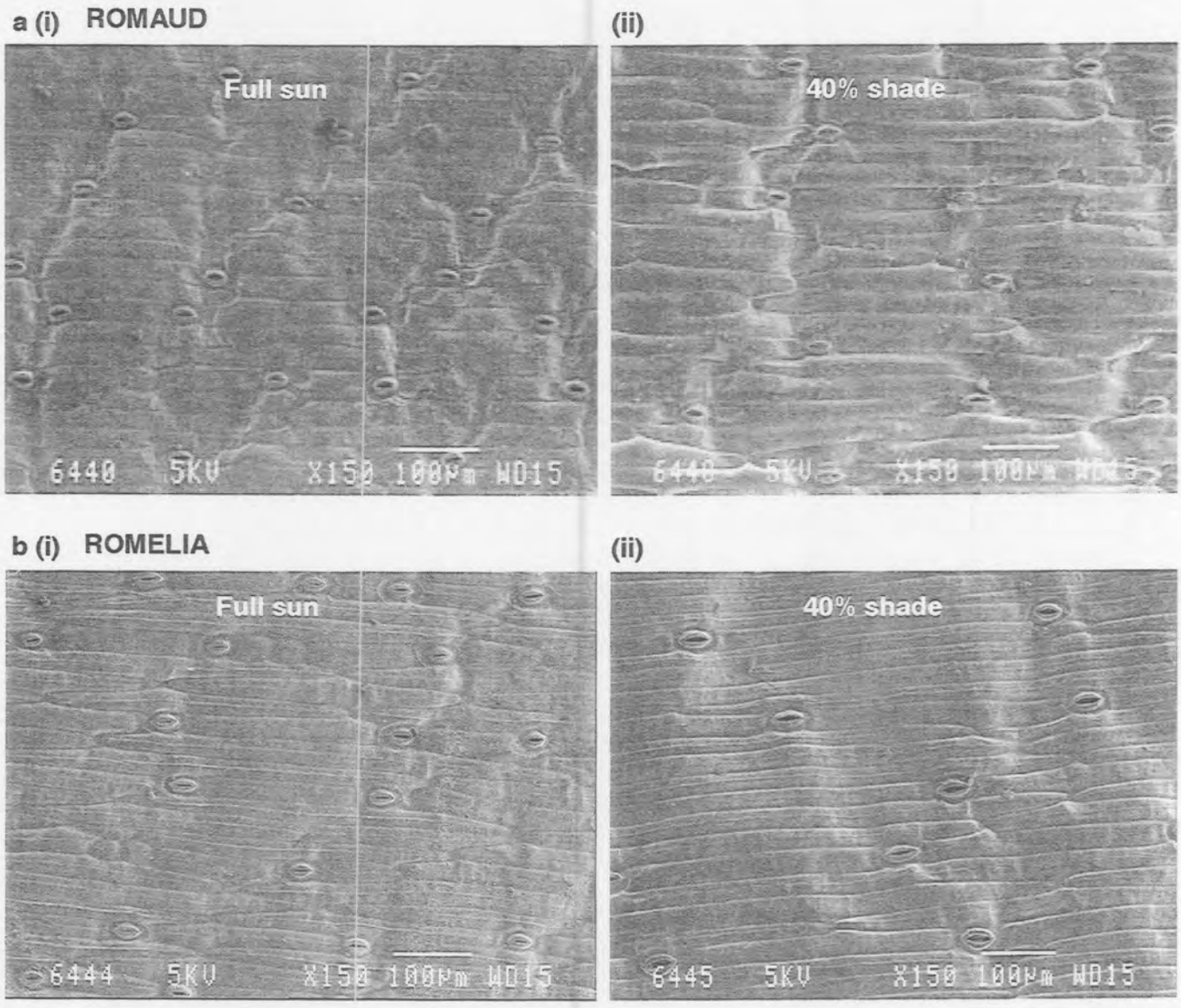

Figure 4.4 A scanning electron micrograph of the adaxial leaf surface of *Lachenalia* cultivar Romaud (a) and cultivar Romelia (b) to illustrate differences in the stomatal distribution of full sun-grown (i) and 40% shade-grown (ii) leaves; scale bars = 100 µm.

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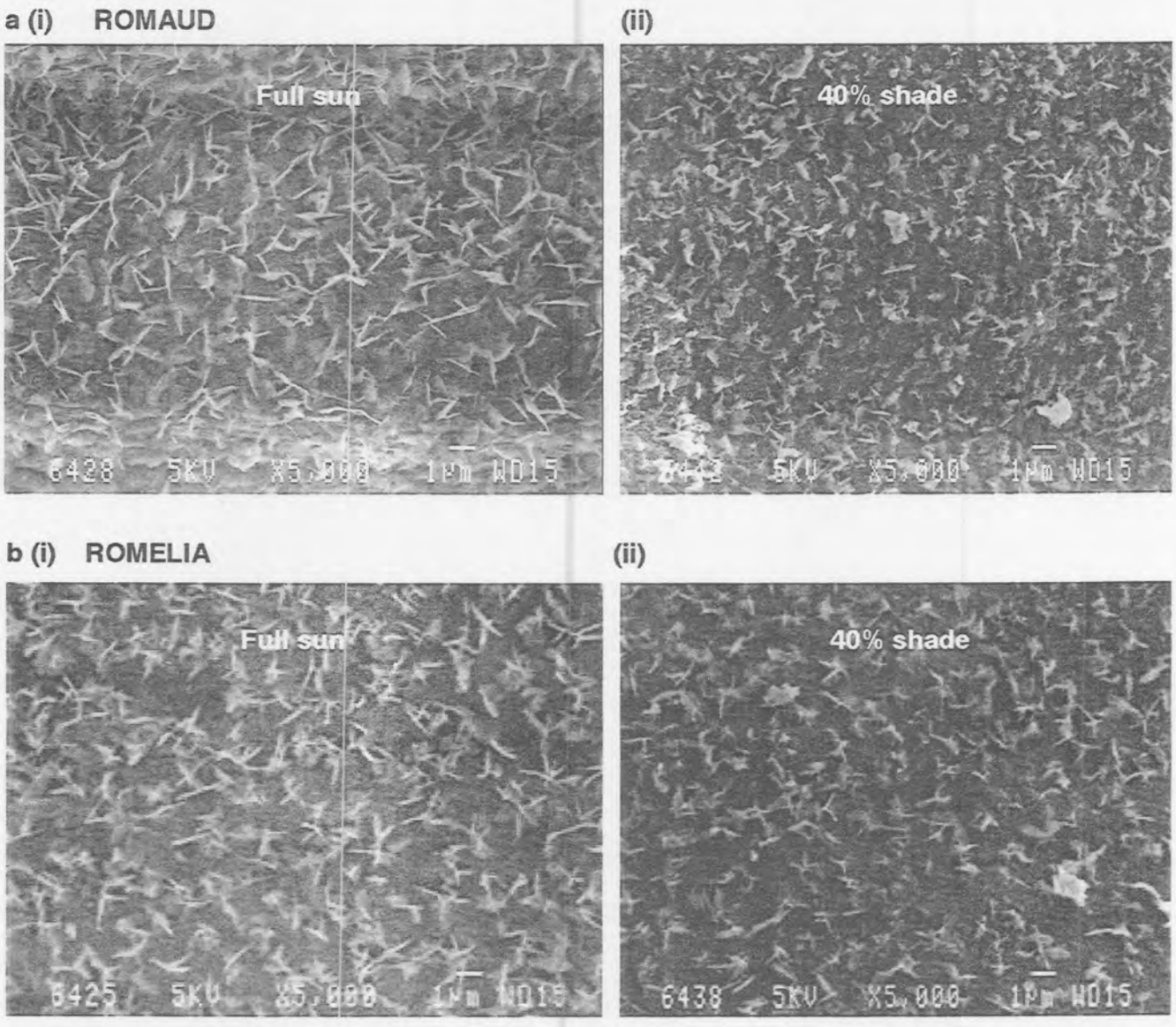

Figure 4.5 A scanning electron micrograph of the adaxial leaf surface of *Lachenalia* cultivar Romaud (a) and cultivar Romelia (b), to illustrate differences in the epicuticular wax layer of full sun-grown (i) and 40% shade-grown (ii) leaves; scale bars = 1 µm.

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CHAPTER 5

INFLUENCE OF GIBBERELLIC ACID ON THE GROWTH, FLOWERING AND VASE LIFE OF TWO *LACHENALIA* CULTIVARS GROWN UNDER FIVE DIFFERENT SHADE NETS

5.1 Summary

Lachenalia, endemic to South Africa, has potential as a cut flower, however for export quality, a longer flower stem is required. Gibberellic acid is known to induce stem growth and flowering and the possibility of applying gibberellic acid (GA_3) in commercial horticulture is considered. Two methods of GA_3 application was used on *Lachenalia* leaves and bulbs at 0 or 10 ppm, namely, a foliar spray and a preplant 1-minute dip. GA_3 applied as a foliar spray during the first season and as a bulb dip in the second season significantly increased inflorescence stem length of cultivars Romaud and Romelia by about 3 cm. Leaf length was also significantly increased, but leaf area significantly decreased for both cultivars. The number of flowers per inflorescence decreased significantly by about 3 to 5 flowers for cultivar Romaud and Romelia when GA_3 was applied as a foliar spray or bulb dip treatment. A significant increase in vase life (2 days) of GA_3 treated plants was observed. Foliar spray and bulb dip treatments significantly decreased mother bulb fresh mass, total daughter bulb fresh mass and number of daughter bulbs for cultivars Romaud and Romelia, possibly as a result of increased inflorescence demand for assimilates.

5.2 Introduction

Great variations in shape and colour between different *Lachenalia* species have attracted much attention and have been successfully manipulated by plant

breeders. Two cultivars with suitable cut flower characteristics were chosen for this study, namely Romaud and Romelia, to determine the potential effect of the growth hormone gibberellin on inflorescence stem length. In this study, the term inflorescence stem length refers to peduncle and rachis length combined. Cultivar Romaud (Figure 3.1a) has a hyacinth-type inflorescence, with closely spaced, trumpet shaped, lemon-yellow flowers, which are slightly fragrant. Cultivar Romelia (Figure 3.1d) has bright yellow, bell-shaped, pendulous flowers and an attractive inflorescence (Hancke and Coertze, 1988).

For the plant physiologist and the floriculture industry, it is particularly important to control plant growth and development, especially the growth of the flower inflorescence stem. The pot plant industry prefers to have a compact plant while the cut flower industry prefers to have a tall plant. Plant growth and development is monitored by the partitioning and distribution of assimilates. Developing storage organs (e.g., lily and tulip bulbs, and gladiolus corms) are capable of moving photosynthates and storing them as reserves (Blaney and Roberts, 1966; Ho and Rees, 1976).

From a metabolic view point, sources produce assimilates by photosynthesis or from stored materials, whereas sinks utilize assimilates in respiration and growth (Wareing and Patrick, 1974). Assimilate patterns are altered by the intensity and location of the demand (sink), when rapidly growing storage organs, flowers or fruits are produced. Increased assimilate translocation to sites of utilization can occur from removal of competing sites, or by applications of plant regulators (Wareing and Patrick, 1974).

Auxins, gibberellins and cytokinins can effectively promote the power of a sink, i.e. the ability of a sink to attract assimilates. Gibberellins are known to enhance growth and flowering in many cold-requiring geophytes, including lily and liatris (De Hertogh and Le Nard, 1993) and was also effective with *Ornithogalum dubium* (Luria *et al.*, 2000). According to Ginzburg (1974), GA_3 promoted

inflorescence growth of gladiolus by directing assimilate movement towards the inflorescence at the expense of the corm. When the period of rapid inflorescence growth was over and the corm became the main sink, translocation of assimilates from the leaf to the corm of the control was inhibited by GA_3, however the total movement to the treated corm increased. It was therefore concluded that a decrease in the ability of the corm to attract assimilates did not cause decreased assimilate movement into the corm, rather this was caused by increased competition from the inflorescence.

Reid and Crozier (1970) observed the transport of assimilates in pea seedlings when leaves were pretreated with growth substances. They showed that gibberellins, applied to a leaf, attract assimilates. In the controls, assimilates were rapidly exported from the leaves, moving acropetally in the inflorescence stem, but very little assimilates were exported from gibberellin-treated leaves. Treatment of plants with large doses of gibberellin results in elongated internodes and long, narrow leaves in monocotyledons (Anon., 1961). Decrease in leaf area has also been reported, although this is less common (Brian *et al.*, 1954). Michniewicz and Lang (1962) found that the response of gibberellins on inflorescence stem elongation and flower formation in cold requiring and photoperiodic plants varied with the gibberellin applied.

Lester *et al.* (1972) measured the effects of GA_3 on net photosynthesis in *Pennisetum clandestinum* Hochst. GA_3 did cause increases in apparent photosynthesis, but this was attributed in part to a change in leaf architecture, i.e., elongation of internodes, which caused leaf blades to be dispersed more in the horizontal plane, resulting in more efficient light utilization. Changes in leaf architecture or in plant form, are major considerations when drawing conclusions on the effects of hormones in stimulating photosynthesis of a plant.

In the past suggestions have been made, where there is an interaction between gibberellin and visible radiation in plants. According to Reid *et al.* (1968), red

light influences gibberellin metabolism in several plant species. In addition, Lockhart (1956) demonstrated that visible radiation acts on stem growth through a decrease in endogenous gibberellins.

Changing the spectral distribution of sunlight by providing different shade nets, results in varying growth responses from *Lachenalia* plants, as were described in Chapter 3. Several distinct morphological effects of visible radiation on inflorescence stem growth were observed. In general, red light promotes stem elongation (Moe, 1990). The most noticeable effect of high irradiances was that it reduced the total length of the inflorescence stem and leaves. Temperatures also varied slightly between the different shade nets. According to Went (1953), the rate of stem elongation in plants is greater when day temperatures are higher than night temperatures.

Kelley and Schlamp (1964) found that the keeping quality of potted lilies was enhanced by the application of gibberellic acid and according to Kays *et al.* (1971), the number of initiated flower buds of potted lilies was reduced.

The objective of this trial was to determine the effect of two GA_3 applications (foliar spray and bulb dip) on *Lachenalia* cultivars Romaud and Romelia. Gibberellins have not been tested on lachenalias before. This trial is therefore a first attempt at producing saleable cut lachenalias with an adequate flower inflorescence stem length for the cut flower industry with the use of growth hormones.

5.3 Materials and Methods

The trial was conducted on the experimental farm of the University of Pretoria (25°45'S, 28°16'E, alt. 1372 m) in a summer rainfall region and received an

average of ca 670 mm a^{-1} during the trial period (March to August). The monthly average maximum was 26.6 °C (March), minimum average was 4.3 °C.

Flowering size bulbs (4.5 cm in circumference and ± 1g each) of two *Lachenalia* cultivars (Romaud and Romelia) were obtained from the ARC-Roodeplaat Vegetable and Ornamental Plant Institute, after approximately four months of storage at 25 °C. Bulbs were planted on 1 March in 20 litre black plastic bags (30 cm diameter) with their growing tips 3-4 cm below the surface of the planting medium. The planting medium used in the trial consisted of pasteurized composted bark mixture. The bulbs were grown under five different shade nets (18% white, 40% green, 40% black, 55% black, 70% black) and in the open as a control in the first season. In the second season, *Lachenalia* bulbs were planted under black 40%, black 55% and black 70% shade nets only. The temperature was measured on a weekly basis. The photosynthetically active radiation (PAR) was measured every two weeks at 12h00 on a cloudless day. Irrigation in combination with the water-soluble hydroponic fertilizer mix was kept constant and applied tree times daily (08h00, 12h00, 17h00), by drip irrigation system.

In the first season, the GA_3 [10 ppm] treatment was applied to the leaves of cultivars Romaud and Romelia. In total, three consecutive treatments with 10-day intervals were applied. The first foliar spray was applied until runoff. About 200 ml of the GA_3 [10 ppm] treatment was applied to each plant when the growth tip of the inflorescence of each cultivar emerged, because the active dividing and elongating cells are located in the zone immediately below the apical meristem. In the second season, the bulbs of cultivars Romaud and Romelia were soaked in GA_3 [10 ppm] for 1 minute prior to planting. Control plants received no GA_3 for both the foliar spray in the first season and the bulb dip treatment in the second season.

Ten randomly selected primary inflorescences as well as ten randomly selected secondary inflorescences were cut at the base and harvested when the oldest

flower on the primary as well as the secondary inflorescences opened. Secondary inflorescences were not analyzed because of poor quality yields which was not suitable for cut flower production. Four primary inflorescences were placed in each water-filled glass vase. The glass vases were sterilized before the experiment. The primary inflorescences were then stored in controlled temperature rooms at 22°C. The cabinets provided a 12 hr photoperiod with a light intensity of ±100 $\mu mol.m^2.s^{-1}$ PAR at plant level to simulate office conditions. Lighting was provided by WHO fluorescent tubes.

The following parameters were observed:

- Date when the first (oldest) flower of the primary inflorescence opened (first flower)
- Date when 80% of the flowers on the primary inflorescence were fully open (full-flower)
- Date when ½ of the 80% fully open primary inflorescence flowers wilted (50% wilt)
- Number of open flowers per inflorescence at full flower
- Inflorescence stem length (peduncle and rachis) (mm) at harvest
- Length of peduncle (mm) at harvest
- Length of rachis (mm) at harvest
- Peduncle diameter (mm) at harvest

From the previous mentioned observations, the following calculations were made:

- Date of full flower, subtracted by the date of first flower (vase life)
- Date of 50% wilt, subtracted by the date of full flower (vase life)

When the inflorescences had wilted at the end of the growing season, the leaves were harvested and measurements were taken of leaf length, fresh mass and leaf area. Leaf area was measured with a LI-COR Model 3100 leaf area meter.

The bulbs were then harvested and sampled. The daughter bulbs were removed from the mother bulbs, counted and weighed. Mother bulb fresh mass was then measured. Similar observations were made for both the foliar spray treatment in the first season and the bulb dip treatment in the second season.

The experimental layout was a randomized block design with four replications. Data were analyzed using the PROC G.L.M. (General Linear Models) procedure in SAS (Statisical Analysis System) program. Analysis of Variance was performed and Tukey's studentized range test (Steele and Torrie, 1980) was applied to compare treatment means.

5.4 Results and Discussion

Average photosynthetically active radiation (PAR) measurements taken are illustrated in Figure 5.1. Figure 5.2. illustrates average minimum and maximum temperature measurements.

In Figure 5.3, the effect of GA_3 [10 ppm], applied to the *Lachenalia* leaves as a spray in the first season and as a bulb dip in the second season is illustrated. Inflorescence stem length of both cultivars Romaud and Romelia increased significantly by about 3 cm for both the foliar spray and the bulb dip treatment for all shade treatments.

Stem elongation is normally brought about by cell division in the sub-apical region, or primary elongating meristem and according to Cutter (1969), the activity of this meristem is at least partially controlled by gibberellic acid. Cleland (1969) observed that gibberellins positively influence the subapical meristem by stimulating cell elongation. Ginzburg (1974) found that GA_3 promoted inflorescence growth in gladiolus by directing assimilate movement towards the inflorescence at the expense of the corm. This could explain why inflorescence

stem growth was enhanced when the plants were treated with GA_3. Increased stimulation of the primary elongating meristem together with an increased supply of assimilates probably resulted in a significantly longer inflorescence stem length compared to those of the control.

Leaf length increased significantly for both the foliar spray and the bulb dip treatment under all shade treatments, except for cultivar Romaud under the black 55% shade net and cultivar Romelia under the green 40% shade net (Figure 5.4). Reid and Crozier (1970) showed that gibberellins, applied to a leaf in pea seedlings, attract assimilates. Very little assimilate were exported from gibberellin-treated leaves, but assimilates were rapidly exported from the leaves in the controls, moving acropetally into the inflorescence stem. Therefore, it is assumed that increased amounts of assimilates of the treated plants, are available to stimulate leaf growth compared to those of the control. Leaf area was significantly reduced as illustrated in Figure 5.5 under all shade treatments, except in the control for both cultivar Romaud and Romelia. A greater amount of assimilates are probably more available for growth under the shade treatments compared to the control, resulting in mainly longer inflorescence stems and leaves.

The number of flowers per primary inflorescence decreased significantly by about 3 to 5 flowers for cultivar Romaud and Romelia, when GA_3 was applied as a foliar spray or as a bulb dip treatment under all shade treatments, except in the control and under the black 40% shade treatment for cultivar Romaud (Figure 5.6). Kays *et al.* (1971) found that the number of initiated flower buds was reduced by the application of gibberellic acid to potted lilies at 1000 ppm prior to flower initiation. A probable reason could have been an increased demand of sugars for inflorescence stem growth in the GA_3 treated inflorescence stems, which resulted in a decreased supply available to the developing flowers and hence flower production was reduced. De Hertogh and Blakely (1972) found that GA_3

applied to *Lilium longiflorum* Thunb., as a soil drench, also decreased total flower number.

Figure 5.7 illustrates a significant increase in vase life (2 days) between the control and the GA_3 foliar spray and bulb dip treatment under all shade treatments and the open as a control. Kelley and Schlamp (1964) found that the keeping quality of potted lilies was enhanced by the application of gibberellic acid. According to Ginzburg (1974), a greater accumulation of photosynthates occurs in cut flower tissues treated with a GA_3 application. The respiration rate can therefore be maintained for a longer period and as a result the reduction of the sugar levels in the flowers after harvest are decreased at a slower rate (Mastalerz, 1987). Vase life is therefore increased when compared to the control.

Mother bulb fresh mass (Figure 5.8), total daughter bulb fresh mass (Figure 5.9) and number of daughter bulbs (Figure 5.10), decreased significantly when both GA_3 foliar spray and bulb dip treatments were applied under all shade treatments and under the open as a control. According to Ginzburg (1974), GA_3 promoted inflorescence growth in gladiolus by directing assimilate movement towards the inflorescence at the expense of the gladiolus corm. The fresh mass of *Lachenalia* mother bulbs decreased notably when plants were treated with GA_3. This is probably because assimilates were exported from the mother bulb to the inflorescence as was observed by Ginzburg (1974) in gladiolus. Carbohydrate reserves in *Lachenalia* mother bulbs therefore probably decreased because of a reduced supply of assimilates. Compared to untreated bulbs, fewer carbohydrates may be available for daughter bulb development in treated GA_3 bulbs, due to increased inflorescence demand. This is probably why the number of daughter bulbs produced after the foliar spray and bulb dip treatments, were lower compared to the control bulbs (Figure 5.10).

Average inflorescence stem length and leaf length for both plants of the control and the GA_3 treatment was higher for the bulb dip treatment in the second season compared to the foliar spray treatment in the first season. This is probably because PAR levels (Figure 5.1) were higher in the second season compared to the first season. This may have led to a rise in leaf temperature and thereby stimulated an increased assimilate supply to the inflorescence stem and leaves, thus promoting growth. When comparing temperatures (Figure 5.2) between the first and second season, no visible differences could be observed under the different shade treatments.

When comparing the general growth responses of the plants under the different shade nets, the most noticeable effect of high irradiances is that it reduces the total length of the inflorescence stems (Figure 5.3) and leaves (Figure 5.4). Mother bulb (Figure 5.8) and daughter bulb (Figure 5.9 and 5.10) development is also reduced under high irradiances. The varying growth response under the five different shade nets and in the control was discussed in detail in Chapter 3. No significant difference between the date of flowering, i.e. when the flower is ready to be harvested, under the different shade nets were observed, data not shown.

Black 70% shade net was found to be most suitable for *Lachenalia* cut flower purposes as the inflorescence stem length of the *Lachenalia* cultivars was the longest under this shade net. Inflorescence stem length of cultivar Romaud under black 70% shade net was 20 cm and 24 cm for cultivar Romelia. When these two cultivars were treated with gibberellic acid [10 ppm], the inflorescence stem length of cultivar Romaud was about 23 cm and about 28 cm for cultivar Romelia.

5.5 Conclusion

The length of the inflorescence stem is an important factor in determining commercial value of cut flowers. GA_3 foliar spray and bulb dip treatments were successful in significantly increasing inflorescence stem length by 3 cm for both cultivar Romelia and Romaud. This is a significant increase for the cut flower industry.

The economic aspects of GA_3 application to floricultural crops either as a foliar spray or a bulb dip should be critically evaluated. In this trial, only one concentration of 10 ppm was tested. In the future the effect of a wide spectrum of different concentrations need to be evaluated in order to establish the optimum concentration required to obtain the maximum increase in inflorescence stem length, without negative effects on quality. Other factors to be taken into consideration, include equipment required to apply the specific growth regulator and cost related to the chemical and labour.

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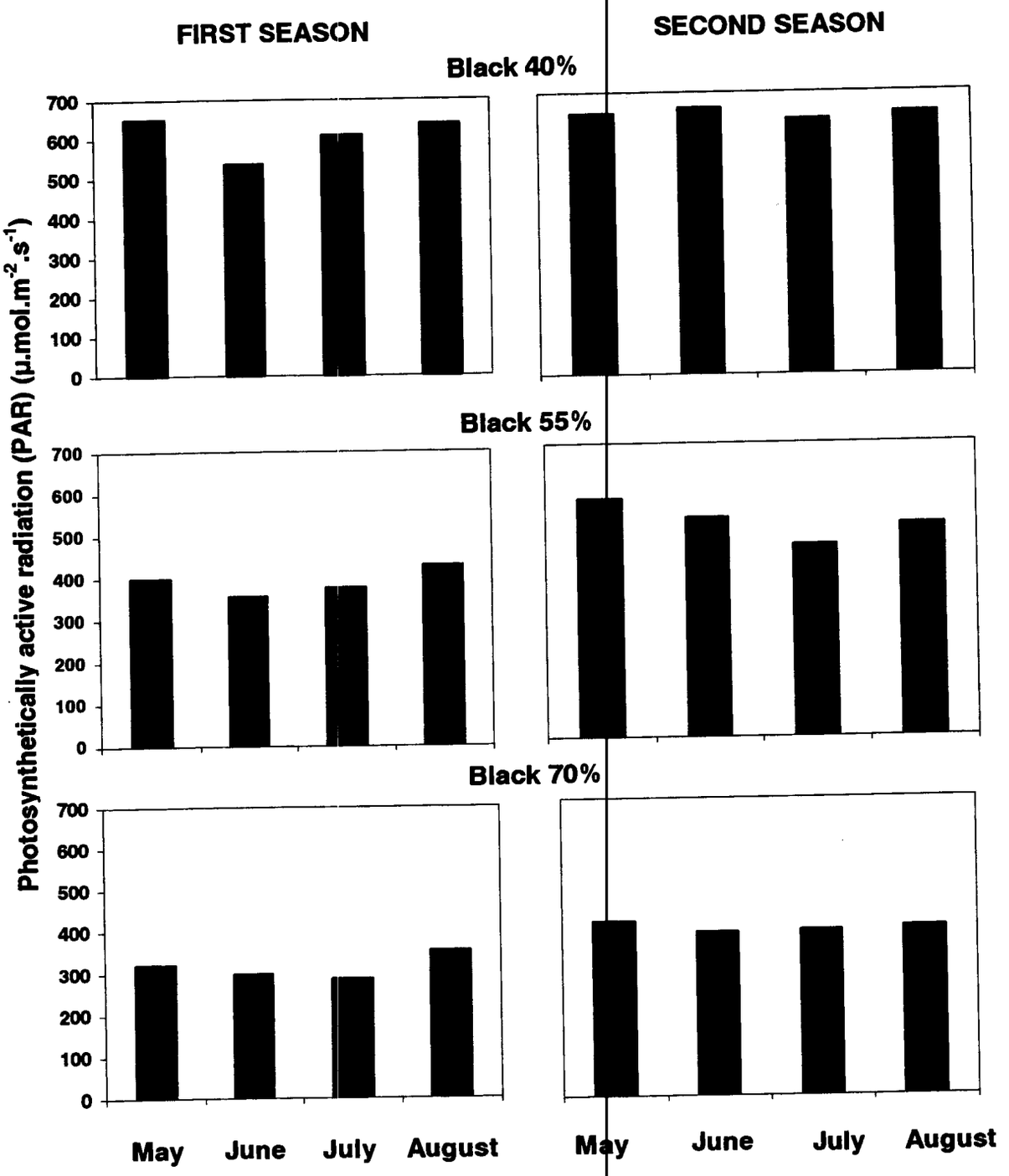

Figure 5.1 Average photosynthetically active radiation (PAR) measurements taken during two seasons under three different shade nets for the GA_3 [10 ppm] foliar spray (first season) and bulb dip treatments (second season).

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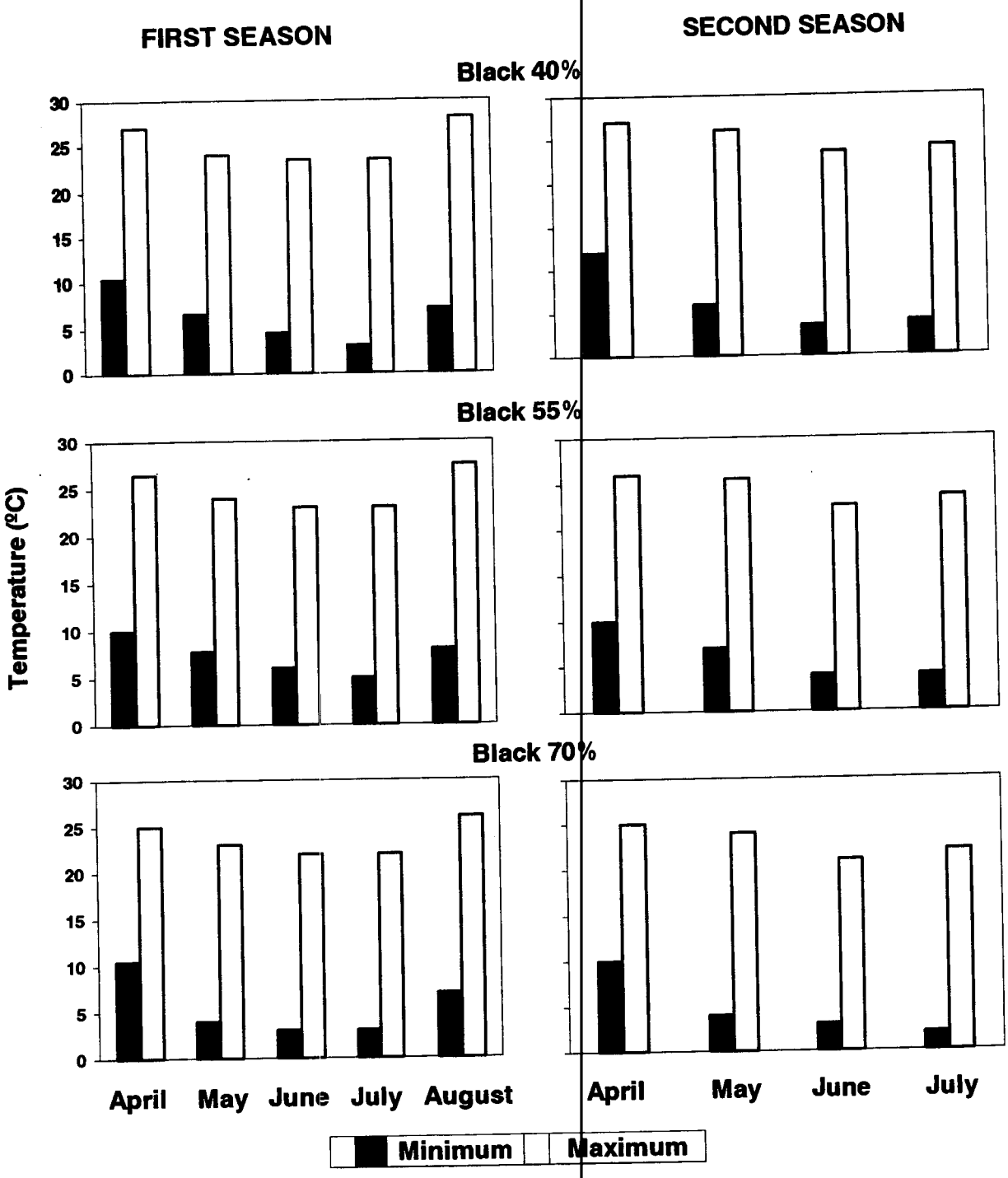

Figure 5.2 Average minimum and maximum temperature measurements taken during two seasons under three different shade nets for the GA_3 [10 ppm] foliar spray (first season) and bulb dip treatments (second season).

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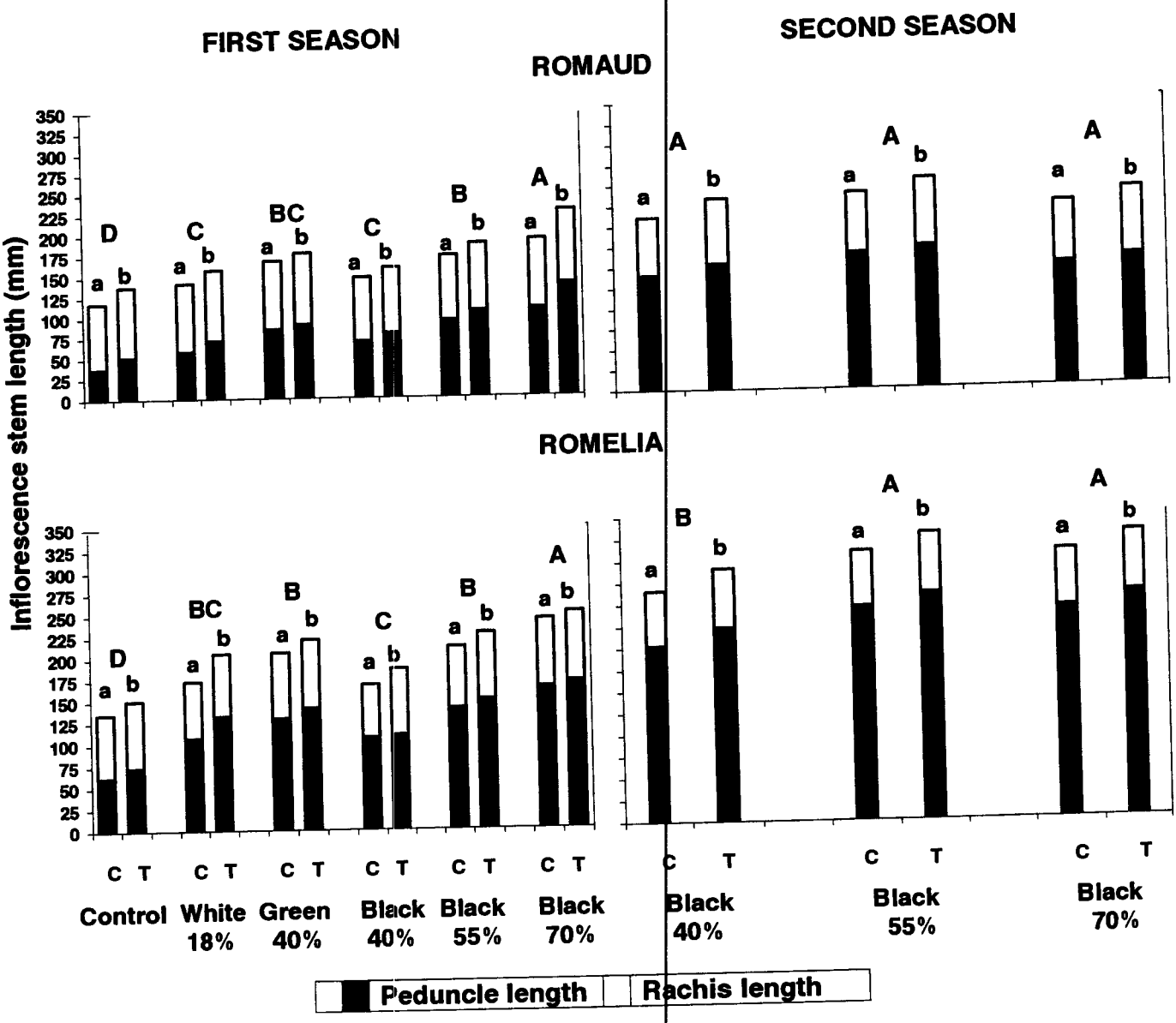

C = Control T = Treatment (GA_3 [10 ppm])

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 5.3 Effect of GA_3 [10 ppm] foliar application (first season) and bulb dip treatment (second season) on inflorescence stem length of two *Lachenalia* cultivars grown under different shade nets.

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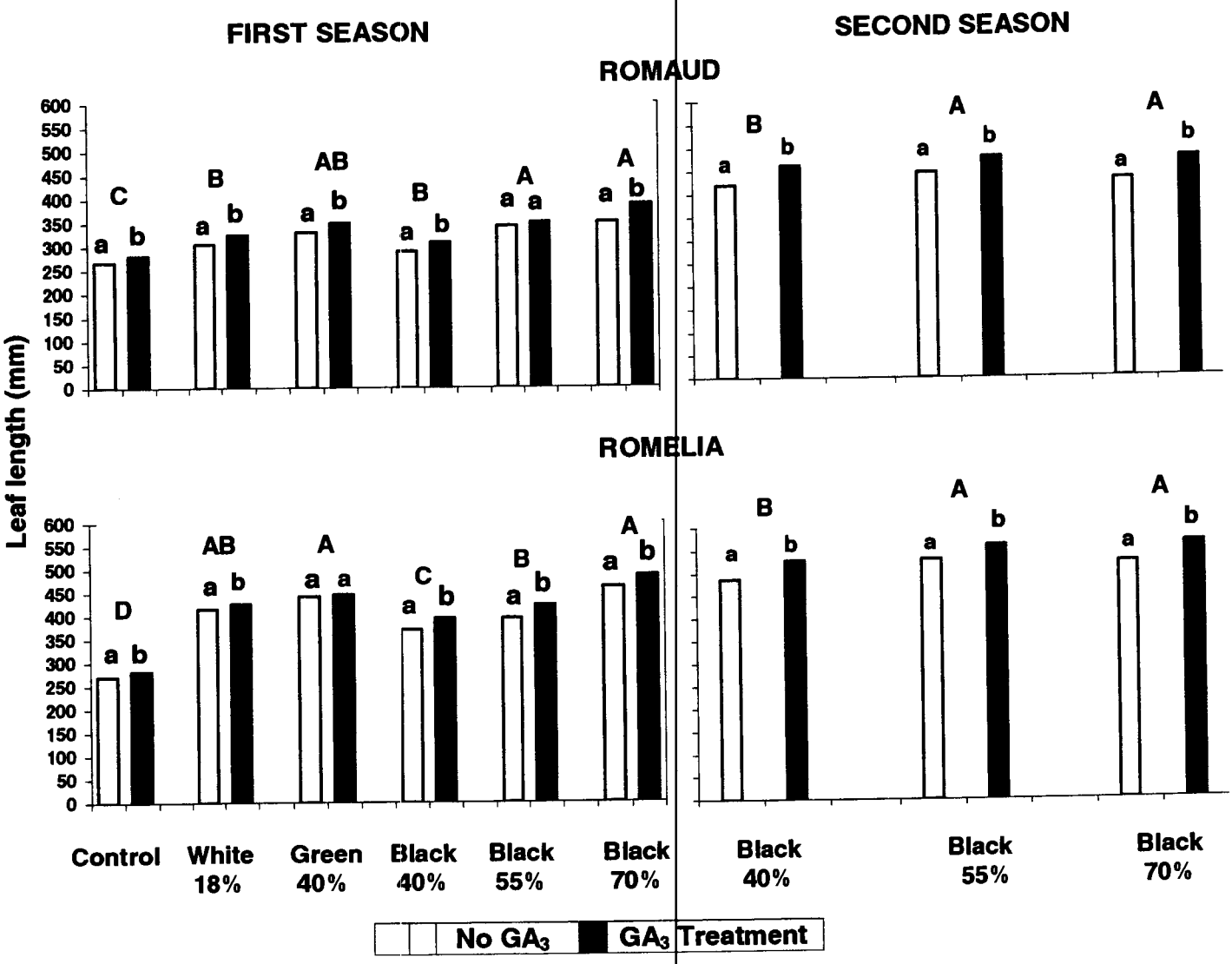

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 5.4 Effect of GA_3 [10 ppm] foliar application (first season) and bulb dip treatment (second season) on leaf length of two *Lachenalia* cultivars grown under different shade nets.

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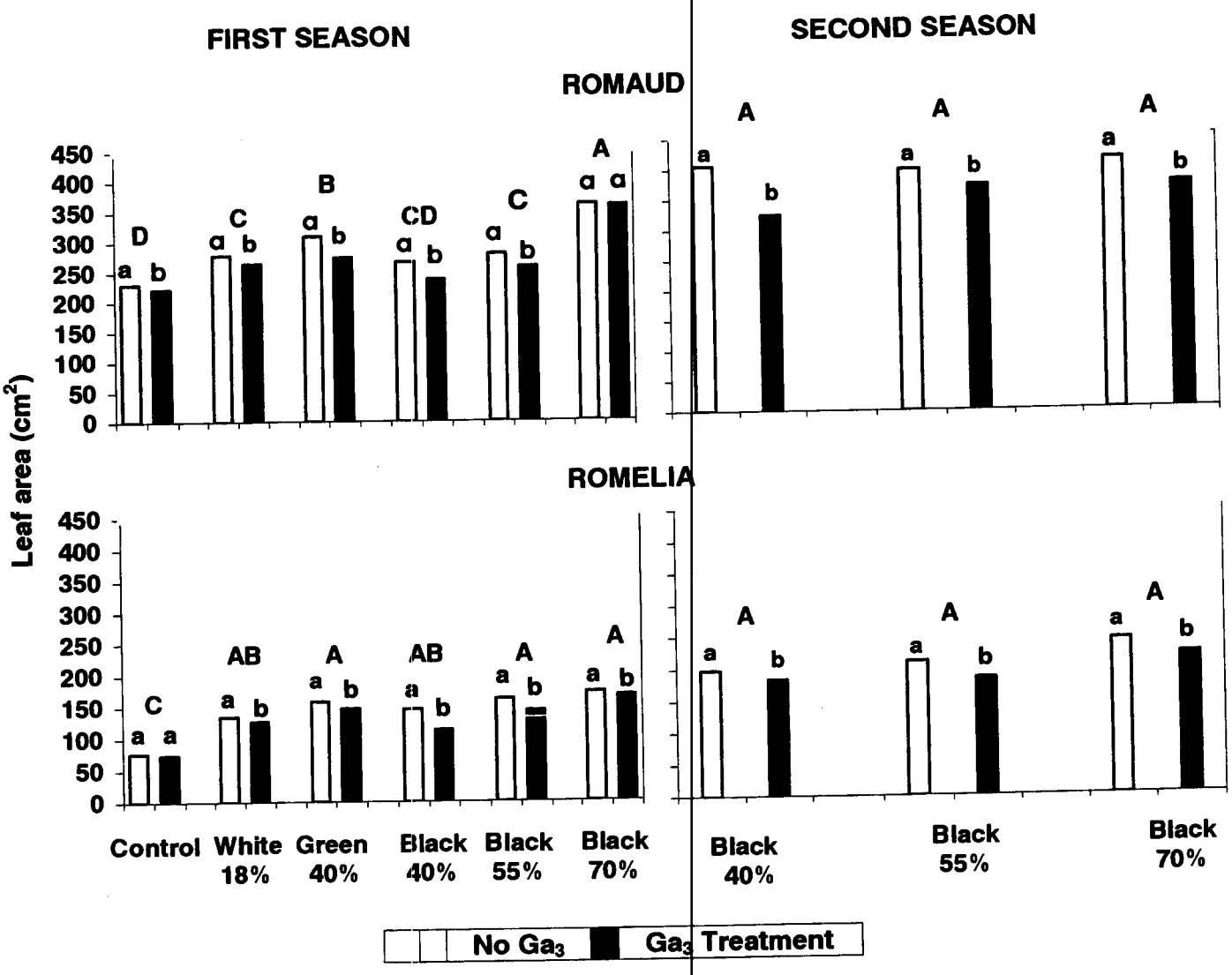

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 5.5 Effect of GA_3 [10 ppm] foliar application (first season) and bulb dip treatment (second season) on leaf area of two *Lachenalia* cultivars grown under different shade nets.

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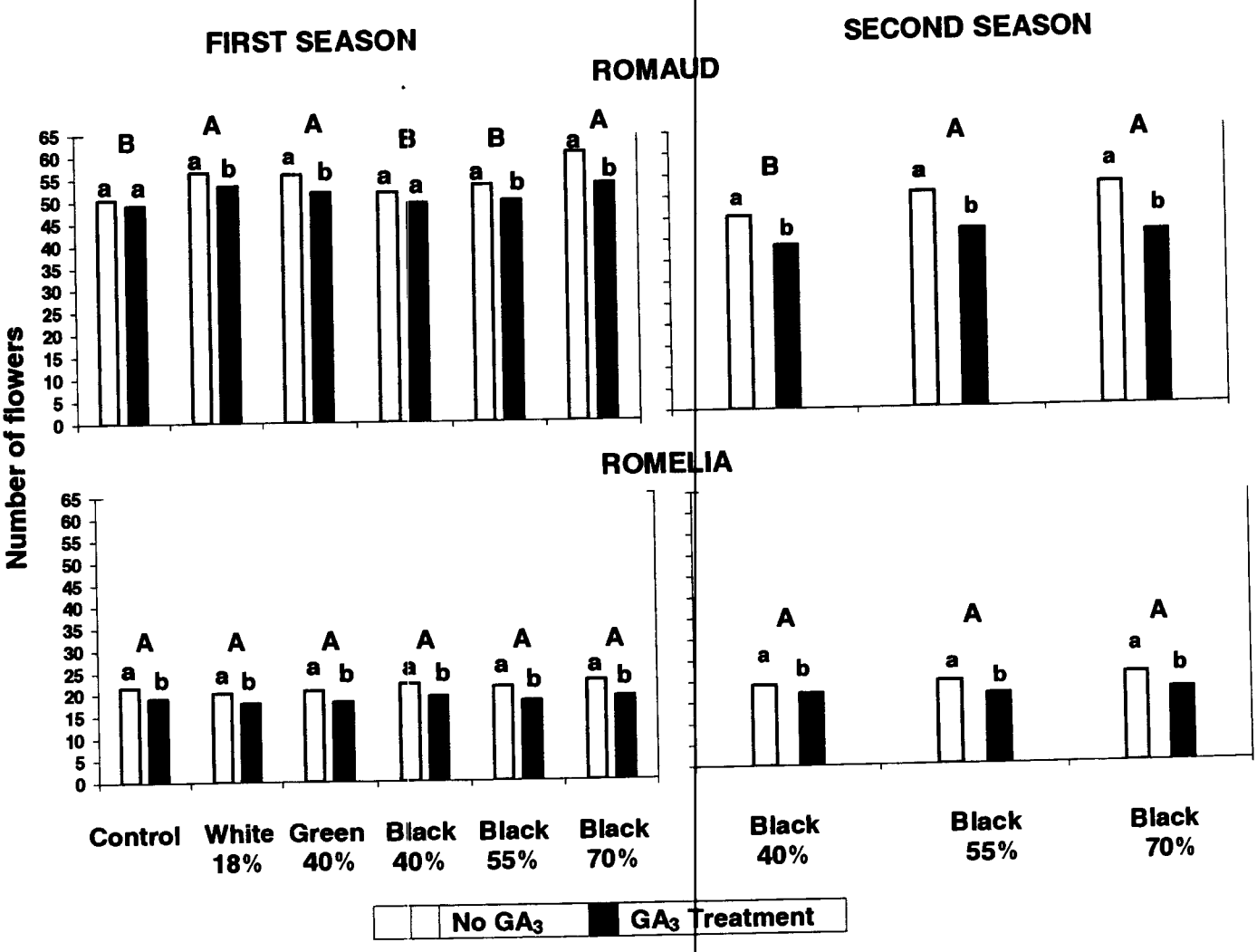

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 5.6 Effect of GA_3 [10 ppm] foliar application (first season) and bulb dip treatment (second season) on number of flowers on the inflorescence of two *Lachenalia* cultivars grown under different shade nets.

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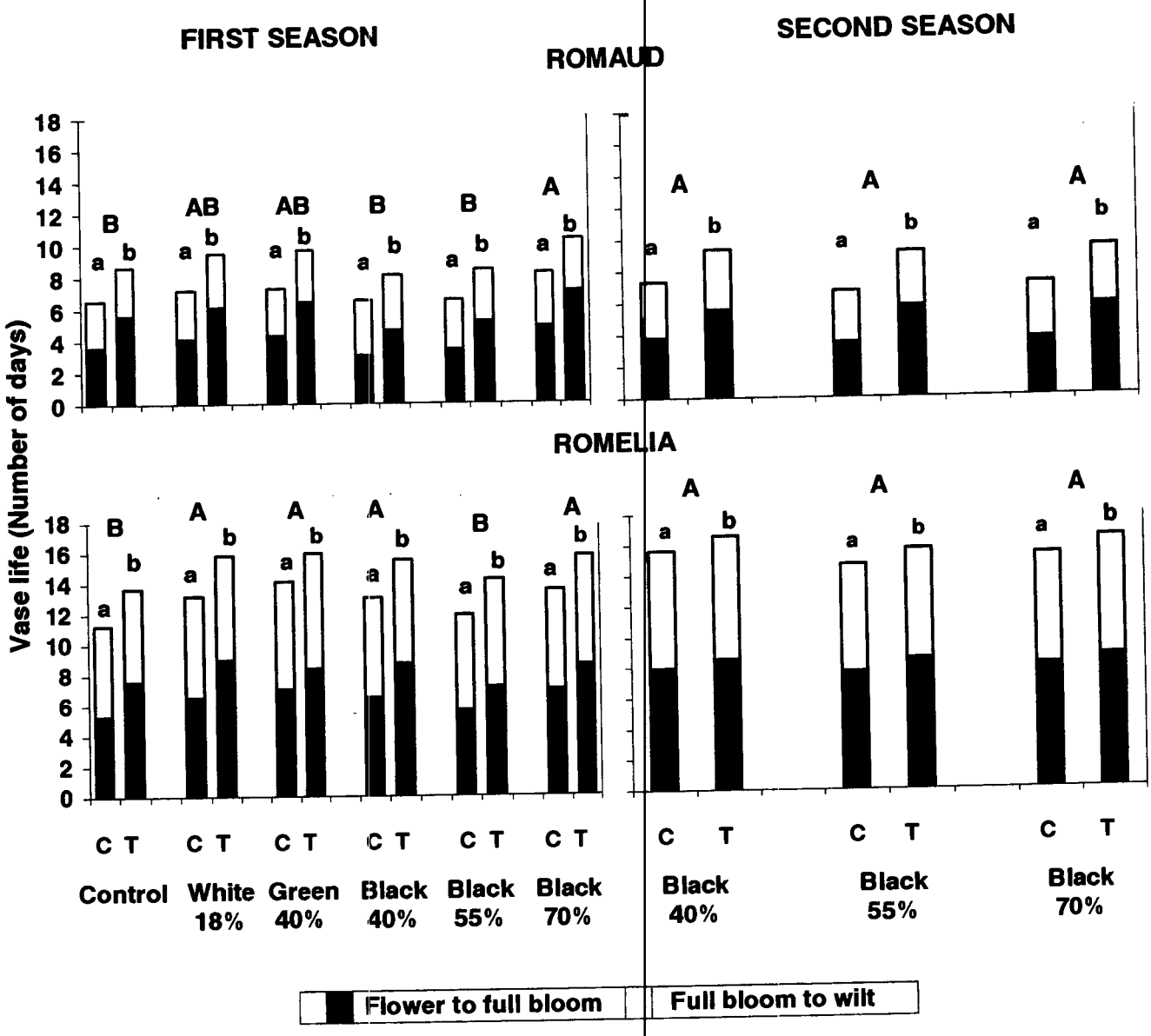

C = Control T = Treatment (GA_3 [10 ppm])

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 5.7 Effect of GA_3 [10 ppm] foliar application (first season) and bulb dip treatment (second season) on the vase life of two *Lachenalia* cultivars grown under different shade nets.

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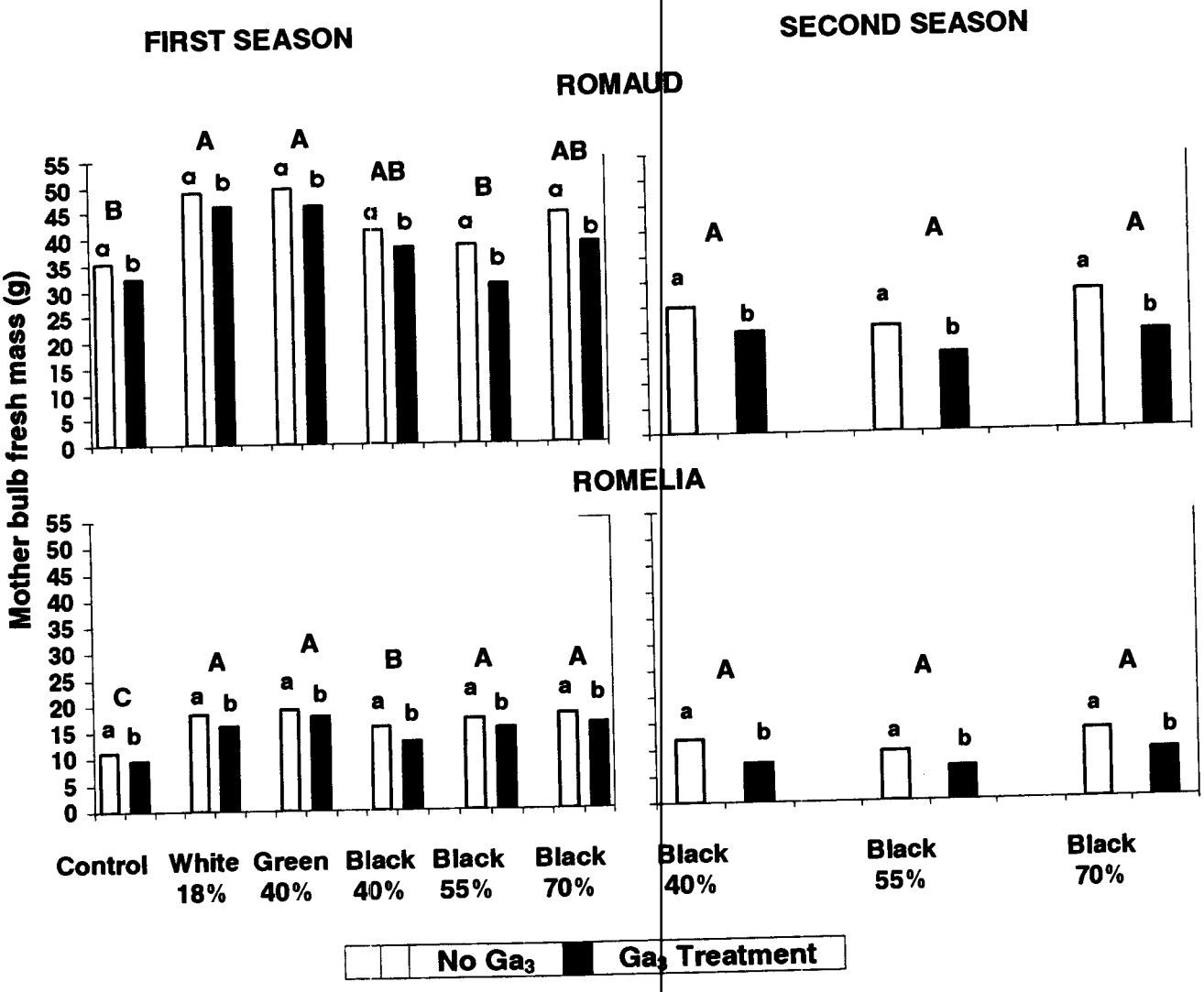

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 5.8 Effect of GA_3 [10 ppm] foliar application (first season) and bulb dip treatment (second season) on mother bulb fresh mass of two *Lachenalia* cultivars grown under different shade nets.

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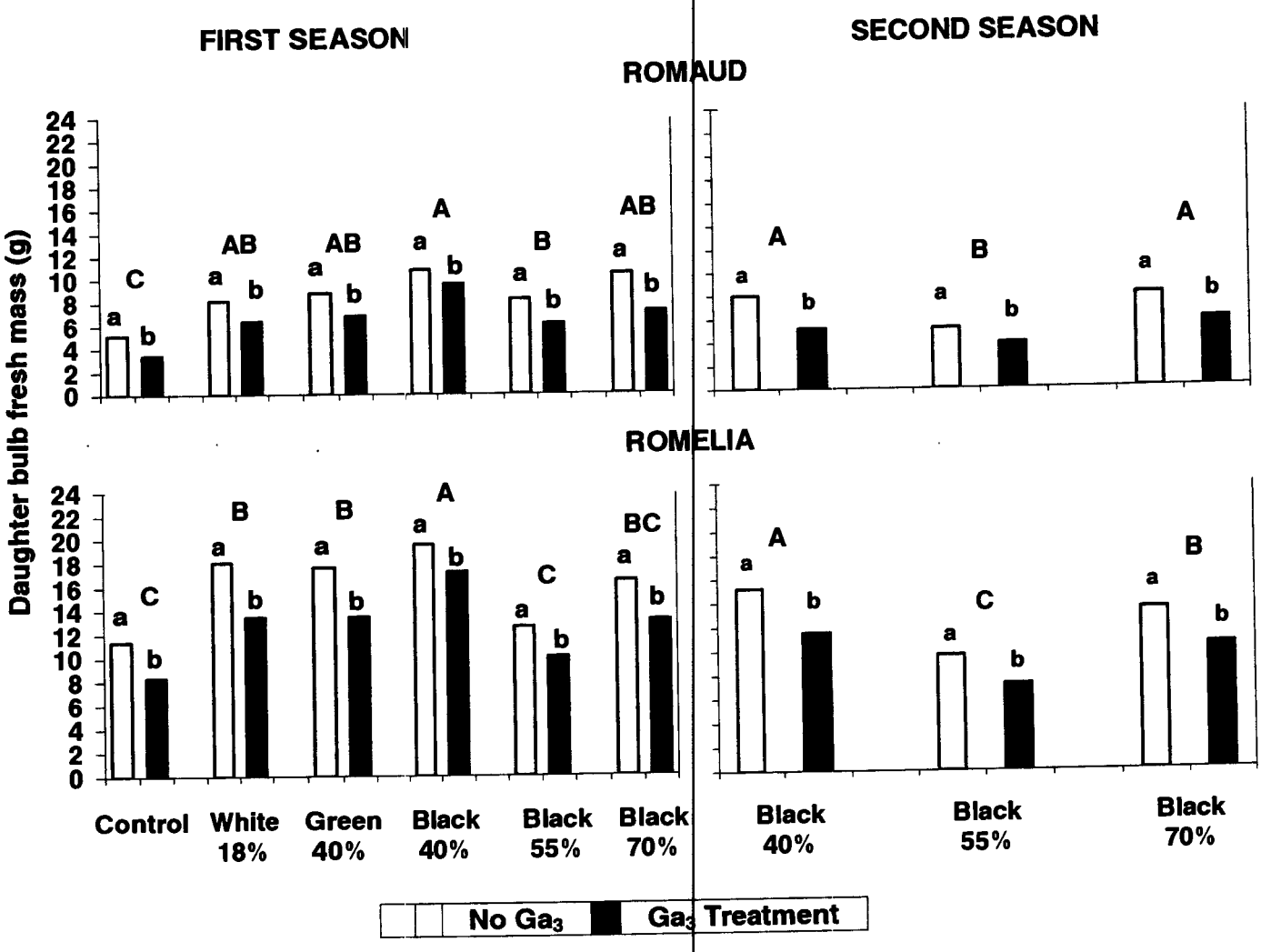

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 5.9 Effect of GA_3 [10 ppm] foliar application (first season) and bulb dip treatment (second season) on daughter bulb fresh mass of two *Lachenalia* cultivars grown under different shade nets.

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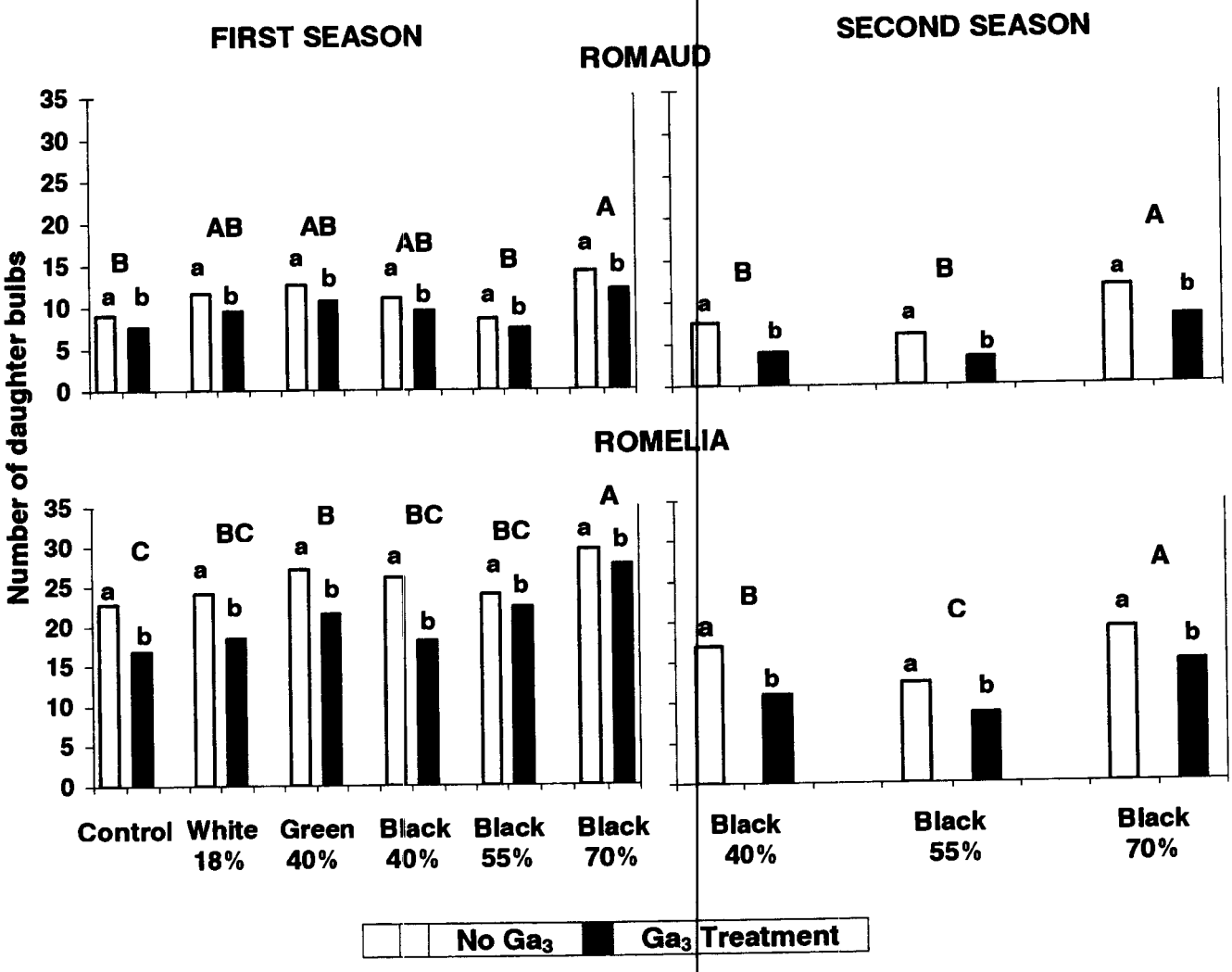

Treatment means with letters in common are not significantly different at $P \leq 0.05$

Figure 5.10 Effect of GA_3 [10 ppm] foliar application (first season) and bulb dip treatment (second season) on the number of daughter bulbs of two *Lachenalia* cultivars grown under different shade nets.

CHAPTER 6

GENERAL DISCUSSION

Lachenalia, endemic to South Africa, has primarily been marketed as a pot plant, but recently the potential use of *Lachenalia* as a cut flower has been recognized. This is because certain cultivars bear relatively long inflorescence stems with flowers of well-developed colour and shape and also have a long vase life. Cultivation factors interact with genetic characteristics of the cultivar, the quality of the harvested flowers being the end-product of this interaction. It is clear that quality management does not start with the harvest but already with the choice of the cultivar. *Lachenalia* cultivars Romaud, Robyn, Rolina and Romelia were chosen to determine which cultivars and cultivation practices are best suited for cut flower purposes. As there is a lack of information regarding the production methods for *Lachenalia* cut flower production, the main aim of this research was to establish basic guidelines for the commercial cut flower grower. Following extensive and critical evaluations, the hypothesis of this study has been met. Maximum average stem lengths of 20cm and higher were produced for all four *Lachenalia* cultivars by making use of different cultivation practices to produce a good quality *Lachenalia* cut flower.

Specific stages of flower development have been described for many cut flowers and used as 'markers' to standardize the specific stages of vase life, in order to achieve a uniform rating for cut flower growers and researchers. A standard uniform rating system of vase life for *Lachenalia* has not yet been established. The complex morphology of *Lachenalia* cultivars complicates the definition of the specific flowering stages. The stage at which 'first flower', 'full flower' and '50% wilt' on the inflorescence of *Lachenalia* cultivar Romaud occured, was illustrated and described in Chapter 2. The same principle used to determine the important flowering stages for cultivar Romaud was then applied to the remaining cultivars in Chapter 3 and 5 to achieve a uniform vase life rating standard in this trial. This

is the first step towards establishing a uniform rating system for *Lachenalia* vase life and leaves space for improvement, if found necessary in the future.

With shade net, it is possible to regulate temperature as well as light quality and intensity to manipulate growing conditions for the specific requirements of various crops and plants. With the development of different coloured shade nets of different densities, the processes of growth and development can be manipulated by changing the spectral quality of the daylight transmitted. This allows the grower to have better control over the environmental conditions that control inflorescence stem length such as light and temperature. A high photosynthetically active radiation (PAR) of 1250 $\mu.mol.m^{-2}.s^{-1}$ and average temperatures of 30ºC and higher in the control, resulted in the shortest inflorescence stem length of about 13 cm for all four cultivars. The inflorescence stem length of 24 cm for cultivars Romaud and Rolina was significantly higher under the black 70% shade net, than the rest of the shade treatments and the control. A low PAR of 400 $\mu.mol.m^{-2}.s^{-1}$ and temperatures in the range of 24ºC to 27ºC prevailed under the black 70% shade net. Cultivars Robyn and Romelia showed interactions with the rest of the shade treatments, but inflorescence stem length was still the highest under the black 70% shade net, followed by the green 40% and black 55% shade nets.

Local climate plays a primary role in causing variation in light and temperature from one habitat to another. Areas of low solar altitudes that receive more light may require greater shade densities than areas of high solar altitudes for the same cultivars. For most shade nets, the shade factor decreases with increasing solar altitude. Therefore in Pretoria, a shade net of higher density may be required compared to Stellenbosch, to be able to produce similar growing environments. Without studying the available light patterns and temperature regimes at a specific growing location, suggestions for a general shading level are speculative.

Stem length is usually controlled by manipulating cultivation practices, for example planting density and by environmental conditions. In Chapter 3, it was confirmed how a high planting density (111 bulbs/m^2) of 10 bulbs per 20 litre black plastic bag (30 cm diameter), significantly increased inflorescence stem length by about 2.5 cm for all four cultivars, compared to the low planting density (56 bulbs/m^2) of 5 bulbs per 20 litre black plastic bag (30 cm diameter).

Mastalerz (1987) found that the ornamental value and vase life of cut flowers is determined by pre-harvest environmental conditions and post-harvest handling and storage conditions. Pre-harvest irradiance and temperature conditions play an influential role in the vase life of *Lachenalia* cut flowers as shown in Chapter 3. The longest vase life of 12 to 14 days and 14 to 16 days under the green 40% and black 40% shade nets was observed for cultivars Rolina and Romelia respectively, when compared to 10 to 11 days and 12 to 14 days in the control.

Cutting, general handling, and placement of the stem in water after harvesting create favourable conditions for contamination of microorganisms, mainly bacteria, on cut surfaces and in the vase water (Larsen and Cromarty, 1967; Marousky, 1969). Bacteria observed in the xylem vessels of *Lachenalia* inflorescences are probably involved in inhibiting water uptake. After day 6 of vase life, the cut surface of the flower stem was covered with bacteria. Bacteria were also identified in the xylem vessels. Fungal hyphae were observed in the parenchyma cells on the cut surface. According to Burdett (1970), the post-harvest quality of cut flowers can be improved by the addition of a bacteriostatic agent to the vase water to reduce blockage of water movement through the stem. In the future, trials should be conducted to determine the effect of different vase life preservatives in prolonging vase life. The incidence of bacteria contaminating the flower stems can be reduced by cutting with a sharp knife or shears to prevent crushing of stem and water-conducting cells.

Temperatures ranged from 31°C to 36°C in the control (full sunlight) and may have led to the abortion of some of the *Lachenalia* inflorescences, as illustrated in Figure 3.8 (Chapter 3). According to Du Toit (2002), inflorescence abortion occurs when *Lachenalia* bulbs are exposed to a high temperature regime. *Tulipa* are also known to abort their flowers when grown or stored under too high or low temperature regimes (De Hertogh and Le Nard, 1993).

Anatomical modifications enable plants to utilize the prevailing environmental conditions, for example high or low light intensity conditions to their optimum capacity. Such modifications were observed in Chapter 4 for *Lachenalia* cultivars Romaud and Romelia. The orientation movement of chloroplasts, the presence of high or low number of chloroplasts and the number of thylakoids/granum amongst others, allows the plant to adjust its photosynthetic processes to changes in the environmental light in order to achieve maximum growth responses. As a result varying changes in plant shape and form are perceived, such as increased flower stem growth, which is required by the cut flower industry. It is therefore important for the grower to consider the effect of different shade densities on plant growth to create optimum conditions necessary for *Lachenalia* cut flower production.

In Chapter 5 it is illustrated how the application of the plant growth regulator gibberellic acid (GA_3), [10 ppm] significantly increased inflorescence stem length by 3 cm for cultivars Romaud and Romelia when applied both as a foliar spray and as a bulb dip treatment. The number of flowers per primary inflorescence decreased significantly by about 3 to 5 flowers for cultivar Romaud and Romelia when GA_3 was applied as a foliar spray or bulb dip treatment. This reduction will not affect the quality of cultivar Romaud because a large number of flowers (about 50) are borne on the inflorescence and a reduction of 3 to 5 flowers will not be noticed. On the other hand, a reduction of 3 to 5 flowers for cultivar Romelia will be easily noticed, because the overall number of flowers borne by the inflorescence is about 20, hence cut flower quality for cultivar Romelia is

reduced. A significant increase in vase life (2 days) of GA_3 treated plants was observed. The increase in length of the inflorescence stem and vase life is an advantage for the cut flower industry, because the overall quality and market value of a cut flower increases with an increase in stem length and vase life.

The economic aspects of GA_3 application to floricultural crops either as a foliar spray or as a bulb dip treatment should be critically evaluated. In this trial, only one concentration of 10 ppm was tested. In the future the effect of a wide spectrum of different concentrations need to be evaluated in order to establish the optimum concentration required to obtain the maximum increase in inflorecence stem length without negative effects on quality. GA_3 may also be more effective when applied at different stages of growth, for example after floral initiation. The use of different gibberellins and their effect on stem elongation should also be evaluated. Other factors to be taken into consideration include, equipment required to apply the specific growth regulator and cost related to the chemical and labour.

Stem length and vase life is an important criterion when evaluating cut flowers. From this study it can be concluded that all four *Lachenalia* cultivars, namely Romaud, Robyn, Rolina and Romelia are suitable for cut flower production. Inflorescence stem lengths with a mean average of 20 cm and higher were produced under the different shade nets and a vase life longer than the required norm by the cut flower industry i.e. 5 to 6 days (De Hertogh, 1977), was achieved by the different cultivation methods for all four *Lachenalia* cultivars. This adds to the pool of potential unique indigenous cut flower species that could provide a competing source of 'new' flowers to countries such as New Zealand and Australia.

Follow up research regarding the effect of different planting dates on *Lachenalia* flower quality and yield is required. A correlation between flower number and planting date has been observed. According to Niederwieser (pers. comm.,

2003), a reduction in the number of flowers on the *Lachenalia* inflorescence occurs, the later the planting date. Different preplant temperatures on inflorescence stem length should also be evaluated to determine the optimum storage temperature for maximum inflorescence stem length. The longest stems for *Ornithogalum dubium* were obtained following six weeks of storage at 13ºC (Luria *et al.*, 2000).

The effect of environmental conditions to which the bulbs were exposed in the previous growing season and storage conditions on cut flower quality will have to be critically evaluated, to determine the most favourable conditions required for *Lachenalia* cut flower production. The acceptance of *Lachenalia* as a new cut flower depends on growers, consumers and marketing skills. There is a need to more thoroughly assess the potential of *Lachenalia* as a new cut flower by applying several criteria such as short turnover production time, good vase life, a good display with multiple flowers at the time of sale and other characteristics. Consumer preferences, such as consumer expectations, must also be evaluated (Lawson and Roh, 1995).

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