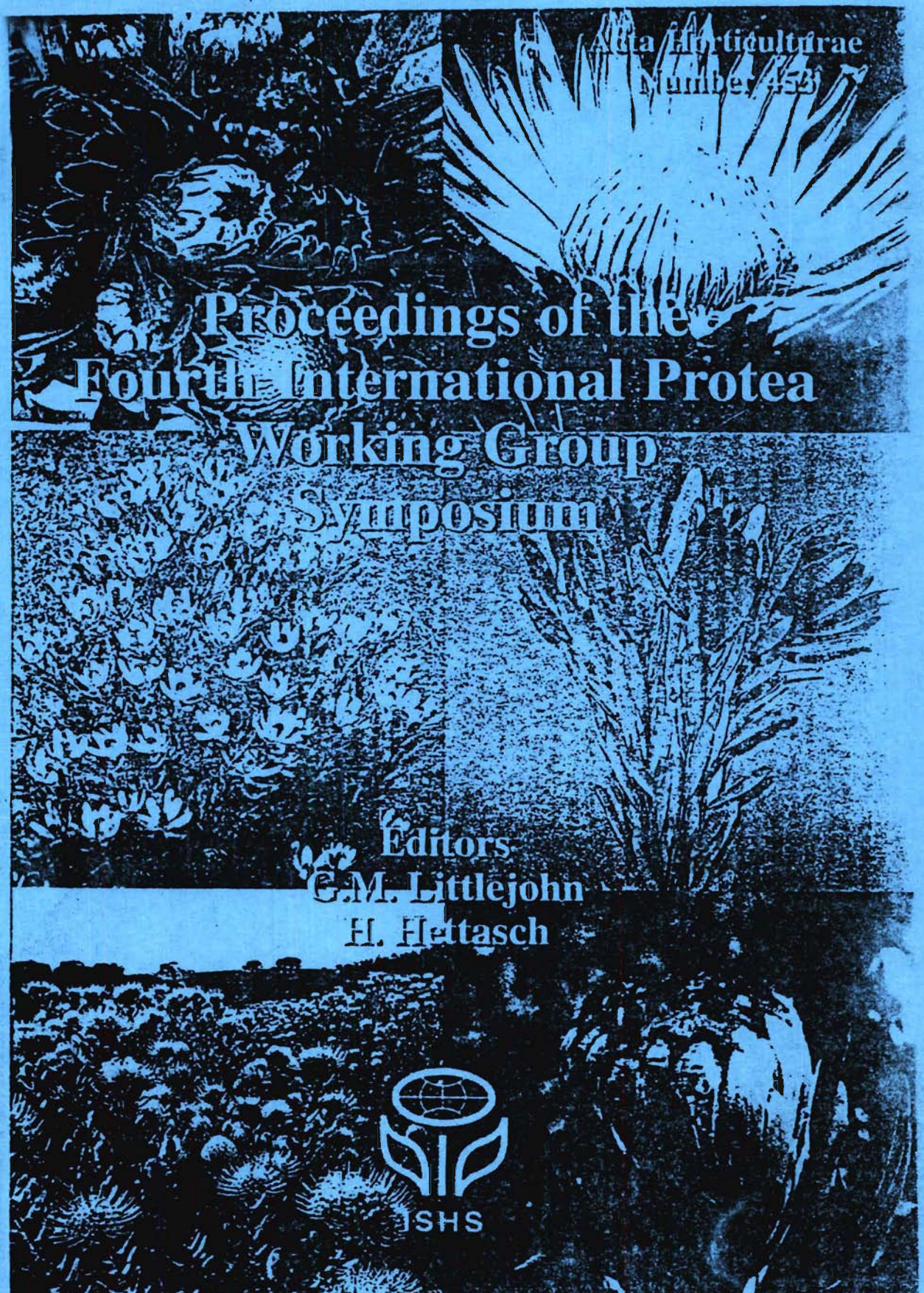


# Proceedings of the Fourth International Protea Working Group Symposium

Editors:
C.M. Littlejohn
H. Hettasch

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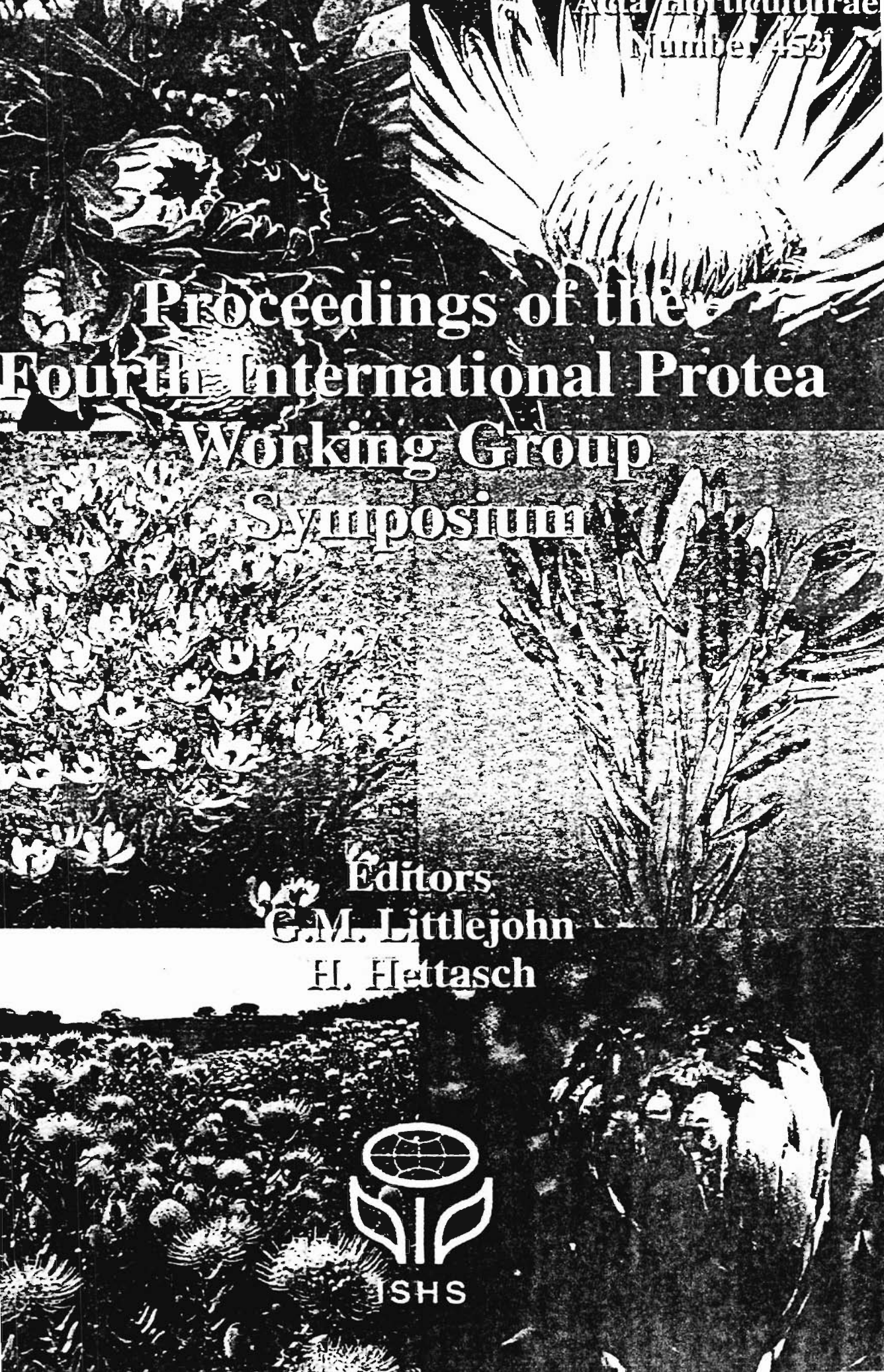
Acta Horticulturae
Number 453



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ISHS

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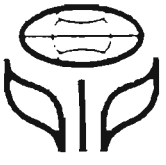



Jerusalem, ISRAEL
17-21 March, 1996

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ISBN 90 6605 929 X. Acta Horticulturae n° 453
Price for non-members of ISHS: Dfl. 100,-
Published by the ISHS, December 1997

Executive Director of ISHS: Ir. J. Van Assche
Kardinaal Mercierlaan 92, 3001 Leuven, Belgium

Printed by Drukkerij Van Damme - Beke, Gulden Peerdestraat 82. 8319 Brugge, Belgium

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## PREFACE

The compilation of this Acta Horticulturae has once again been a marathon event, looking for papers, editing, re-editing and fitting all this in between the necessities of research. However, it has also been fun and hopefully the final documents will provide information for all until the next gathering of minds.

The emphasis in this compilation is somewhat different from previous publications of International Protea Working Group Symposia. The organizing committee in Israel felt that the subject should be broadened to include other plant families from the Southern Hemisphere, therefore the inclusion of papers on plants such as Geraldton Wax. Also, during the conference no distinction was made between presentations made by IPWG members and IPA members. This has resulted in a good mix in the papers included for publication and will make far more interesting reading.

A vote of thanks is extended to all persons (too many to name) assisting in the running of the conference and with the editing and compilation of this Acta: you all did a sterling job.

# SESSION A :
# 'SAFARI SUNSET' AND OTHER *LEUCADENDRONS*

# "CUTTING GRAFTS" FOR *LEUCOSPERMUM* AND *LEUCADENDRON* - A METHOD FOR QUICK PROPAGATION BY SIMULTANEOUS ROOTING AND GRAFTING

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Abstract

The use of grafting onto lime-resistant *Leucospermum* and *Leucadendron* rootstocks has become a successful commercial practice in Israel and, following the perfection of methods for rooting and grafting, it has been shown that simultaneous rooting and grafting is commercially feasible.
A method was developed for quick propagation of these plants under conditions prevailing in Israel, based on grafting desirable cultivars (scions) onto unrooted cuttings (rootstocks) in one operation. Formation of the graft union and of adventitious roots occurred concurrently in a mist propagation unit, resulting in a complete plant in 7-8 weeks.
Using this technique, it is possible to prepare small grafted plants, ready for planting, in 4 months. Since we developed this technology (1992) about 10 ha of 'Safari Sunset' on 'Orot' have been planted in Israel. These plants have developed much more rapidly and better than ungrafted plants.

## 1. Introduction

The problems encountered with growing proteas differ in different parts of the world, and so do the solutions required to facilitate commercial production (Ben-Jaacov, 1986; Harre, 1988; Brits, 1990 a,b; Ackerman, *et al.*, 1995a).

Cultivation of the usual, commercial proteaceous cultivars in Israel is limited by high-pH, alkaline soil, high nutrient levels, root diseases and nematodes (Ben-Jaacov, *et al.*,1992 a,b; Ackerman, *et al.*, 1994). To overcome these problems, we selected highly tolerant and vigorous rootstocks (Ben-Jaacov, *et al.*, 1991; Ackerman, *et al.*, 1995c), since the development of plants grafted onto these rootstocks forms the key for successful protea cultivation on a large commercial scale in Israel (Ben-Jaacov, *et al.*, 1991 a,b ; 1992; 1994; Ackerman, *et al.*, 1994; Ackerman, *et al.*, 1995 b,c).

The problems and effectiveness of conventional grafting techniques in protea were studied by Brits, 1990a. Experiments with wedge grafting of containerized rootstocks with semi-hardwood scions gave good results with *Leucospermum* and *Protea* (Brits, 1990a,b; Turnbull and Moffatt 1994, Ackerman, *et al.*, 1995b). Table grafting onto pot-grown rootstocks is more widely used for woody ornamentals than for unrooted cutting grafts (Hartman, *et al.*, 1990).

The cutting-grafting technique is based on grafting scions onto unrooted rootstocks: they are tied together and placed into a mist propagation that stimulates concurrent, quick rooting of the rootstock and a union of the scion and the rootstock to produce new grafted plant. This technique is not new (Bailey, 1896); it has been used successfully in *Rhododendron* (Eichelser, 1967), *Grevillea* (Burke, 1989; Gibian and Gibian, 1989), *Rose* (van de Pol and Breukelaar, 1982), *Protea*, and *Leucospermum* (Jacobs, 1981; Brits, 1990a; Turnbull and Moffatt, 1994; Moffatt and Turnbull, 1994).

The objectives of the present study were: an improvement of the cutting-graft technique and its adaptation for year-round commercial use, for quick propagation of *Leucadendron* and *Leucospermum* cultivars grafted on rootstocks tolerant to calcareous soils.

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Eds. G.M. Littlejohn, H. Hettasch
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## 2. Materials and methods

### 2.1. Plant material

The plant material was obtained from plants grown at the Department of Ornamental Horticulture, A.R.O., the Volcani Center, Bet Dagan.

The rootstocks: The lime-tolerant *Leucospermum* rootstocks, 'Nemastrong' and 'Carmeli' (Ackerman, *et al.*, 1995c) and *Leucadendron* rootstock, 'Orot' (Ben-Jaacov, *et al.*, 1991; 1992a,b; 1994), were used.

The cultivars: The following *Leucospermum* cultivars were used as scions: 'Ballerina', 'Caroline', 'Vlam', 'High Gold', 'Yellow Bird', 'Sunrise', and the *Leucadendron*, 'Safari Sunset'.

### 2.2. Grafting procedure

The wedge-grafting technique was carried out for the closest possible match between cambium tissues of the scions and rootstocks. The bound scion-rootstock combinations, 15-20 cm in length were treated as conventional cuttings.

Scion preparation: 10-15-cm-long semi-hardwood terminal shoots were used. They were cut into 2 or 3 scion units (5 cm each). Leaves were removed from the base of each scion, leaving 2 - 4 leaves at the top. Two sloping cuts, about 2 cm long were made to form a wedge (figure 4. A).

Rootstock preparation: Semi-hardwood stem sections, 10-15 cm long, from the current season's growth, were used. Several leaves from the top and the base of the cuttings were removed, leaving a few leaves (3 leaves on *Leucospermum* and 4-6 on *Leucadendron*) on the central section of the cutting-rootstock (figure 4. B). Vertical cuts were made and after matching the graft (figure 4. C), tying was done with P.V.C. elastic grafting tape or 10-cm-long laboratory parafilim strips ("M" parafilim (TM) manufactured by American National Can) that decompose naturally after 3-4 months.

### 2.3. Treatment of cutting-graft

The base of the unrooted cutting-grafts were dipped into a 4,000-ppm solution of IBA for 10 seconds as usual with conventional cuttings.

### 2.4. Rooting medium

Well aerated rooting medium comprising of 40% peat with 60% polystyrene was placed in multi-hole plastic propagating trays (51 or 99 holes), and the bases of cutting-grafts were inserted to a depth of 2 cm.

### 2.5. Rooting conditions

Rooting was generally done under standard controlled mist-bed conditions. When rooting was done during the summer months ventilation and shading (40%) were necessary to prevent excessive heat in the greenhouse.

The cutting-graft trays were placed in a mist propagation unit with a bottom temperature of 21-22 °C. The successfully rooted and sprouted plants were potted in 6.5 x 6.5 x 7.5-cm plastic pots and were ready for planting 4 months after the cutting-grafts had been made.

2.6. Time of cutting-grafts

Grafting experiments with *Leucospermum* were conducted during the summer and autumn. Cutting-graft experiments with *Leucadendron* were conducted in a commercial protea nursery in the summer, autumn and winter.

2.7. Effectiveness of grafting

The percentages of successful grafts of *Leucospermum* and *Leucadendron* cultivars were evaluated after 2 and 3 months, respectively.

## 3. Results

3.1. Take percentage of cutting-grafts of 6 *Leucospermum* cultivars onto 'Nemastrong' and 'Carmeli' rootstocks.

The grafting and rooting success rates in *Leucospermum* are presented as percentages in table 1; they are affected by three main factors: The rootstock (fig. 1), the cultivar (fig. 2), and the season (fig. 3).

Figure 1 shows that the overall cutting-graft take percentage of 6 *Leucospermum* cvs. grafted onto 'Nemastrong' and 'Carmeli' rootstocks were 71 and 72%, respectively.

Figure 2 shows that the cutting-graft take percentages of 6 *Leucospermum* cvs. grafted on the two rootstocks were between 63 and 79%. The highest graft take percentages were of 'Sunrise', 'Vlam' and 'High Gold', and the lowest percentage was of 'Caroline'.

Figure 3. Here we can see that the best overall graft-take percentages of six *Leucospermum* cultivars grafted on the two rootstocks were for those grafted at the end of summer and in autumn.

3.2. Take percentages of cutting-grafts of *Leucadendron* 'Safari Sunset' onto 'Orot' rootstock.

The cutting-grafts were made and data was collected at the Polak commercial nurseries in summer, autumn and winter. The final evaluation was made 90 days after grafting (table 2), and the cutting-graft take percentage was 72-88%. Part (66%) of the 'Safari Sunset' cutting-grafts were ready for potting 60 days after grafting.

## 4. Discussion

Many of the problems associated with the protea root system can be overcome by grafting commercial cultivars onto tolerant rootstocks.

In proteas the problems and efficiency of the conventional technique of grafting on containerized rootstocks were studied by Ben-Jaacov, *et al.* (1991; 1992; 1994), Brits (1990a,b), Turnbull and Moffatt (1994) and Ackerman, *et al.* (1995b), but that technique takes more time than the cutting-graft method, is more expensive (fig. 5), and was unsuccessful during the summer (unpublished data).

The method for quick propagation by simultaneous rooting and grafting is not new and indeed has been used by many researchers on an experimental scale. This method is being used commercially for roses in the Netherlands and in Israel.

Perfection of the technology of cutting-grafts has been followed by the successful large-scale use of this method in the commercial propagation of *Leucadendron* cultivars in Israel. With this method it is possible to produce complete grafted plants in 4-8 weeks for *Leucospermum* (figs. 6 and 7) and 6-8 weeks for *Leucadendron* (fig. 9).

Enhancement of the commercial use of cutting-graft in *Leucospermum* was possible after the development of the 'Carmeli' and 'Nemastrong' fast-rooting rootstocks (figs. 6,7,8 and 10).

The advantages of cutting-grafts are:

1. Cultivars grafted onto tolerant rootstocks gave more vigorous growth, higher production and better quality of flowers.
2. Cutting-graft is a quick propagation technique that can be applied year-round and is suitable for rapid large-scale commercial production.

    a) Formation of the graft union and of adventitious roots occurred concurrently under mist, resulting in a complete grafted plant in 4-8 weeks.
    b) Those plants transplanted into small containers were ready for field planting in 3-4 months.

3. This technique results in greatly reduced time, growing-space requirements and cost, for the production of small grafted plants.

## 5. Conclusions

Since we developed this technology in 1992, about 10 hectares of 'Safari Sunset' on 'Orot' have been planted in Israel. These plants have developed much more rapidly and better than ungrafted plants. The method is also ready for large-scale, commercial production of *Leucospermum*. Presently, we are testing the possibility that young plants produced by cutting-grafts are of higher quality than those grafted on containerized rootstocks (since less root-bounding occurs in cutting-graft plants).

## Acknowledgments

Contribution from the Agricultural Research Organization, The Volcanic Center, Bet Dagan. No. 1879 E 1996 series.
The authors wish to acknowledge Nilli Shemi and Edna Peleg for their help in grafting, and to R. Arlevski and S. Polak of Polak Nurserises for providing the propagation facilities and for help in commercial grafting and data collecting.

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Table 1. Cutting-graft take percentages of *Leucospermum* cultivars on two lime-tolerant rootstocks: 'Nemastrong' and 'Carmeli'*

| Scion | Date of grafting | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 6/94 | | 7/94 | | 8/94 | | 10/94 | | 11/94 | |
| | Rootstock | | | | | | | | | |
| | Nem. | Carm. | Nem. | Carm. | Nem. | Carm. | Nem | Carm. | Nem. | Carm. |
| Ballerina | 45 | 40 | 30 | 35 | 86 | 78 | 89 | 92 | 96 | 90 |
| High Gold | 70 | 85 | 24 | 71 | 97 | 66 | 95 | 71 | 72 | 85 |
| Yellow Bird | 69 | 74 | 43 | 74 | 88 | 65 | 67 | 38 | 67 | 86 |
| Caroline | 71 | 75 | 46 | 50 | 66 | 38 | 72 | 74 | 68 | 67 |
| Sunrise | 86 | 88 | 69 | 74 | 84 | 67 | 91 | 91 | 86 | 77 |
| Vlam | 67 | 69 | 56 | 77 | 95 | 92 | 62 | 93 | 89 | 71 |

* Results of 150 scion-rootstock combination at each date (A.R.O., Bet Dagan).

Table 2. Cutting-graft take percentage of *Leucadendron* 'Safari Sunset' on 'Orot' rootstock*

| Days after | Date of grafting | | | | | | |
|---|---|---|---|---|---|---|---|
| grafting | 17/5/95 | 15/6/95 | 15/7/95 | 17/8/95 | 20/9/95 | 3/10/95 | 5/11/95 |
| 60 | 56 | 58 | 77 | 63 | 73 | 69 | 75 |
| 90 | 72 | 78 | 84 | 74 | 80 | 79 | 88 |

*The results of 300 cutting-grafts on each date were collected at Polak Nurseries.

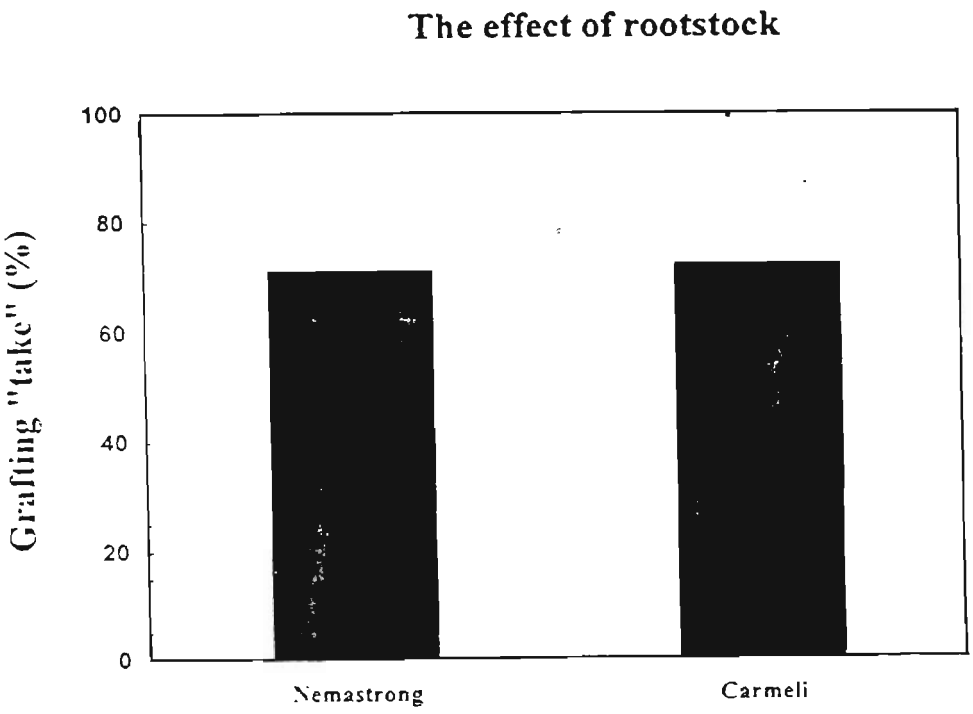


Fig. 1. Cutting-graft take percentage of six *Leucospermum* cultivars grafted on two rootstocks.

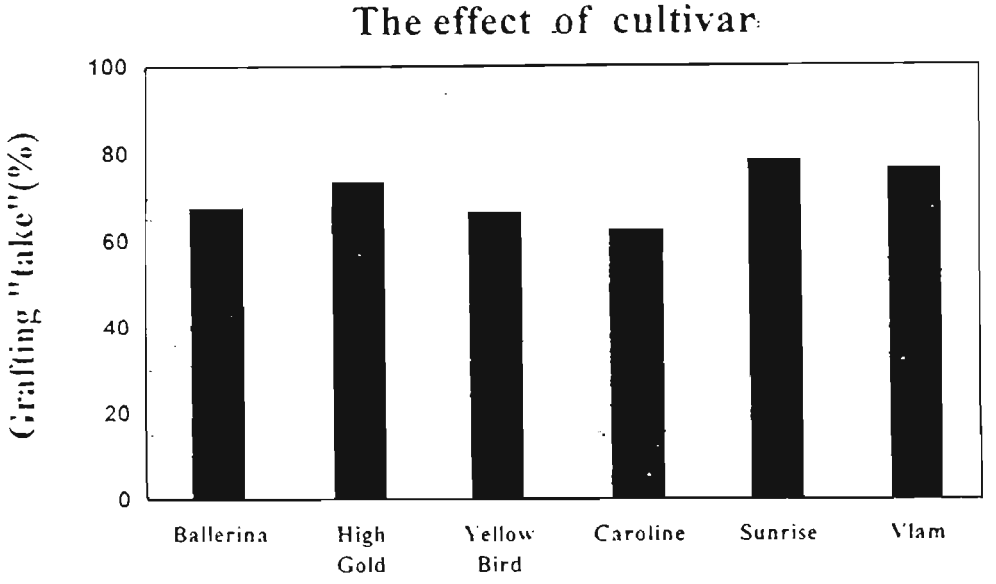


Fig. 2. Cutting-graft take percentage of six *Leucospermum* cultivars grafted on two rootstocks ('Nemastrong' and 'Carmeli')

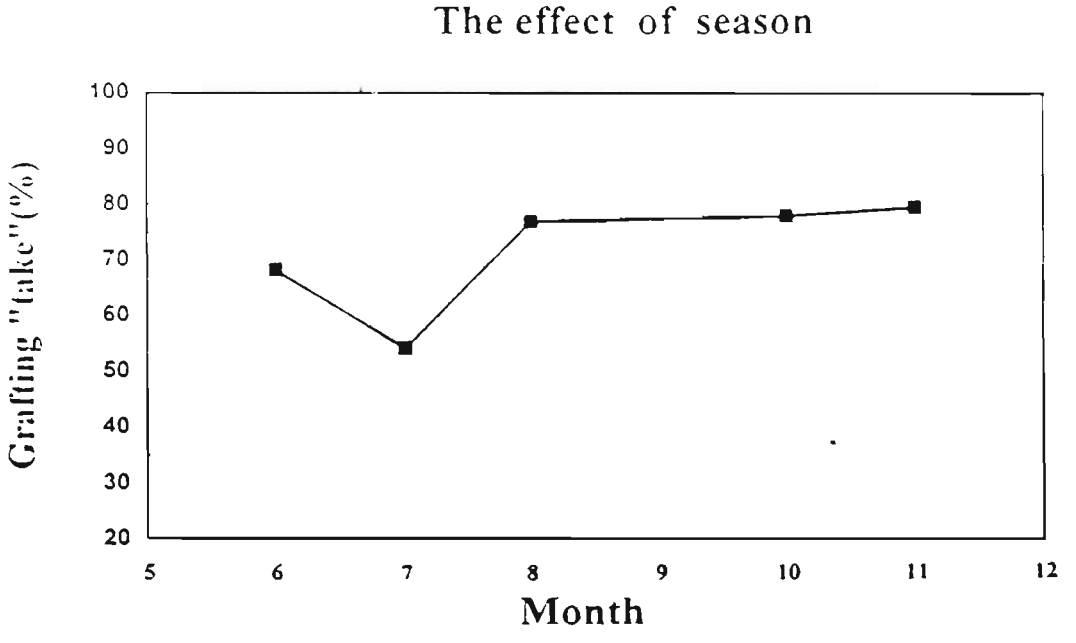


Fig. 3. Cutting-graft take percentage of six *Leucospermum* cultivars grafted on two rootstocks grafted at different times.

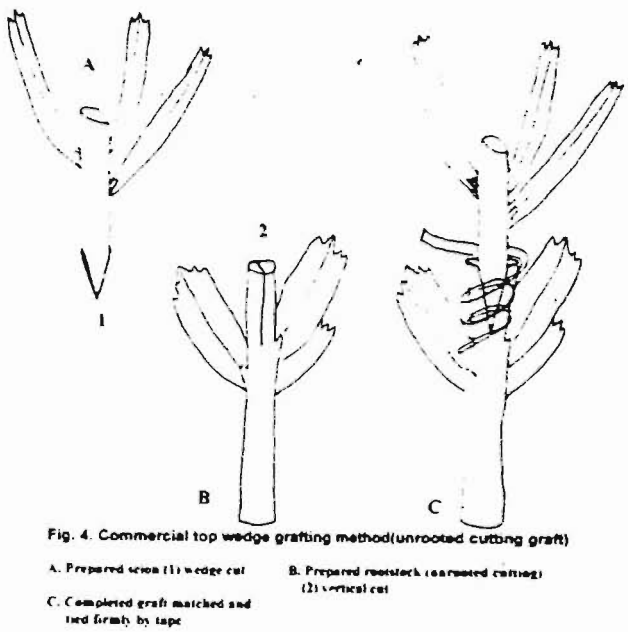


Fig. 4. Commercial top wedge grafting method(unrooted cutting graft)

A. Prepared scion (1) wedge cut

B. Prepared rootstock (unrooted cutting) (2) vertical cut

C. Completed graft matched and tied firmly by tape

Fig. 4. Commercial top wedge grafting method (unrooted cutting graft)
A. Prepared scion (1) wedge cut
B. Pepared rootsrock (unrooted cuttings)
C. Completed graft matched and tied firmly by tape

Rootstocks

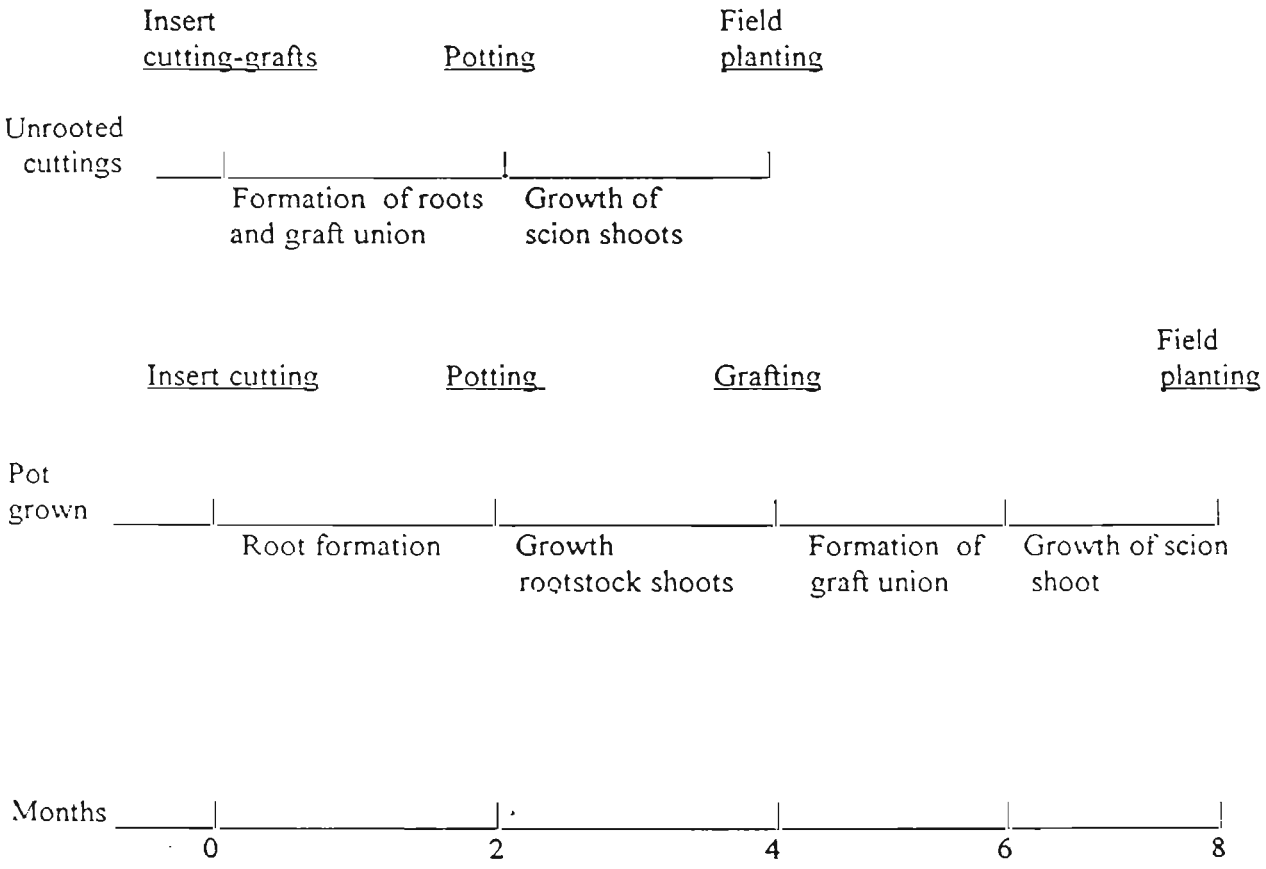


Figure 5. Diagram of basic production systems of desirable plants top-wedge grafted onto pot-grown and unrooted rootstocks.


Fig. 6. Complete grafted plant, 1 month old of 'Ballerina' grafted onto 'Carmeli' rootstock.


Fig. 7. 'High Gold' grafted onto 'Nemastrong' rootstock, 8 weeks old.

Fig. 8. Fast-rooting cutting of 'Carmeli' rootstock after 1 month in the propagation unit.


Fig. 9. Complete grafted plant, 2 months old, of 'Safari Sunset' grafted onto 'Orot' rootstock.

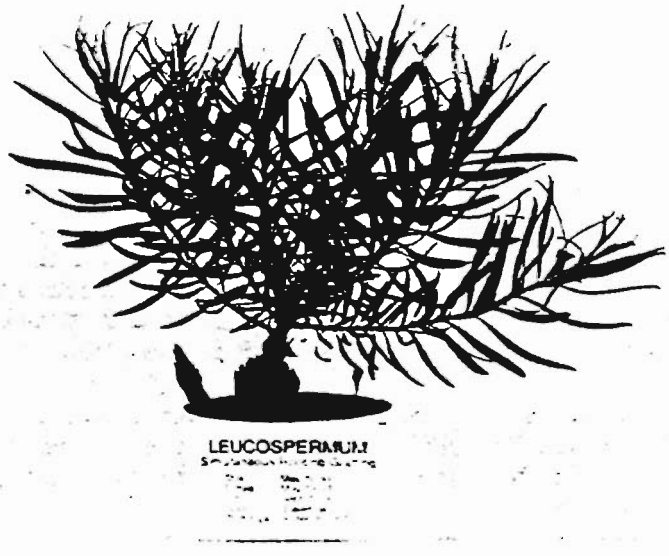


Fig. 10. Four month old 'Ballerina' plant grafted onto 'Carmeli' rootstock by cutting-graft.

# INFLUENCE OF CUTTING POSITION, WOUNDING AND IBA ON THE ROOTING OF *LEUCADENDRON DISCOLOR* STEM CUTTINGS

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Abstract

*Leucadendron discolor* was introduced in Tenerife in 1988 by the cooperative Florican. Rooted cuttings were imported from Israel and a small plantation was set in Los Rodeos (La Laguna) at 600 m.a.s.l.
The attempts to propagate *L. discolor* by stem cuttings using the standard technique in the Florican nursery proved to present some difficulties, with rooting percentage not satisfactory from the commercial point of view (about 50%).
With the purpose of observing if the basal wounding technique (two shallow and opposite incisions) combined with different IBA concentrations, could improve the results of the rooting process, an experiment was carried out in which terminal and basal cuttings were rooted in winter-spring with bottom heat (25 ± 2 °C) and microjet irrigation.
A randomized block design was used with five treatments and four replications. The number of cuttings for each treatment was 10. The total number of cuttings was 200. The treatments used were the following: A) wounded terminal cuttings treated with 4000 ppm of IBA; B and D) wounded and no wounded basal cuttings treated with 2000 ppm of IBA, respectively; C and E) wounded and non wounded basal cuttings treated with 4000 ppm of IBA, respectively.
At the end of the trial (20 weeks) treatment A showed the higher percentage of transplantable cuttings (85%), followed by treatments C (52.5%), B (25%), E (15%) and D (5%). The rooting process was much faster and the cuttings developed a more vigorous root system in treatment A, which was significantly different from the other four treatments.
In wounded cuttings two ranks of callus nodules appeared along the edges of each incision. Roots emerged associated with the ranks of callus nodules.

## 1. Introduction

The cultivation of *Leucadendron discolor* L. was introduced in Tenerife in 1988 by the cooperative Florican, which imported rooted cuttings form Israel and set a small plantation in Los Rodeos (La Laguna) at 600 m above sea level. A nursery to provide protea plants to the growers was established a few years later.

Terminal and subterminal stem cuttings are commonly used in the propagation of *Leucadendron* spp. (Jacobs and Steenkamp, 1975; Malan, 1992). As there is a cluster of nodes at the base of the cuttings that favours the rooting process, the utilization of basal cuttings has been recommended (Harré, 1988)

As in other protea species, great differences in the rooting ability of stem cuttings exist among *L. discolor* clones. Rooting percentages of 5%, 50% and 80% (Brits, *et al.*, 1992) and of 0 - 77% (Epstein and Ackerman, 1993) have been reported.

The basal wounding technique alone or combined with other treatments (IBA) has been used to stimulate root formation in some plant species (Edwards and Thomas, 1979; Pontikis, *et al.*, 1984; Howard, *et al.*, 1984b; Howard, *et al.*, 1984a).The technique has been used successfully for propagation of *Protea obtusifolia* (Rodríguez Pérez, 1990) and *Leucadendron* 'Safari Sunset' (Rodríguez Pérez, *et al.*, 1993).

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The commercial propagation of *L. discolor* by terminal cuttings gave unsatisfactory results in the Florican nursery, with rooting percentages around 50%.

In a previous trial, it was found that wounded terminal cuttings treated with 4 000 ppm of IBA rooted better and faster than unwounded ones.

In order to study the influence of cutting position (terminal and basal), wounding and IBA concentration on the rooting of *L. discolor* stem cuttings, the present study was carried out.

## 2. Material and methods

Semi-hardwood cuttings of *L. discolor*, 17 cm long, from current season's growth, were taken in January. Mother plants were approximately four and a half years old. Terminal cuttings were from stems over 30 cm long, taken from 6 plants. Basal cuttings, from shorter stems were collected from 14 plants.

A randomized block design with five treatments (10 cuttings per treatment) and four replications was used. The total number of cuttings was 200.

The treatments used were the following:

| | | |
|---|---|---|
| A. wounded | terminal cuttings treated with | 4 000 ppm of IBA. |
| B. wounded | basal cuttings treated with | 2 000 ppm of IBA. |
| C. wounded | basal cuttings treated with | 4 000 ppm of IBA. |
| D. unwounded | basal cuttings treated with | 2 000 ppm of IBA. |
| E. unwounded | basal cuttings treated with | 4 000 ppm of IBA. |

The solution of IBA was in 50% ethanol. In wounded cuttings, two shallow and opposite incisions were made with a sharp blade in the basal bark, penetrating as far as the outer cortex and extending upwards for about 2 cm.

Cuttings were striped of leaves on their basal half and a fresh cut 2 cm long was made at the base of each cutting. The cuttings were then, wounded or not, according to the treatment, dipped on the hormonal solution to 2mm depth, for five seconds, followed by a dip in talc containing benomyl and captan, both at 5% of a.m. concentration, before planting them in a mixture of polysterene grains and peat moss (6:4 in volume) in plastic propagating trays. The trays were placed on a bed with bottom heat (25 ± 2 °C) in a well ventilated greenhouse, with 60% reduction of natural light. Irrigation was by microjets, at 50 l/h for 10 - 20 seconds, depending on the weather, every half hour, between 9:00 and 16:00 h.

Cuttings were sprayed weekly with a mixture of benomyl, captan, chlortalonil or iprodione, and diazinon or metomilo to control pests and diseases.

At 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20 weeks from planting, cuttings were scored as follows:

a = dead cuttings.
b = cuttings without callus.
c = cuttings with callus.
d = rooted cuttings but not transplantable.
e = transplantable cuttings.

Results as percentage of transplantable cuttings were subjected to analysis of variance, using the arcsin transformation, and to the Duncan test. Chi square tests for independence were performed when necessary.

## 3. Results and discussion

The development of the cuttings throughout the experiment can be seen in figure 1. Wounding accelerated the formation of roots in basal cuttings. At 2 weeks from planting treatments B and C (wounded) showed 25% and 27.5% of cuttings with roots but not transplantable, whilst treatments D and E (unwounded) showed 0% and 7.5%, respectively. However, treatment A (terminal, wounded) showed the highest percentage of cuttings of this type (30%). These results are in accordance with those obtained by Pontikis, *et al.* (1984) in M27 apple; Howard, *et al.* (1984a) in *Simmondsia chinensis*; Howard, *et al.* (1984b) in M26 apple; Rodríguez-Pérez (1990) in *Protea obtusifolia*, and Rodríguez-Pérez, *et al.* (1993) in *Leucadendron* 'Safari Sunset'.

Increasing IBA concentration favoured root formation in unwounded basal cuttings. After 4 weeks from planting, treatment E (4 000 ppm of IBA) showed 80% of cuttings with roots but not transplantable compared with 50% of treatment D (2 000 ppm of IBA). Wounded basal cuttings showed the same behaviour, but the effect was not so clear, as treatment C (4 000 ppm of IBA) showed 85% of rooted cuttings compared with 72.5% of treatment B (2 000 ppm of IBA). These results agree with those obtained by Howard, *et al.* (1984b) in M.26 apple.

The first transplantable cuttings of treatments A and C appeared at 4 and 8 weeks, respectively, while those of treatments B, D and E appeared at the end of the trial (at 20 weeks). The rooting process was much faster and the cuttings developed a more vigorous root system in treatment A than in the other treatments.

In wounded cuttings, both terminal and basal, two ranks of callus nodules appeared along the edges of each incision. Roots emerged associated with the ranks of callus nodules. Split base wounded winter cuttings of M.26 apple rootstock had showed the same behaviour (Howard, *et al.*, 1984b; Mackenzie, *et al.*, 1986).

At the end of the experiment treatment A showed the highest percentage of transplantable cuttings (85%), followed by treatments C (52.5%), B (25%), E (15%), and D (5%). The analysis of variance and the Duncan test indicated that treatment A was significantly different from the other four treatments, at the level of 5% (Table 1). Although between treatments C and B there were not significant differences, the former was significantly different from treatments D and E. However, when treatment B was compared with treatment C in a Chi square test for independence in a 2 X 2 contingency table, there was a significant difference at the 5% level between both treatments ( $\chi^2 = 6.37$ ).

In conclusion, the use of wounded terminal cuttings treated with 4 000 ppm of IBA is recommended for the propagation of *L. discolor* by stem cuttings. The same treatments are also recommended if basal cuttings were used.

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Table 1 - Influence of cutting position, wounding and IBA on the rooting of *Leucadendron discolor* stem cuttings.

| Treatments | Rooting percentage |
|---|---|
| A (T, W, 4 000 ppm IBA) | 85.0 a[z] |
| B (B, W, 2 000 ppm IBA) | 25.0 bc |
| C (B, W, 4 000 ppm IBA) | 52.5 b |
| D (B, U, 2 000 ppm IBA) | 5.0 d |
| E (B, U, 4 000 ppm IBA) | 15.0 cd |

[z] Mean separation by the Duncan test, 5% level, performed on arcsin transformed data.
T=terminal; B=basal; W=wounded; U=unwounded.

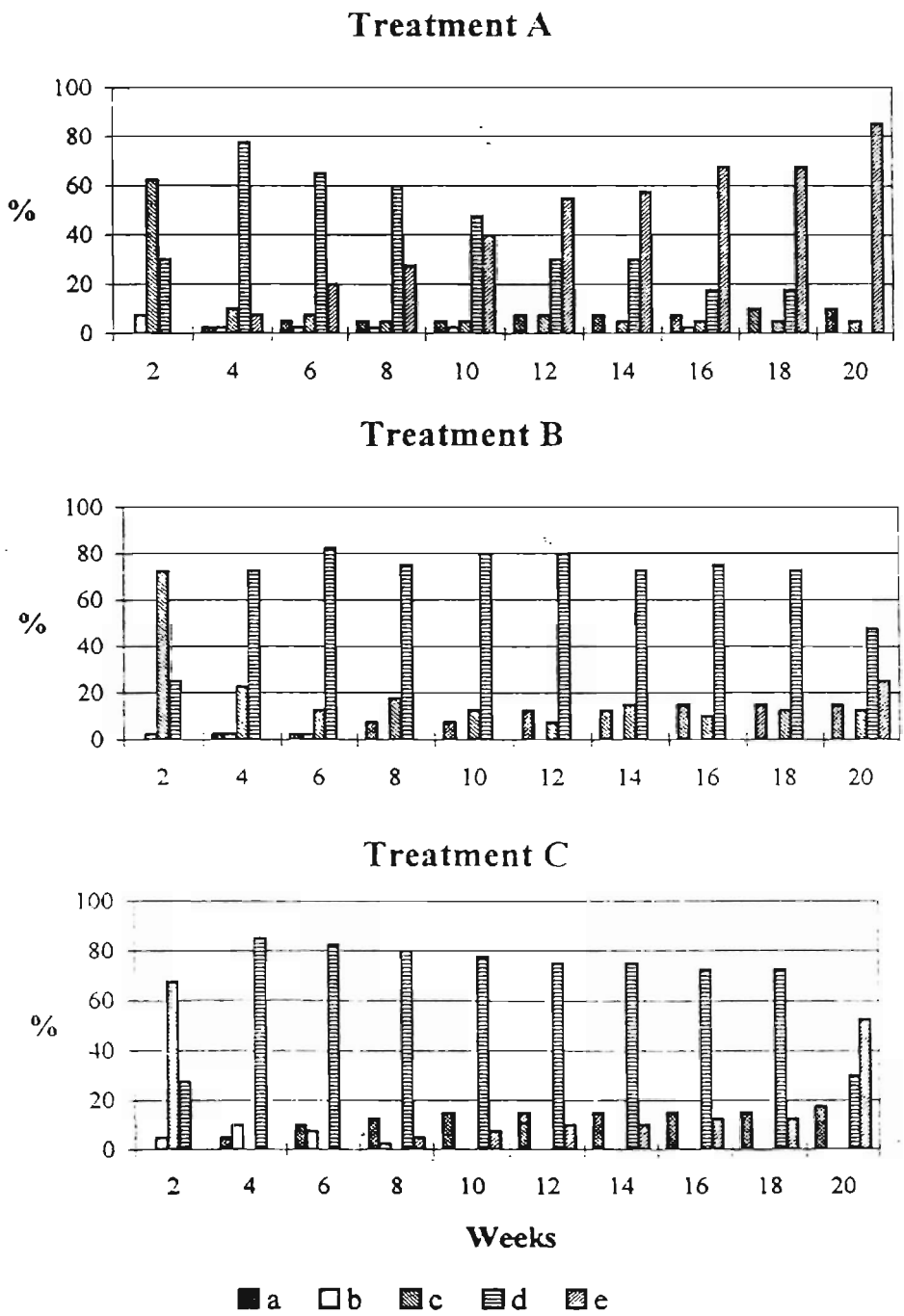


Figure 1 - Influence of cutting position, wounding and IBA on the rooting of *Leucadendron discolor* stem cuttings.
a = dead cuttings; b = cuttings without callus; c = cuttings with callus

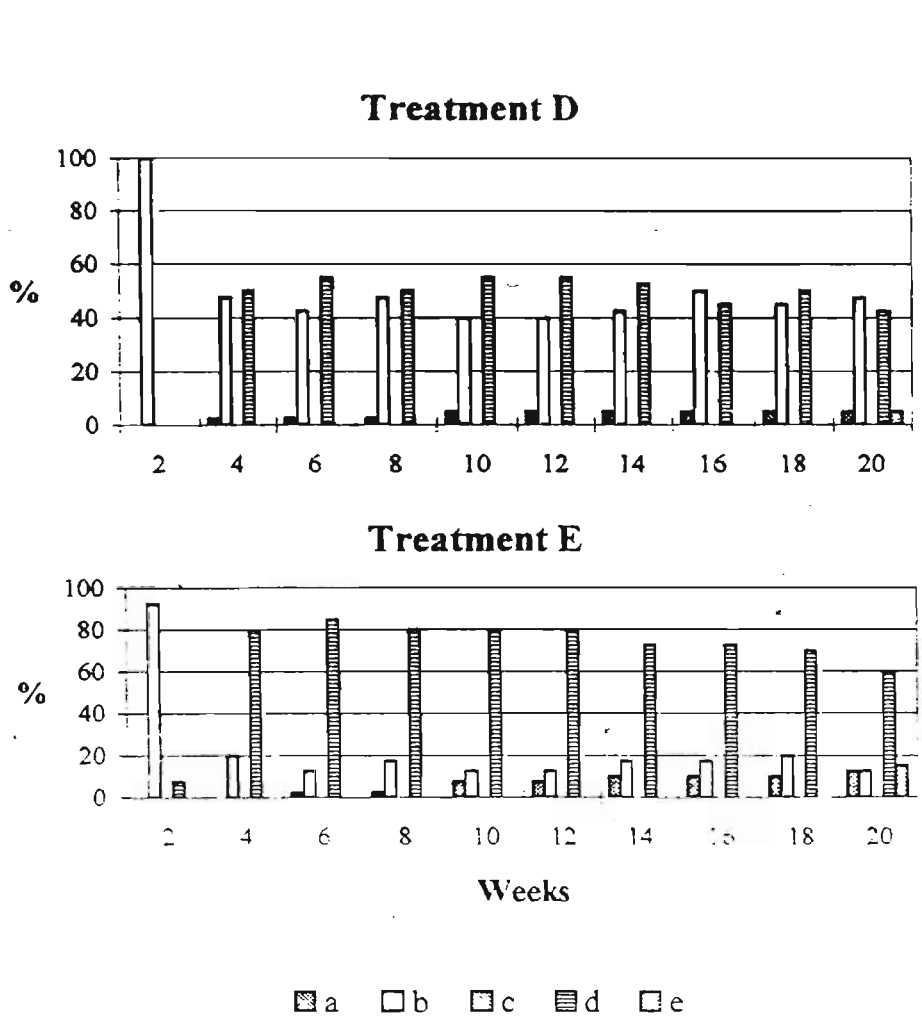


Figure 1 - Influence of cutting position, wounding and IBA on the rooting of *Leucadendron discolor* stem cuttings.
d = rooted cuttings but not transplantable; e = transplantable cuttings.

# EFFECTS OF PHOSPHORUS AND NITROGEN CONCENTRATION ON *LEUCADENDRON* 'SAFARI SUNSET' DEVELOPMENT

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## Abstract

A greenhouse experiment was conducted to establish the optimal fertilization management for *Leucadendron* 'Safari Sunset'. Adding fertilizers or raising phosphorus concentration increased yield and improved plant growth. Root weight increased as nutrient levels rose. Clusters of proteoid roots were present all along the root system of tap-water-irrigated plants, only few proteoid roots developed on plants irrigated with complete nutrient solution when only P was omitted, and none were developed in any of the other treatments.
Elevating the total nutrients or P concentrations increased N and P concentrations in the plants. The calculated N and P concentrations in mature leaves required to achieve maximal shoot weight were 33.1 and 10.7 g $kg^{-1}$ dry matter, respectively.
The present study demonstrates that as long as sufficient amounts of micronutrients are provided through the irrigation solution, addition of 20 mg $l^{-1}$ P improves 'Safari Sunset' growth without indication of toxic symptoms that could be attributed to an excess of P.

## 1. Introduction

The Proteaceae family originated in Australia and South Africa, where most of the cultivated species grow on acidic, washed soils, which are poor in nutrients. The general belief is that the plants belonging to this family are unresponsive to fertilization (Buining and Cresswell, 1993), and sensitive to high phosphorus concentration (Nichols, *et al.*, 1979). Toxicity symptoms such as growth reduction and leaf necrosis in the presence of high P concentration, have been described in many Proteaceae plants (Goodwin, 1983). Despite the proper climate, growing Proteaceae plants in Israel is problematic because of soil limiting factors, such as basic pH and high free lime content. *Leucadendron* 'Safari Sunset' is the sole commercially product of Proteaceae species in Israel (Ben-Jaacov, 1986). Israeli growers attributed various growth disorders of plants to high soil P content and therefore their cultivation was restricted to soils having low P concentration.

To avoid soil restrictions, 'Safari Sunset' is grown in Israel in tuff at the immediate root system. Tuff is a volcanic material, characterized by high porosity and high saturated hydraulic conductivity. Therefore, tuff enables frequent irrigation without fear of air deficiency.

The objective of this research was to study the response to the nutrient concentration of *Leucadendron* 'Safari Sunset' plants grown in tuff. A special attempt was made to determine the role of P in the growth and development of these plants in order to establish the optimal management of fertigation.

## 2. Materials and methods

The experiment was conducted in a screen-house at Bet Dagan, Israel (35°E, 31°N, 50 m alt.) irradiated by natural sunlight (1400-1600 $\mu mol^{-1}$ m-PPF) at a temperature range between 12 and 35 °C. Two-month-old *Leucadendron* 'Safari Sunset' plants were planted

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in 10 l pots filled with 0-8 mm tuff, two plants per pot. The experiment started in May, 1992, and was terminated in December 1992. The plants were irrigated daily with 1 l of the experimental nutrient solutions. The experiment consisted of six treatments in a non-factorial design (Table 1).

Ten single-pot replicates were arranged in a completely randomized design. Control containers without plants were fertilized identically to the experimental treatments in order to determine nutrient retention by the tuff. Leachates were collected weekly into containers placed under the pots, sampled, and analyzed for pH, EC and nutrient concentrations. Element concentrations were determined as follows: Na and K by EEL flame photometer, total N and P by Technicon Autoanalyzer, Ca and Mg by Perkin Elmer 460 atomic adsorption spectrophotometer, and Cl by Buchler Cotlove chloridometer automatic titrator. Water uptake by plants was calculated from the difference between volume of leachate collected from pots with plants and from control pots without plant.

During the experiment, stem diameter of all plants was measured five times at the same height. At the end of the experiment the plants were divided into roots, stems, mature leaves and young leaves. Fresh and dry (after drying at 60 °C) weights of the plant organs were determined. Dry plant material was ground to pass a 20-mesh sieve. One hundred mg samples were wet ashed with $H_2SO_4$ - $H_2O_2$ for analysis of Na, K, total N and P, and $HClO_4$ for Ca and Mg. Chloride was extracted with deionized water by shaking and filtering the solution for 30 min.

Data were subjected to analysis of variance (ANOVA) using the GLM procedure of SAS (SAS, Cary, NC). Different letters in tables or figures indicate significant difference at the $p \leq 0.05$ level. The NLIN or the orthogonal analysis (using the stepwise regression) procedures of SAS (SAS, Cary, NC) were used to estimate coefficients in various equations used from the pertinent experimental data.

## 3. Results and discussion

### 3.1. Yield and plant development

Addition of fertilizer to the irrigation water resulted in increasing fresh matter production compared with tap-water-irrigated plants (Fig. 1): 580 g plant$^{-1}$ was obtained at the highest nutrient level (treatment V) vs. 52 g plant$^{-1}$ in the tap-water-irrigated plants (treatment I). Increasing the P concentration improved plant growth significantly (Fig. 1) and could be described by a linear equation (Fig. 2).

The cultivar 'Safari Sunset' was not sensitive to a high P level in the nutrient solution (at the pertinent experimental conditions applied in this study). During the experiment there was no indication of toxic symptoms that could be attributed to an excess of P. On the contrary, it could be seen that at low available P, growth was inhibited. These results are in agreement with those of Prasad and Dennis (1986) for 'Safari Sunset' but contradict the general view that species of the Proteaceae family are very sensitive to P concentration. Growth reduction at high P levels was reported for Proteaceae plants by Nichols, *et al* (1979) and Thomas (1974) but these workers used extremely high soluble P levels (360 and 177 mg l$^{-1}$, respectively).

### 3.2. Root morphology and development

The nutritional treatments affected the development of proteoid roots. Clusters of proteoid roots were present along the entire root system of tap-water-irrigated plants. Few proteoid roots developed on plants irrigated with nutrient solution when P was omitted, and none developed in any of the other treatments. Lamont (1986) showed that proteoid roots developed only when N and P were omitted from the nutrient solution of *Banksia* and *Hakea* plants grown in sand culture, according to him the abundance of proteoid roots is a sign of health in Proteaceae plants. However, in the present study proteoid roots were abundant only in undeveloped plants, exposed to a poor nutrient solution (tap water or

absence of P), whereas they were absent in developed plants provided with sufficient nutrients.

Total root weight rose as nutritional level increased. A significant correlation was obtained using a second-degree polynomal, between total fresh weight of shoot and root (Fig. 3), as described previously for *Hakea* plants (Proteaceae family) by Lamont (1972).

### 3.3. Stem width

At planting, the stem width was about 4 mm and it expanded during the experiment in correlation with nutritional treatments.

(Fig. 4). The correlation between stem width ($D_t$; mm) and the time elapse from planting (t; days) could be described by a linear equation:

$$[1] \qquad D_t = A_t + b_t \times t$$

A and b are empirical constants and t refers to treatments. All the relevant parameters are presented in Tab. 2.

The lowest stem width was obtained in tap water irrigated plants after 180 days of (5.7 mm). Nutrient application without P increased stem width by two folds (10.7 mm) and addition of P caused a further increase (Fig. 4).

### 3.4. Water uptake

Water uptake by plants was affected by the applied nutrient solutions (Fig. 5). The differences between the treatments became significant 70 days after planting. By presenting water uptake as affected by the treatments, three groups, each with similar water consumption could be distinguished. Thus, might explain the limiting factor: (i) lack of nutrient (tap water irrigated plants); (ii) lack of P (treat. II and III); and (iii) lack of water (treat. IV, V and VI). The correlation between stem width and the water uptake could be described by a linear equation (Fig. 6).

### 3.5. Nutrient content in plant organs

Nitrogen concentrations increased as a result of increased nutrient levels (Table 3). Stepwise regression was conducted on the effect of N and P concentrations in the mature leaves on shoot weight in two groups of treatments: increasing nutrient levels (treatments I, III and V) and increasing P levels (treatments II, III and IV) (Table 4). Nitrogen ($C_N$-max) and P ($C_P$-max) concentrations required to achieve maximal shoot weight were calculated (from the derivations of the second order equations presented in Tables 4 and 5. According to these calculations), $C_N$-max and $C_P$-max are 33.1 and 10.7 g $kg^{-1}$ dry matter, respectively (Fig. 7). The N and P concentrations measured in the mature leaves in all the treatments were lower than the calculated $C_N$-max and $C_P$-max, except for the N concentration in the high $NH_4$ ratio. From the above calculations it could be deduced that N and P concentrations in the irrigation water limited plant growth. Increasing N and P concentrations above 100 and 20 $mg.l^{-1}$, respectively, might produce higher yields.

By the same analysis for P levels, the calculated P concentration required to achieve maximal shoot weight ($C_{P2}$-max) was 9.05 $g.kg^{-1}$ dry matter (Table 5). Phosphorus concentration measured in treat. IV was higher than the calculated $C_{P2}$-max (Tab. 5). Nitrogen concentration in treatments II III and IV was only 50 $g.l^{-1}$, which probably inhibited plant development, as shown for the first series.

Potassium content in the 'Safari Sunset' plant organs was very low compared with other ornamental plants (Benton Jones, 1991). Potassium content in the tap-water-irrigated plants (treat. I) was higher than in the nutrient-amended plants, probably as a result of dilution.

## 4. Conclusions

No detrimental effect on plants was observed even at the highest level of nutrients added. The present study demonstrated that as long as a sufficient amount of micronutrients is supplied via the irrigation solution, addition of 20 mg P $l^{-1}$ improves 'Safari Sunset' growth.

No relationship was found between added K in the nutrient solution and K content in plant organs. Potassium content in the plant organs was very low in comparison with other plants or compared with Na, but without any visible signs of damage.

## Acknowledgments

The authors gratefully acknowledge the able technical support of S. Gilad, B. Michnik, Sara Davidov, Shoshana Suriano and Rivka Rosenberg.

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Table 1. Concentration of elements (mg $l^{-1}$) added to the irrigation water.

FERTILIZER LEVELS

| Treat. No. | $N\text{-}NH_4$ | $N\text{-}NO_3$ | Total-N | P | K | pH | EC dS $m^{-1}$ | Micro-elements |
|---|---|---|---|---|---|---|---|---|
| I | 0 | 0 | 0 | 0 | 0 | 7.9 | 1.0 | 0 |
| III | 25 | 25 | 50 | 10 | 50 | 6.6 | 1.4 | I |
| V | 50 | 50 | 100 | 20 | 100 | 6.3 | 1.8 | II |

P LEVELS

| Treat. No. | $N\text{-}NH_4$ | $N\text{-}NO_3$ | Total-N | P | K | pH | EC dS $m^{-1}$ | Micro-elements |
|---|---|---|---|---|---|---|---|---|
| II | 25 | 25 | 50 | 0 | 50 | 6.6 | 1.4 | I |
| III | 25 | 25 | 50 | 10 | 50 | 6.6 | 1.4 | I |
| IV | 25 | 25 | 50 | 20 | 50 | 6.4 | 1.4 | I |

$NH_4$: $NO_3$ RATIO

| Treat. No. | $N\text{-}NH_4$ | $N\text{-}NO_3$ | Total-N | P | K | pH | EC dS $m^{-1}$ | Micro-elements |
|---|---|---|---|---|---|---|---|---|
| III | 25 | 25 | 50 | 10 | 50 | 6.6 | 1.4 | I |
| VI | 40 | 10 | 50 | 10 | 50 | 6.5 | 1.6 | I |

Micro-element concentrations: I - Fe - 2 mg $l^{-1}$ as EDDHA-Fe (Sequestrene) in addition to EDTA-based: Fe - 0.69, Mn - 0.34, Zn - 0.17, Cu - 0.025, Mo - 0.019 and B - 0.25 mg $l^{-1}$. II - double the I concentrations. The nutrient solutions were prepared using commercial fertilizers and tap water consisting of approximately: $NO_3$ - 10, P - 0.4, K - 6, Ca- 50, Mg - 20, Na - 100 and Cl - 140 mg $l^{-1}$.

Table 2. Treatment effects on stem width at the end of the experiment. A and b are emperical constants for stem width dependence on time from planting (days).

| Treatment | Stem Width (mm) | A | b | $R^2$ | F | SSE |
|---|---|---|---|---|---|---|
| I | 5.7 c | 4.3** | 0.007** | 0.99 | 4394*** | 0.12 |
| II | 10.7 b | 4.2* | 0.038** | 0.99 | 2464*** | 0.24 |
| III | 12.7 a | 3.9* | 0.050* | 0.99 | 893*** | 0.45 |
| IV | 13.5 a | 4.3* | 0.054* | 0.99 | 1107*** | 0.44 |
| V | 14.1 a | 4.4* | 0.054** | 0.99 | 1617*** | 0.36 |
| VI | 12.9 a | 4.1** | 0.052** | 0.99 | 4419*** | 0.21 |

*, **, *** - significant at $p \leq 0.05$, 0.01, and 0.005, respectively;

Table 3. Treatment effects on element concentrations (g $kg^{-1}$ dry matter) in different organs of 'Safari Sunset' plants.

| | N | P | K | Na |
|---|---|---|---|---|
| | Young | Leaves | | |
| I | 11.0 | 1.4 | 9.8 | 8.9 |
| II | 31.1 | 1.8 | 7.4 | 6.3 |
| III | 30.1 | 4.8 | 8.8 | 8.9 |
| IV | 28.7 | 7.5 | 8.4 | 10.5 |
| V | 34.6 | 7.9 | 9.3 | 11.0 |
| VI | 37.0 | 3.3 | 8.1 | 7.3 |
| | Mature | Leaves | | |
| I | 9.6 | 1.9 | 11.5 | 6.0 |
| II | 28.2 | 1.6 | 8.1 | 7.9 |
| III | 25.4 | 5.1 | 9.1 | 10.3 |
| IV | 23.6 | 9.8 | 7.8 | 12.1 |
| V | 28.4 | 8.5 | 8.3 | 11.9 |
| VI | 34.9 | 3.9 | 8.5 | 9.3 |
| | | Stems | | |
| I | 3.6 | 1.5 | 11.9 | 5.2 |
| II | 9.9 | 0.9 | 12.1 | 2.9 |
| III | 11.1 | 2.9 | 10.6 | 3.5 |
| IV | 13.0 | 4.6 | 9.5 | 4.0 |
| V | 15.6 | 4.4 | 10.4 | 3.5 |
| VI | 13.8 | 2.1 | 10.4 | 2.9 |
| | | Roots | | |
| I | 5.5 | 1.5 | 7.4 | 5.6 |
| II | 17.2 | 1.6 | 6.8 | 4.8 |
| III | 19.9 | 3.1 | 5.7 | 4.9 |
| IV | 22.7 | 4.5 | 4.4 | 5.6 |
| V | 26.8 | 4.7 | 5.3 | 5.5 |
| VI | 19.3 | 2.8 | 5.6 | 4.8 |
| **F-test** | | | | |
| Treatment | 285*** | 327*** | 14*** | 73*** |
| Organ | 525*** | 143*** | 117*** | 818*** |
| Treat. x Org. | 16*** | 18*** | 2.7*** | 30*** |
| **$LSD_{0.05}$** | | | | |
| Treatment | 1.1 | 0.3 | 0.6 | 0.3 |
| Organ | 0.9 | 0.3 | 0.5 | 0.3 |

Table 4. Orthogonal analysis of the dependence between N ($C_N$) and P ($C_P$) concentrations in mature leaves and shoot fresh weight (SH; g plant$^{-1}$) (of 'Safari Sunset' plants. Three levels of nutrients added (treat. I, III and V).

| | $R^2$ | F-test |
|---|---|---|
| **First order equation** | | |
| $SH = a_0+a_1 \times C_N$<br>$a_0$ = -116.2 n.s.<br>$a_1$ = 19.2** | 0.75 | 50.9*** |
| $SH = a_0+a_1 \times C_N+a_2 \times C_P$<br>$a_0$ = -103.5 n.s.<br>$a_1$ = 12.1***<br>$a_2$ = 25.9* | 0.82 | 36.6*** |
| **Second order equations** | | |
| $SH = a_0+a_1 \times C_P+a_2 \times C_P^2$<br>$a_0$ = -164.1*<br>$a_1$ = 126.9***<br>$a_2$ = -5.9***<br>$C_P$-max = 10.7 | 0.83 | 40*** |
| $SH = a_0+a_1 \times C_N+a_2 \times C_N^2$<br>$a_0$ = -369.5**<br>$a_1$ = 49.6**<br>$a_2$ = -0.75*<br>$C_N$-max = 33.1 | 0.81 | 34.7*** |
| $SH = a_0+a_1 \times C_N+a_2 \times C_P+a_3 \times C_P^2$<br>$a_0$ = -170.4*<br>$a_1$ = 6.7 n.s.<br>$a_2$ = 87.3*<br>$a_3$ = -3.9 n.s.<br>$C_P$-max = 11.1 | 0.86 | 29.6*** |
| $SH = a_0+a_1 \times C_P+a_2 \times C_N+a_3 \times C_N^2$<br>$a_0$ = -317.1*<br>$a_1$ = 22.2*<br>$a_2$ = 38.4**<br>$a_3$ = -0.62*<br>$C_N$-max = 30.97 | 0.86 | 31.5*** |

*, **, *** - significant differences between means at $p \leq 0.05$, 0.01, and 0.005, respectively; n.s. - non-significant; Cp-max , $C_N$-max - P and N concentrations in mature leaves, respectively, required to achieve maximal shoot weight.

Table 5 Orthogonal analysis of the dependence between P concentration ($C_{P2}$) in mature leaves and shoot fresh weight ($SH_2$; g plant$^{-1}$) of 'Safari Sunset' plants. Three levels of P added (treat. II, III and IV)

| | $R^2$ | F |
|---|---|---|
| **First order equation**<br>$SH_2 = a_0 + a_1 \times C_P$<br>$a_0 = 240.1^*$<br>$a_1 = 15.8^{***}$ | 0.57 | 23.9*** |
| **Second order equation**<br>$SH_2 = a_0 + a_1 \times C_P + a_3 \times C_P^2$<br>$a_0 = 178^{**}$<br>$a_1 = 46.9^{**}$<br>$a_3 = -2.6^*$<br>$C_{P2}$-max = 9.05 | 0.69 | 19.3*** |

*, **, *** - significant differences between means at $p \leq 0.05$, 0.01, and 0.005, respectively; n.s. - non-significant; Cp-max , $C_N$-max - P and N concentrations in mature leaves, respectively, required to achieve maximal shoot weight.

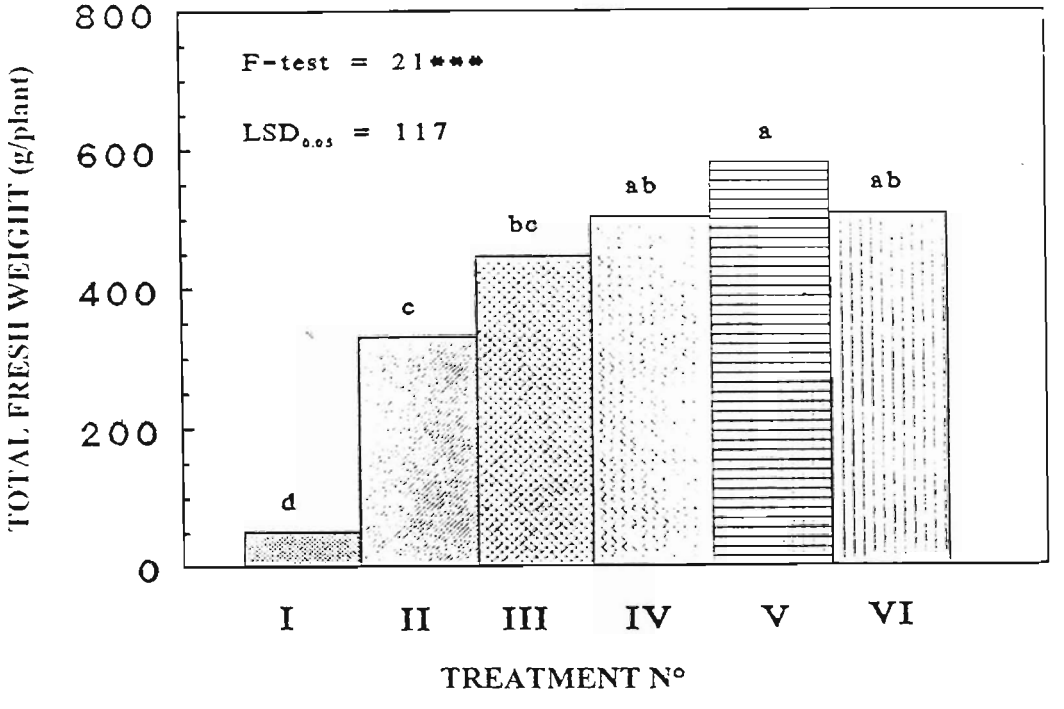


Figure 1. Total fresh weight (g plant$^{-1}$) of 'Safari Sunset' plants as a function of nutrient solution. Different letters indicate significant difference at the $p \leq 0.05$ level.

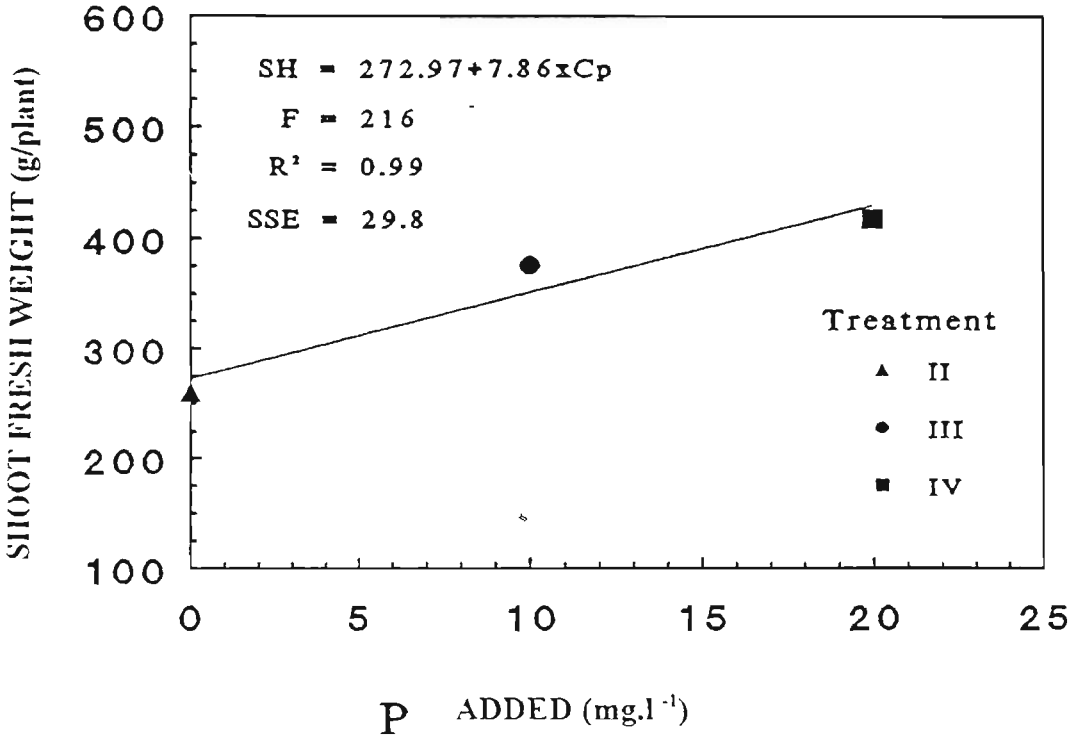


Figure. 2. Total fresh weight (SH; g plant$^{-1}$) of 'Safari Sunset' plants as a function of P concentration (Cp; mg l$^{-1}$) in the nutrient solution. The line was calculated according to a first-order equation; parameters were significant at $p \leq 0.05$.

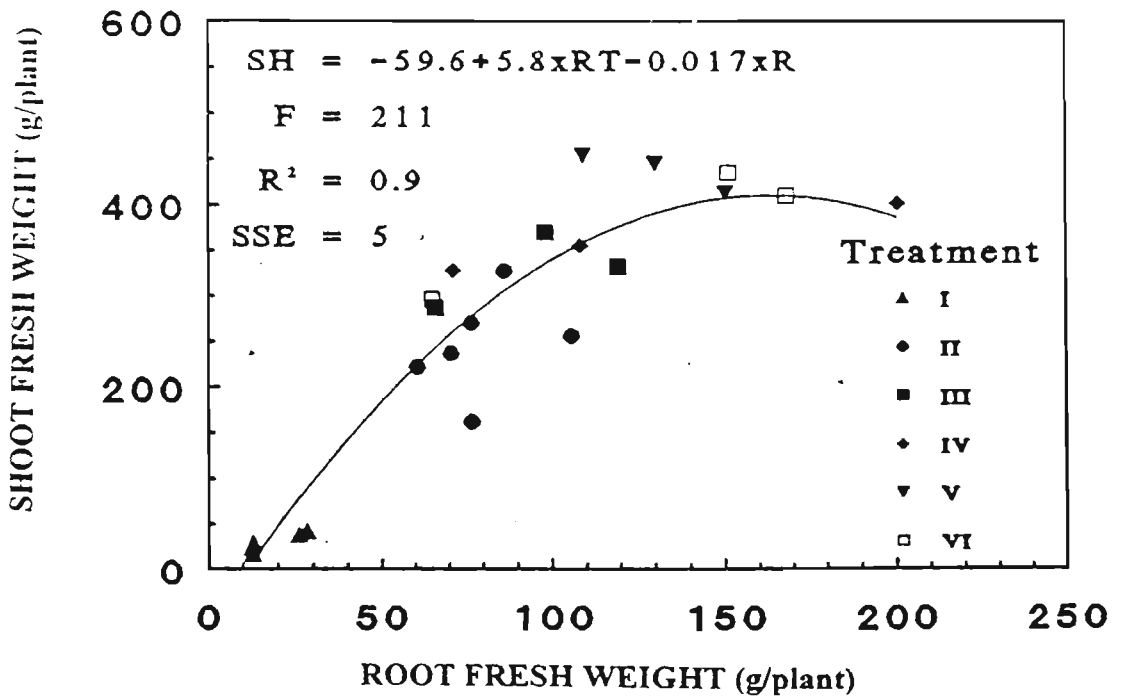


Figure 3. Shoot fresh weight (SH) as a function of root fresh weight (SH and RT, respectively; g plant$^{-1}$). The line was calculated according to a second-order equation and the experimental points; parameters were significant at $p \leq 0.05$.

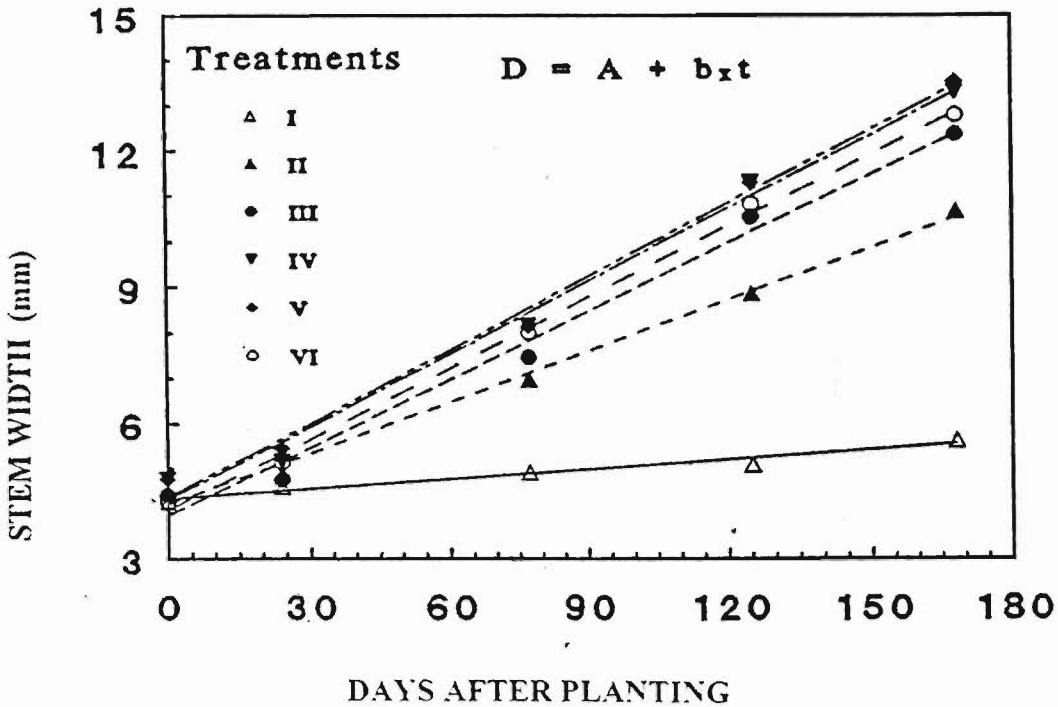


Figure 4. Stem width (D; mm) as a function of time (t; days) after planting. The lines were calculated according to eq. [1] and the experimental points. (All the parameters are presented in Tab. 2.)

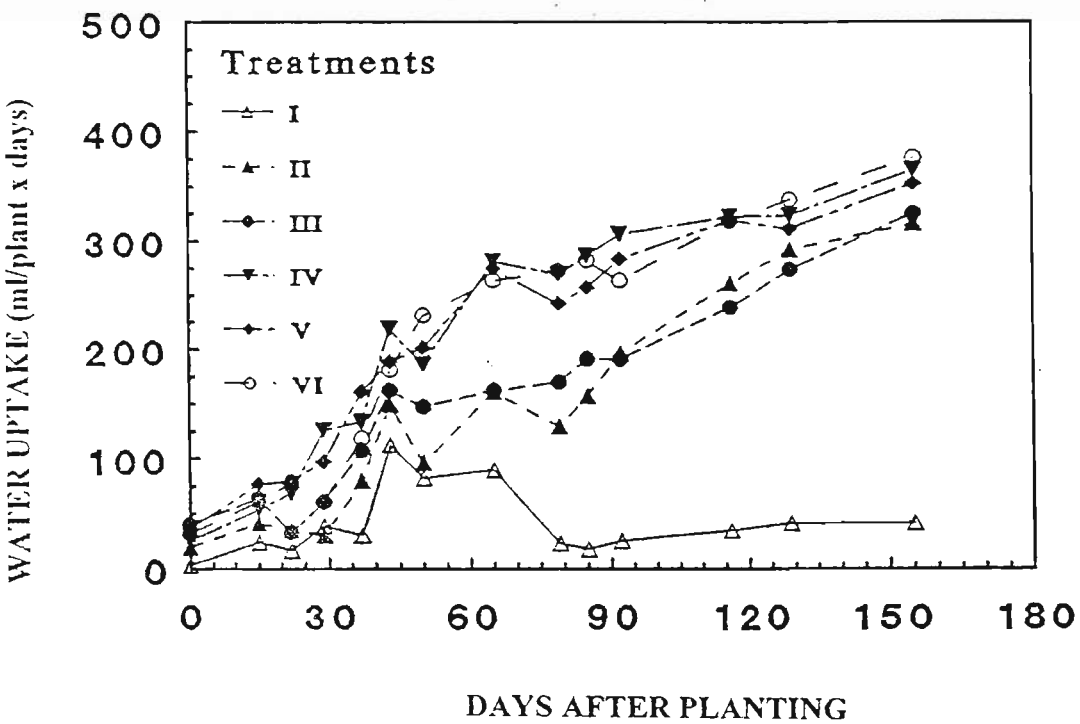


Figure 5. Water uptake by plants as a function of time (days) after planting.

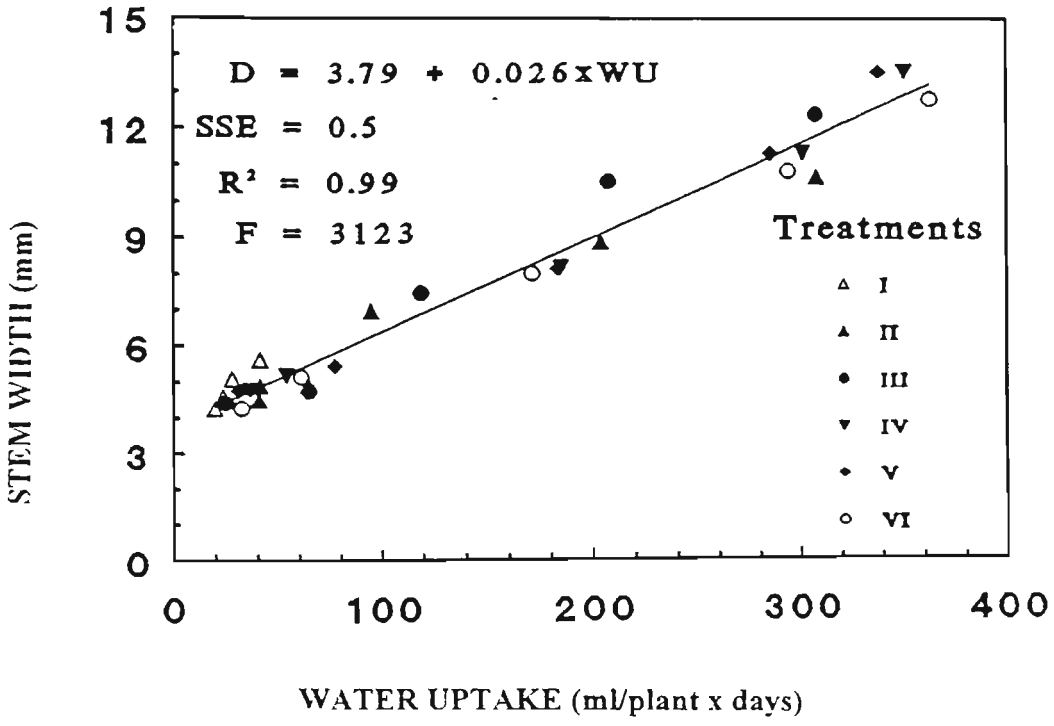


Figure 6. Stem width (D; mm) as a function of daily water uptake (WU; mm plant$^{-1}$ day$^{-1}$). The line was calculated according to a first-order equation and the experimental points. Parameters were significant at $p \leq 0.05$.

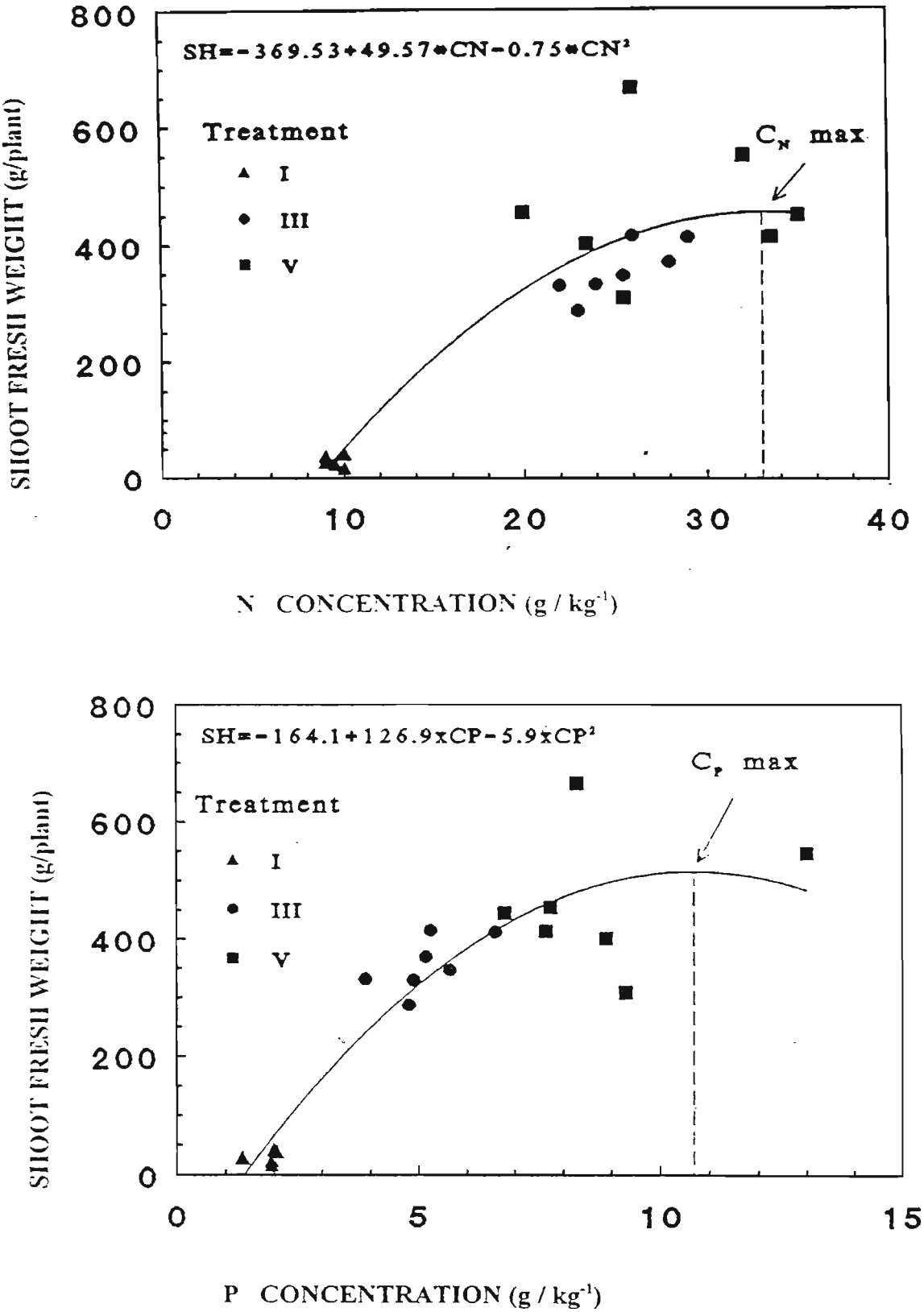


Fig. 7. Shoot fresh weight (SH; g plant$^{-1}$) as a function of N and P concentrations (CN and CP, respectively; g kg$^{-1}$ dry matter) in mature leaves. The lines were calculated according to second-order equations (Table 4) and the experimental points in Table 3.

# EFFECT OF pH ON THE DEVELOPMENT OF *LEUCADENDRON* 'SAFARI SUNSET'

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Abstract

Proteaceous plants grow naturally on acidic washed soils in Australia and South-Africa, therefore their cut flower production is difficult in Israel., where soils are mostly basic and calcareous. An experiment was conducted in an aerohydroponic system to establish the effect of pH on the development and growth of *Leucadendron* 'Safari Sunset'. Total fresh weight, root fresh weight percentage and N and P where concentrations decreased significantly in plants grown in high pH (7.0) solutions compared to plants grown in low pH solutions (5.5). The high pH inhibited root growth and subsequent shoot growth. A marked effect of the pH on the proliferation of root hairs was demonstrated by using a scanning electron microscope. In roots of plants grown at high pH, root hair development was arrested, thus decreasing the potential surface area, which may decrease in plant nutrient uptake. L. 'Safari Sunset' required low pH in its rhizosphere for adequate growth, as root hairs developed only at pH lower than 6.

## 1.Introduction

Proteaceae family originated from Australia and South Africa, where most of the species grow on acid washed soils, poor in nutrients. Most of the species in the family have a double root system: proteoid and normal root systems. Much attention has been directed to the role of proteoid roots in the growth and development of plants (Lamont, 1972). Proteoid, short life, roots, are regarded as an alternative system for enhancing nutrient uptake in poor soils (Lamont, *et al.*, 1984; Lamont, 1986). They increase root surface thus increasing the absorbing and exuding area of the root system. Proteoid roots formation is suppressed by high nutrient availability. Roots hairs, although differ in their developmental origin, can be compared to proteoid roots in their life length and contribution to the root surface area (Hofer, 1995). Root hair size and development is influenced by environmental factors such as pH (Ewens and Leigh, 1984) and ion concentration (Marschner and Romhed, 1995). PH has a direct effect on growth and root elongation, as was documented by Tan, *et al.* (1993) and Yan, *et al.* (1992)

In Israel, an effort was made in the last decade to cultivate Proteaceae species for cut flowers (Ben-Jaacov, 1986; Ben-Jaacov, *et al*, 1989). Although the climate is suitable, the soils are mostly calcareous, with high pH. The commercial cultivation raised the question if low pH in the rhizosphere is necessary for plant development.

The purpose of the experiment was to establish the effect of pH on the development and growth of *Leucadendron* 'Safari Sunset'

## 2. Materials and methods

The experiment was conducted in a screen house in Bet Dagan, Israel (35°E, 31°N, 50 m altitude) irradiated by natural sunlight (1400-1600 μmol $m^{-1}$ PPF) at a temperature range between 12-35°C.

Two months old *Leucadendron* 'Safari Sunset' plants were transplanted on 6 June 1993 into an aerohydroponic system (Feigin, *et al.*, 1984), consisting of two separate 50 cm x 29 cm x 20 cm deep polystyrene boxed mounted on a 140 l container (1 plot). Roots were

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exposed continuously to the nutrient solution which was circulated by means of a plastic tube system with small holes through which the solution was ejected. The solution leached to the bottom of the container and recirculated continuously. The experiment was arranged in randomized blocks with 5 replicates each block had 12 plants.

The experiment consisted of six treatments in a non factorial design (Table 1): two levels of P (7 and 20 mg/l), two $NO_3/NH_4$ ratios (40/60 and 60/40) and two pH levels (5.5 and 7.0).

Micro nutrients and Fe were: Mn, 0.234; Cu 0.025; Zn,0.18; Mo, 0.02, B, 0.25 and Fe, 0.67 mg/l as EDTA chelate and 2.0 mg/l Fe as Sequestrin. The nutrient solutions were prepared with commercial fertilizers: $KNO_3$, $(NH_4)SO_4$, $NH_4NO_3$, KCl, $KH_2PO_4$, Koratin and Sequestrin added to tap water consisting of approximately Na, 100; P, 0.4; $NO_3$, 10; Ca, 50; Mg, 20 and Cl, 140 mg/l. The pH was monitored daily. To maintain low and high pH, $H_2SO_4$ and NaOH was added respectively. The electric conductivity was 2 ddS/m and did not change significantly by adding $H_2SO_4$ or NaOH.

The solutions were renewed weekly and daily loss of water was returned.

At the end of the experiment, 25 August, 1993 plants were removed and divided into root and shoot, fresh and dry weight were determined in the plant organs.

Scanning electron microscopy pictures were taken from roots of plants grown in nutrient solution, at the two pH treatments.

Data were subjected to analysis of variance (ANOVA) using the GLM procedure of SAS (SAS, 1985) Different letters in table indicate significant difference at the $p<0.05$ level.

## 3. Results and discussion

### 3.1. Yield

Plant total fresh weight, root fresh weight and percentage of root weight of total weight, of L. 'Safari Sunset' as affected by pH, P concentration and $NH_4/NO_3$ ratio are presented in Table 2.

The maximum fresh matter production (74.23 g/pl) was obtained in treatment I (pH-5.5, P-7 mg/l and $NH_4NO_3$ ratio of 60/40), while the minimum fresh matter production (26.98 g pl) was obtained in treatment V (pH-7.5, P-20 mg/l and $NH_4NO_3$ ratio of 60/40). Thus, growth response was about threefold greater comparing both treatments. Total fresh weight, and root fresh weight of plants grown in high pH (7) solutions were significantly low compared to plants grown in low pH solutions (5.5). The high pH inhibited primarily root growth and subsequently shoot growth.

Decreasing the $NH_4/NO_3$ ratio from 60/40 (treatments I and IV) to 40/60 (treatments III and VI) decreased the yield from 74.23 g/pl to 59.38 g/pl in the presence of low pH. The preference for high $NH_4/NO_3$ ratio in the solution was also reported by Heinson and Paramenter (1985) for *Leucadendron salignum* Berg grown in water culture. Increasing P concentration in the nutrient solution from 7 mg/l to 20 mg/l resulted in a decrease of total and root fresh weight. The effect was stronger in the plants grown in low pH.

Percentage of root weight from total plant weight was lower in the treatments with high pH (18.5-23.0) compared to treatments with low ph. treatments (22.4-29.6). The inhibited root probably affected plant development.

### 3.2. Root morphology

#### 3.2.1. Root system morphology

The effect of pH on root development is presented in Plate 1. The root development of plants grown at high pH is restricted because of poor branching and dead roots (black roots). No proteoid roots, which develop for improving nutrient uptake were observed since the ion composition and concentration were not limiting factors. In the presence of sufficient ion concentration no proteoid rood developed as was reported for *L.* 'Safari sunset' (Silber, *et al.* 1996) and for other species (Lamont, 1982; Racette, *et al.* 1990).

3.2.2. Development of root hairs

The effect of pH on the development of root epidermal cells and root hairs using a scanning electron microscope is presente din Plate 2. Root hair development was inhibited in plants grown at high pH. This decreased the potential surface area, which may lead to the decrease in plant mineral uptake (direct effect of pH) or exuding of organic acids to the rhizosphere (indirect effect of pH).

3.2.3. Cell elongation

High pH affected root length probably by inhibiting cell elongation. Cells were measured for length and width at 1 mm distance from the root tip. The low pH root cells were longer (30-40 μm) compared to high pH root cells (20-32 μm) but there width was similar (6-8 μm).

The reduction of 'safari sunset' root growth at pH of 7.0 could be attributed to inhibition of cell elongation without affecting cell division, as was also reported for lupine roots (White, 1990; Tang, *et al.*, 1993). The mechanism by which high pH impairs cell elongation and restriction of root hair formation is unknown. Cell wall acidification, causing loosening of cellulose microfibrils in the walls is suggested to be the cause of optimal cell growth (Taiz, 1984).

4. Conclusions

Poor growth of L. 'Safari sunset' on alkaline soils has been reported but there are no previous studies on the specific effect of high pH. The present study shows that high pH inhibited root growth and decreased shoot plant weight. *L.* 'Safari sunset' required low pH in its rhizosphere for adequate growth, as root hairs developed only at pH lower than 6.

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Table 1. Concentration of main nutrients (mg/l) in the nutrient solution.

| Treatment | K | P | $NO_3$ mg/l | $NH_4$ | pH |
|---|---|---|---|---|---|
| I | 50 | 7 | 15 | 35 | 5.5 |
| II | 50 | 20 | 15 | 35 | 5.5 |
| III | 50 | 7 | 35 | 15 | 5.5 |
| IV | 50 | 7 | 15 | 35 | 7 |
| V | 50 | 20 | 15 | 35 | 7 |
| VI | 50 | 7 | 35 | 15 | 7 |

Micro-elements concentration added: $Fe^{+3}$, as EDDHA-Fe (sequestrine) in addition to the EDTA-based: Fe-0.69, Mn-0.34, Zn-0.17, Cu-0.025, Mo-0.019 and B-0.25 mg/l.
The nutrient solution were prepared by using commercial fertilizers and tap water consisting of approximately: NO3-10, P-0.4, Ca-50, Mg-20, Na-100 and Cl-140 mg/l.

Table 2. Total and root fresh weight (g/plant) and percentage of root of total fresh weight of 'Safari Sunset' plants grown in an aerohydroponic system, as affected by pH (5.5-I, II, and III; 7.0-IV, V and VI), P concentration (7mg/l-I, III, IV and VI; 20 mg/l- II and V) and $NH_4/NO_3$ ratio 60/40- I, II, IV and V; 40/60- II and VI).

| Treatment | pH | $NO_3$ | $NH_4$ mg/l | P | Total fresh weight | Root fresh weight g/plant |
|---|---|---|---|---|---|---|
| I | 5.5 | 15 | 35 | 7 | 67.2 a | 21.7 a |
| II | 5.5 | 15 | 35 | 20 | 51.5 ab | 13.0 bc |
| III | 5.5 | 35 | 15 | 7 | 58.6 ab | 20.3 ab |
| IV | 7 | 15 | 35 | 7 | 34.3 bc | 7.9 c |
| V | 7 | 15 | 35 | 20 | 23.8 c | 5.7 c |
| VI | 7 | 35 | 15 | 7 | 24.5 bc | 8.4 c |
| F test | | | | 66*** | 8.12*** | |
| $LSD_{0.05}$ | | | | 20.1 | 7.3 | |

Plate 1. Effect of the pH of the nutrient solution on the development of L. 'Safari Sunset' plants, after two months in the experimental condition. A-pH 5.5, B-pH 7.0. 1-whole plant, 2-root system.

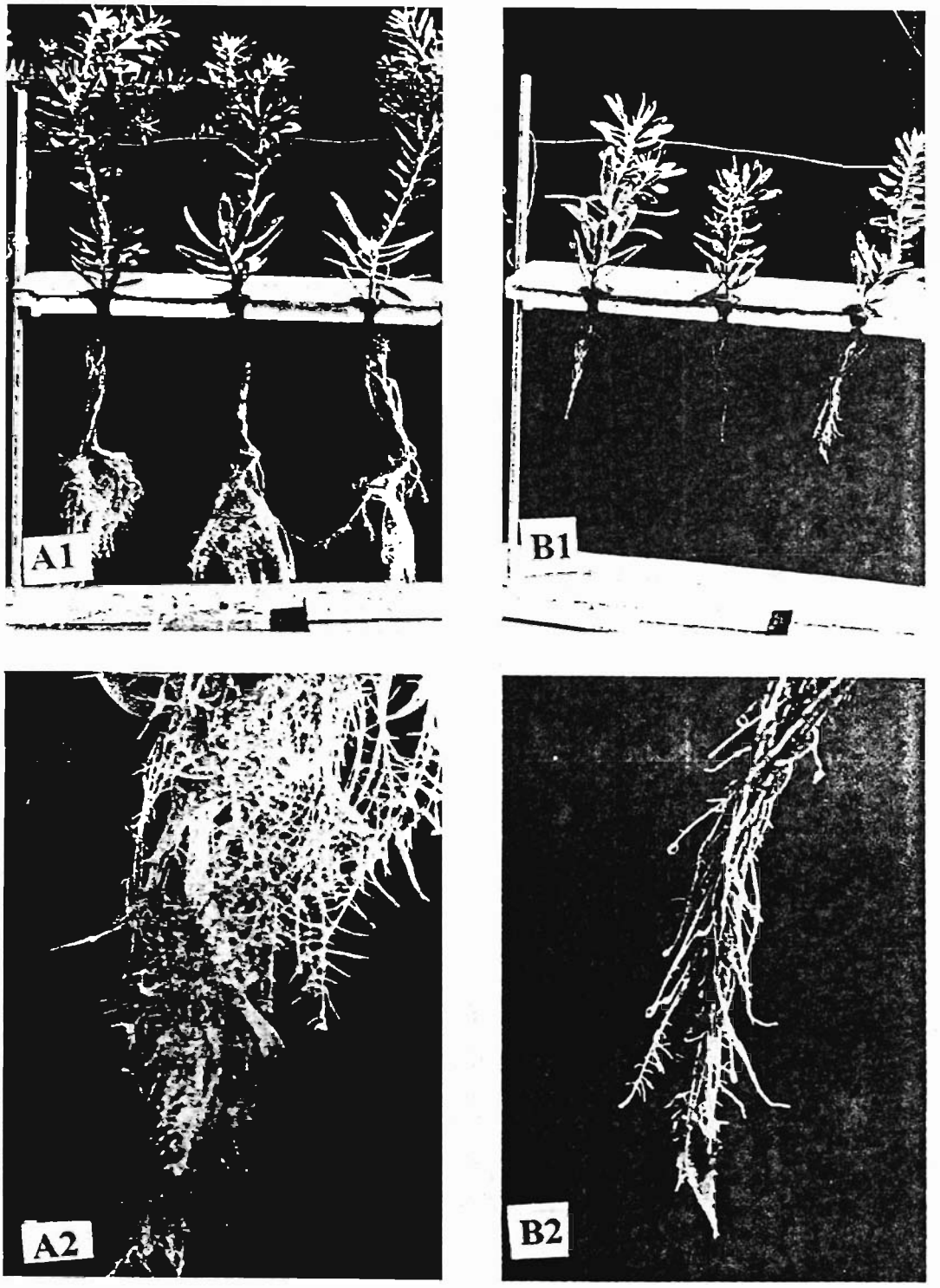
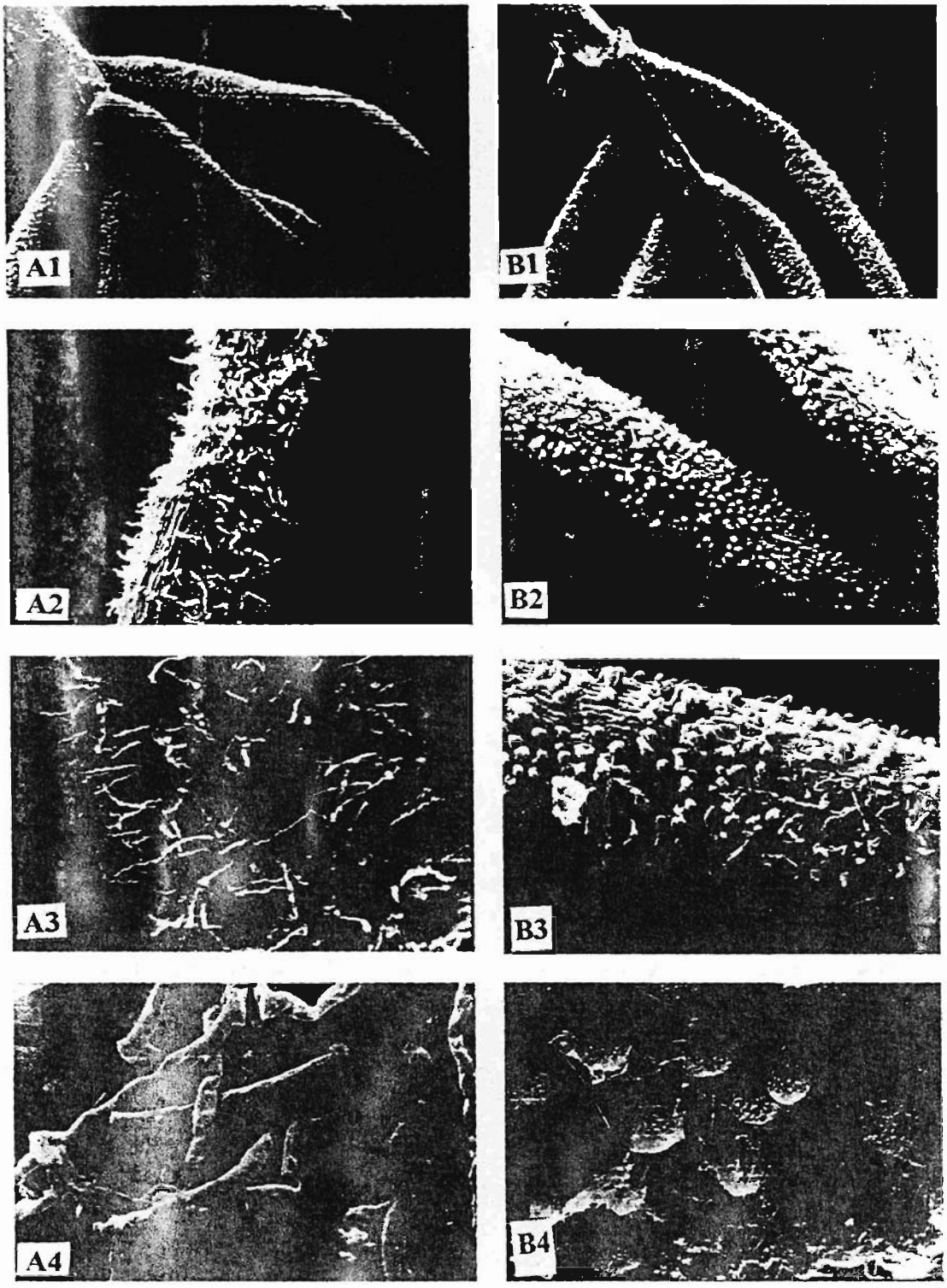


Plate 2. Scanning electron microphotographs of the effect of the nutrient solution pH on the development of root epidermal cells and root hairs of *L.* 'Safari Sunset' plants, 1.5 mm distance from the root tip. A-pH 5.5, B-pH 7.0. 1- x 35 (13 mm = 500μ), 2-x100 (8 mm = 100μ), 3-x200 (16 mm = 100μ) and 4-x1000 (8 mm = 10μ),



# EVALUATION OF *LEUCADENDRON* SELECTIONS AS SINGLE STEM CUT FLOWERS

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Abstract

In South Africa, the dioecious genus *Leucadendron* has largely been ignored as a source of single stem cut flowers. Hybridization between species is relatively successful in this genus, promising an excellent return on the investment of time and effort in breeding. However, newly bred hybrids need to be selected and the greater the numbers to choose from, the more stringent the selection process must be. Characterization and evaluation of clones provide tools for comparing traits of importance to breeders and to commercial growers. The results of characterization and yield evaluation of clones grown at Elsenburg Experimental Farm in South Africa are presented, highlighting differences between individual clones, as well as types of clones.

## 1. Introduction

The dioecious genus *Leucadendron* of the Proteaceae family has largely been ignored as a cut flower product in South Africa, even though many interspecific hybrids have been produced by countries such as New Zealand (Bell, 1988). This is most likely due to the abundance of some *Leucadendron* species growing wild in South Africa and harvested from the wild as well as to the use of broadcast sown stands for fresh and dried material. Neither of these types of material can supply good quality, fresh, single-stem cut flowers of *Leucadendron*.

Van den Berg and Brits (1995) reported on the results of preliminary hybridization and evaluation of *Leucadendron*, indicating vast potential for hybridization in comparison to other genera of the Proteaceae. The ability to produce larger numbers of hybrid progeny implies that greater stringency can and must be applied to the selection of worthy hybrid genotypes. This enables quicker progress towards the breeding aims of high yield of marketable stems per plant, long marketing period, early plant maturity and aesthetic qualities including appearance, shelf and vase life.

The evaluation method reported on in this paper describes the application of an evaluation system for single-stem cut flowers of *Leucadendron*, aimed at providing tools to compare clones and types of hybrids, assess the genetic variability between clones and obtain an indication of the commercial potential of the clones.

## 2. Materials and methods

Thirty four entries in the field genebank of four different types of *Leucadendron* clone, i.e. *L. laureolum* types (7 entries), *L. salignum* (15 entries), *L. salignum / L. discolor* hybrids (5 entries) and *L. salignum / L. laureolum* hybrids (7 entries), were planted during October 1991 in a randomized block on a south west facing slope on Hutton soil. The plant spacing was 1 m in the rows, 3 m between rows. Between 10 and fifty plants of each clone were planted. Characteristics marginally affected by the environment, such as the bush characteristics, leaf shape, size and color, and flower shape and size were determined by visual inspection during 1995. These are called characterization data. Four plants of each clone were randomly chosen for the yield evaluation. These young plants were pruned back

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during 1992. The first harvest was started during February 1993, harvesting all hardened flowers from the plants until flowering time. The plants were pruned back without cleaning out all soft shoots after the end of flowering time. This was repeated during 1994 and 1995. Insect and disease control during the three year period was on an as necessary basis, using chemicals registered for use on ornamental plants. The stems harvested during 1994 and 1995 were classes as single-flower or multi-flower and then further subdivided into length classes of 40 to 55 cm, 56 to 70 cm, 71 to 85 cm and above 85 cm. All comparisons between clones and statistical analyses were based on the mean yield per plant per year.

## 3. Results

### 3.1. Bush characteristics

The pruning regime followed tended to keep the bushes smaller than if they had not been pruned. The growth habit of the different clones differed within groups as well as between groups. The greatest variation in bush growth habit was observed in the *L. salignum* group, ranging from erect to spreading and variations in-between. The *L. salignum / L. discolor* and the *L. salignum / L. laureolum* hybrids all had a semi erect to erect growth habit.

### 3.2. Leaf characteristics

The leaf characteristics within the *L. laureolum* and *L. salignum* groups varied little. The leaf characteristics of the hybrid clones differed in shape, size and attitude on the stem.

### 3.3. Flower characteristics

The flowering times of the different clones were spread over the winter (southern hemisphere) period June to September. Flowering times varied in length (3 to 12 weeks) and the month(s) in which flowering occurred. Greatest variation for flowering time was observed within the *L. salignum* group. The flowering time of the *L. salignum / L. discolor* clones differed little, as did those of the *L. laureolum* clones. The flowering duration of the *L. salignum / L. laureolum* hybrids differed between clones.

The flower size varied more between groups than within, with *L. salignum* bearing small flowers, the *L. salignum / L. discolor* clones generally medium sized, and the *L. laureolum* and *L. salignum / L. laureolum* clones bearing large flowers.

The onset of flowering was generally preceded by a color change in the flower, however the *L. salignum / L. discolor* clones underwent several color changes during the year. The majority of the clones were female. The male clones are generally discarded due to poor shelf life and an extremely short marketing period.

### 3.4. Post flowering characteristics

Male flowers are not usable after flowering while the female flowers either become a tight bud around the cone or open up to expose a mature cone. The female is thus aesthetically pleasing before, during and after flowering extending the harvesting period of female clones. The usefulness of the plant after flowering depends on whether new growth begins soon after the cessation of flowering and whether the plant will recover sufficiently from late pruning to produce an acceptable harvest in the following year. Great variation was observed for the latter two characteristics both within and between groups.

### 3.5. Yield evaluation

During 1993, 28 of the 34 clones produced a harvest of straight stems exceeding 40 cm in length, the average stem yield per plant was 8.5 (± 1.4). During 1994, 34 clones produced a harvest of straight stems over 40 cm in length, the average stem yield per plant was 16.4

± 1.9). The 34 clones produced on average 41.3 (± 3.4) marketable stems per plant during 1995.

Comparison of the types of clone indicated non-significant differences between the average total stem yield of the four types of clone. When this same comparison is made for the numbers of single stems, the *L. salignum* clones showed significantly lower single stem yields, compared to the other three groups. These significant differences between the groups were observed for the 1994 and the 1995 harvest indicating that the production of single stems is not only influenced by external factors, but is an inherent characteristic of the plant that needs to be stringently selected for. In this trial this characteristic could be measured early in the production life of the bush.

Comparisons within the groups indicated large differences between clones for total stem yield per plant, in particular within the *L. salignum* group, where large variation was observed for total stem yield as well as for the numbers of single stems produced per plant (Figure 1). The classification of the stem harvest according to stem length also discriminated between clones which produced a large proportion of stems in the 40cm to 55cm class, such as the cultivar 'Red Gem', compared to clones which produced higher proportions of longer stems, such as the cultivar 'Rising Sun' and 'Safari Sunset' (Figure 2).

## 4. Discussion

While an erect or semi-erect bush is generally easier to harvest, prune and control insects and diseases, in this trial there was no correlation between marketable yield and bush characteristics. The leaf characteristics influenced the perception of aesthetic excellence. The relationship between leaf size, shape and attitude compared to flower size and shape influenced the perception of aesthetic excellance more than the actual measurements of the leaves. Actual flowering time of the clones was important if this coincided with the only change in colour, such as in the cultivar 'Inca Gold', where it is marketed in the yellow stage observed only during flowering. The *L. salignum / L. laureolum* and *L. salignum / L. discolor* clones could be harvested at any time of the year if the leaf tissue was sufficiently hardened so that blackening would not occur. This characteristic allows a greater flexibility in the decision of the grower as to when to harvest. The large differences in total stem yield per plant, the differences in production of single stems and of stem length classes, underscore the importance of testing similar-looking clones on site before deciding on mass plantings. The large differences within the specie *L. salignum*, detected in this study, emphasize the necessity of stringently selecting parental clones for use as parents in the production of hybrids.

The evaluation and characterization procedure followed provided tools to compare clones, assess the genetic variability between clones and obtain an indication of the commercial potential of the clones.

## Acknowledgments

SAPPEX is gratefully thanked for funding the ARC Proteaceae breeding project from which this work is derived. Thanks are also due to G.C. van den Berg, S. Gertse and F. Cooksen for technical assistance.

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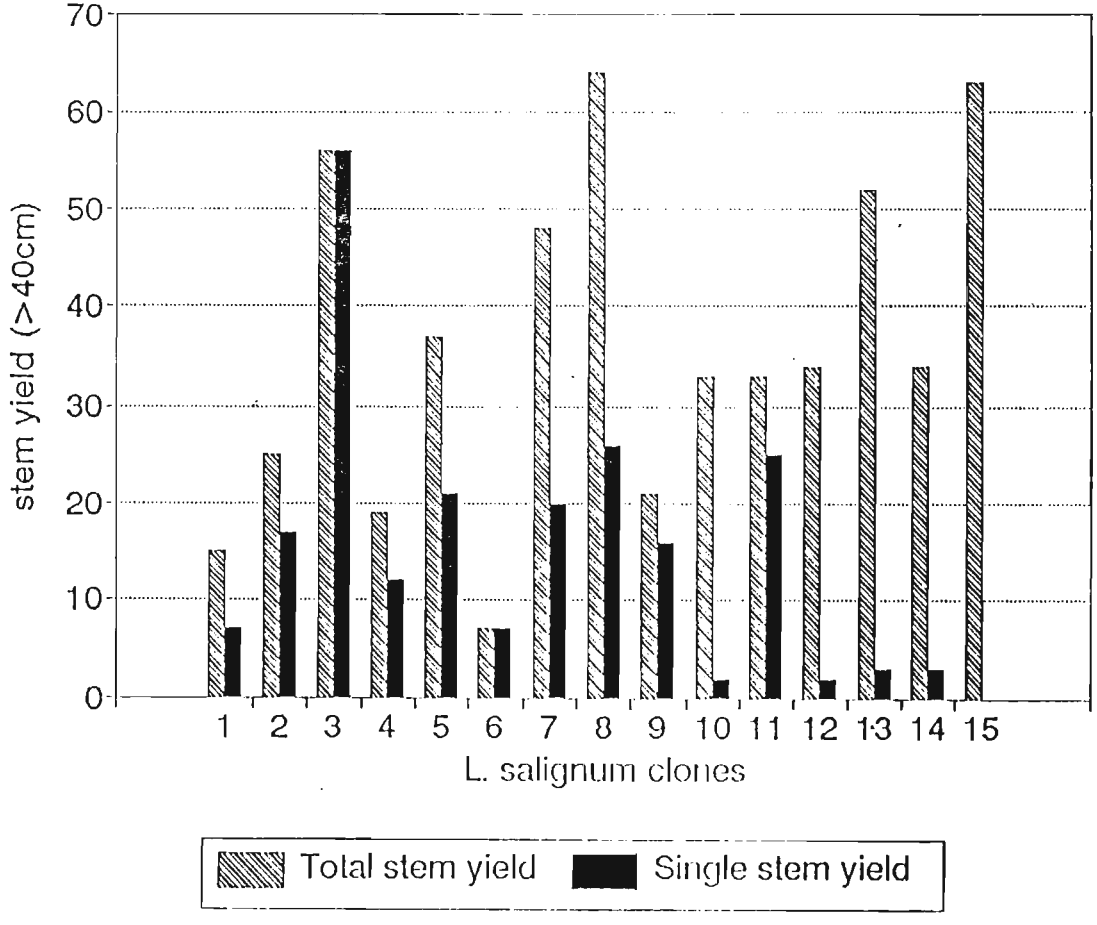


Figure 1. The total stem yield and the single stem yield of each *L. salignum* clone used in the trial, indicating the variation in total yield as well as the variation in ability to produce stems with single flowers.

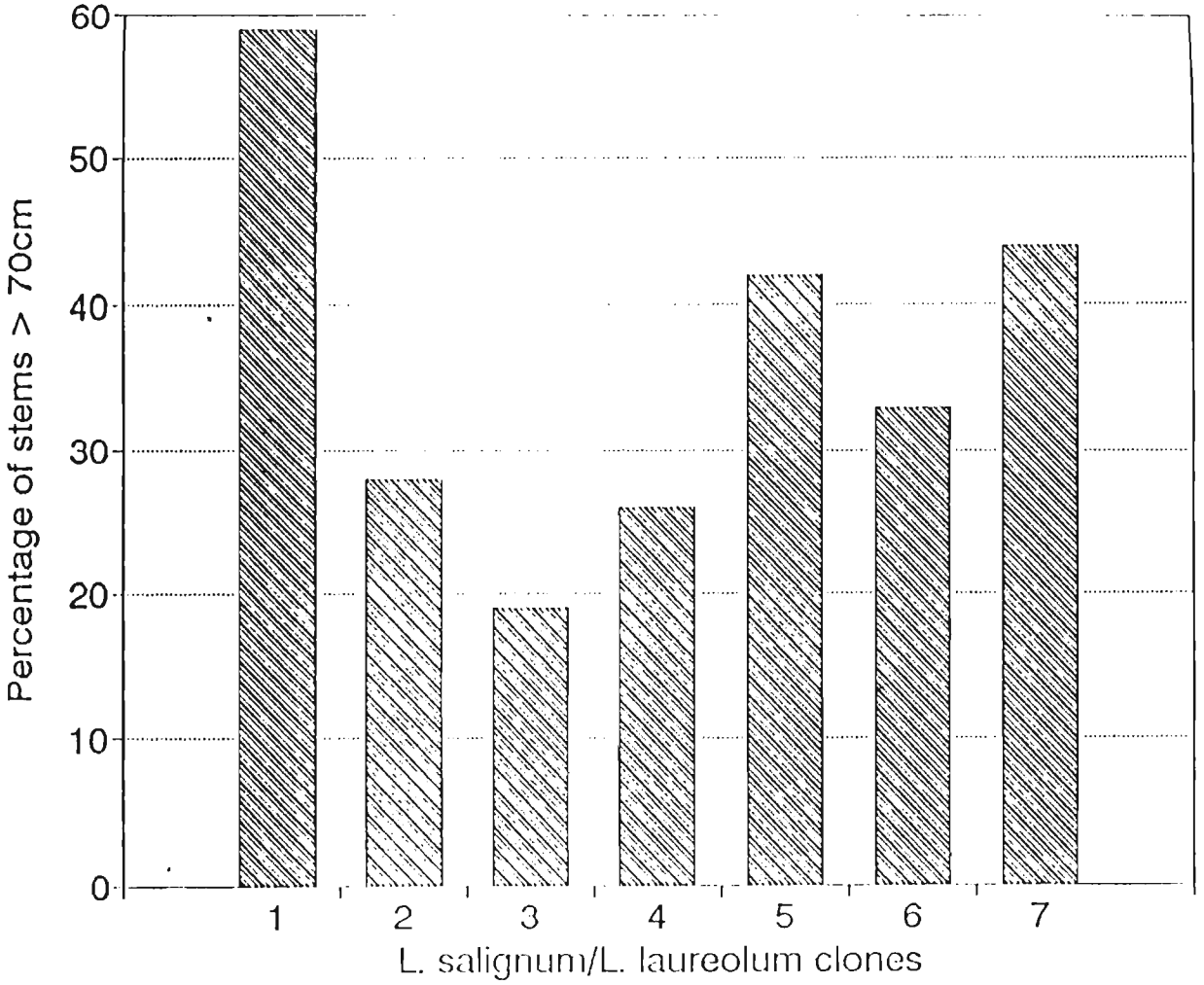


Figure 2.Comparison of the proportion of stems longer than 70cm to the total number of stems longer than 40cm harvested from the *L. salignum / L. laoureolum* clones, indicating variation between clones with similar genetic backgrounds for the production of long single stems. 1=Rising Sun, 2=Inca Gold, 3=Red Gem, 4 -T8-40607, 5 -Safari Sunset, 6- Magenta Sunset, 7 -T930501.

# SESSION B :
# WAX FLOWER AND OTHER *MYRTACEAE*

# ADVANCING AND SPREADING OUT FLOWERING OF OUT-DOOR CULTIVATION IN THE GERALDTON WAX FLOWER BY SHORT DAY TREATMENT

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## Abstract

In earlier studies, wax flower (*Chamelaucium uncinatum* Schauer) was identified as a short-day plant (Shillo, *et al.*, 1985). Under optimal temperature conditions and short days, some cultivars reach flowering within four months. However, under field conditions flowering time varies considerably between years and cultivars, and the period to flowering may increase to 5-7 months. In order to obtain early flowering under field conditions and a steady supply of cut flowers for the European market during the October-May export season, three years of experiments on advancing of flowering by shortening the days were carried out at the Besor Experimental Station, in the southern region of Israel. It was found that under prevailing field conditions the flowering times of both the natural and the forced plants changed from year to year and were affected by the ambient temperatures. A better response to short-day treatment occurred when night temperatures did not exceed 17-18°C during the induction and initiation period. Earlier flowering occurred when the temperature did not fall below 12-14°C during the flower development period. The late cultivars 'Snow Flake' and 'Wendy' did not respond to the short-day treatment and presumably they initiate flowers when temperatures drop to about 14°C. Choosing responsive cultivars and suitable climatic niches with cool nights during late summer is the way to advance flowering by short-day treatment and to improve distribution of flowering throughout the winter.

## 1. Introduction

Wax flower is considered to be the largest outdoor flowering crop in Israel; but production peaked in 1993/94 and currently appears to be declining (Fig. 1). Natural blooming occurs in winter to late spring, peaking in March (Fig. 2). However, the European market demands a continuous supply of flowering branches from October to May. A number of cultivars with different flowering times and a variety of color shades (white, pink and purple) have been introduced from Australia. From these introductions, Israel has selected and bred new cultivars that are better suited to meet the European demand. The current assortment of Israeli and Australian cultivars consists of early-flowering, mid-season and late-flowering types. The early cultivars start to bloom in December, the mid-season cultivars in January-February and the late cultivars in March-April.

In controlled environments with temperature regimes of 16-18/25-30°C (night/day) early and mid-season cultivars appear in October-November and are induced by prevailing conditions. In mid-season cultivars, bud appearance occurs in December and they are presumably induced by the ambient environment of late autumn, i.e., short days and mild temperatures.

Even though the short daylength is the major factor, temperature also affects both the transition from vegetative to reproductive phase and the development of flowers up the anthesis (Shillo, 1985, Shillo, *et al.*, 1985; Dawson and King, 1993). As a result, blooming time varies considerably among cultivars and between years. For instance it is

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well known in Israel that an early cold winter will postpone flowering to late spring, which results in a flooding of the market with unsold flowers.

The objective of our research for the past three years has been to advance flower initiation ahead of the natural season by using black plastic curtains to shorten the day-length. This technology enables early flower development before a significant drop of temperature can occur. Advancement of the initiation time by shortening the days with black plastic curtains, and thus facilitating fast flower development before temperatures drop was thus the goal of our three year study in the western Negev of Israel.

## 2. Materials and methods

Experiments over three years were carried out at the Besor Experimental Station located in the middle of 150-hectare wax flower production area of the western Negev. Each year the most popular cultivar 'Purple Pride' was included. In the second and third years, other cultivars such as 'Nir', 'Orchid', hybrids of *C. megalopetallum* x *C. uncinatum* and *C. floriferum* x *C. uncinatum* were also studied.

Rooted cuttings obtained from Nir Nursery, Israel were used throughout the studies. In the first year, rooted cuttings that had been planted directly into the sandy soil, one and a half years previously were used. In the following years, rooted cuttings that had been planted in 10-l buckets containing 0-8 mm scoria-gravel, 3-4 months previously were used. The plants were placed in the open field for development. Irrigation, fertilization and pest control were carried out as practiced in commercial Israeli enterprises.

The common treatment to the cultivars in all three years was shortening of day-length to 10 h (16:00 - 6:00) by using tunnels (20 x 3 x 2.5m) with black curtains on rollers. Plants not exposed to the tunnel enclosures served as the control treatment.

The experiments were designed to answer the following questions: 1) On what calendar date short-day treatment should be started to give the earliest flowering. 2) For how long should the short-day treatment be given. 3) What was the timing performance of the cultivar 'Purple Pride' in the different years under normal-day and short-day conditions.

In the first year, five plants were used for each treatment. In the following years, ten plants were used per treatment.

## 3. Results

The main results of the cultivar 'Purple Pride' are presented.

### 3.1. First year (1992/93)

One-and half-year-old plants were grown in sandy soil beds in the open field. The short day treatment began on 30 August 1992 and continued until 5 December 1992 at which time the short-day plants were in full bloom. The short day caused the earlier appearance, by 25 days, of flowering buds and advanced flowering and harvesting by 100 days (Table 1). No reduction in branch weight was found in the treated plants even though their development period had been drastically shortened.

### 3.2. Second year (1993/94)

#### 3.2.1. Effect of date of short-day initiation

Rooted cuttings that had been planted in April 1993 in 10 l buckets were placed in the open field. On dates during August and September, 20 days apart starting August 5, a group of ten plants, at each date, were moved to a tunnel for short-day treatment for a period of 62 to 67 days. Thereafter buds appeared and treatments were terminated. Relative to control plants, short-day treatments advanced bud appearance from one to one

and a half months, depending on date of short-day initiation. Bud opening and harvesting dates were both advanced by up to two months (Table 2). The three different starting dates did not differ significantly from one another.

3.2.2. Effect of length of short-day treatment

There were three treatment lengths: 3,5 and 7 weeks imposed on two dates of short-day treatment initiation, August 5 and September 15. Relative to the control plants, short-day initiation on August 5 advanced bud appearance and harvesting by up to 40 and 46 days for treatment lengths of 5 and 7 weeks, respectively (Table 3). but by only 24 days and 12 days, respectively, for the 3-week short-day treatment gave similar results at each date of short-day treatment initiation, the 3-week period was not long enough for the August 5 date to significantly advance bud initiation and development. For the September 15 initiation date, the 3 week treatment did advance bud initiation and development. For the September 15 initiation date, the 3 other two treatment lengths (Table 3).

3.3. Third year (1994/95)

3.3.1. Effect of short-day initiation date

Using the same technology as in the second year, rooted cuttings were planted on 19 May 1994. In the third year only a 5-week short-day length was studied, but at three short-day initiation dates, August 15, September 1 and September 15.

Relative to the control plants, short-day treated plants exhibited advanced flower initiation and development by 22 days only (range 2-22 days). The earlier the date of short-day initiation, the smaller the effect (Table 4). Short-day treatment reduced the number of flowering branches per plant due to the reduced time for overall plant development.

4. Discussion

During three years of studying the effect of short-day treatment on *C. uncinatum* 'Purple Pride' under field conditions, different timing patterns of bud initiation and bud development to anthesis were observed over the years for naturally flowering plants (Fig.3). This finding is in agreement with our earlier observations on outdoor flowering of wax flower (Shillo, *et al.*, 1985). Even more pronounced variations within years (Tables 2, 3 and 4) and between years (Fig. 3) resulted from short-day treatments. From these results, it can be postulated that in addition to the primary inductive effect of short-day treatment, temperature, in particular during the night, also significantly influences all phases of flower initiation and development. High temperatures (over 19°C at night) in autumn delayed flower initiation and bud appearance. Thus, the high temperatures of the late summer are the main limiting factor for starting short-day treatment early than September 1 in the Besor region.

Flower development to anthesis was extended with the lowering of temperatures during the late fall (November) and winter; thus anthesis of plants forced by short-day treatment could be delayed by several months in colder early winters than in comparison with mild winters. These effects are clearly depicted in Fig.3. Flowering development to anthesis was extended with the lowering of temperatures during the late fall and winter and because of this anthesis could be delayed by several months in colder vs. normal winters. In order to induce early flowering under field conditions, short days should be started when night temperatures are approximately 18°C but not higher than 20°C.

Finally, selecting early and mid-season flowering cultivars, which we have found to be most responsive to short-day treatments within mild environmental niches such as Israel's Negev Highlands in August-October, should give the maximum advancement of blooming, because these cultivars will flower before temperatures drop below 12-14°C at

night.

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Table 1 - Effect of short days on flowering of wax flower cv. 'Purple Pride' (92/3)

| | Normal days | Short days | Advancement of flowering (days) |
|---|---|---|---|
| Bud appearance | Nov. 8 | Oct. 13 | 25 |
| Harvesting date | Mar. 1 | Nov. 20 | 100 |
| No. of flowering branches / plant | 99.3 | 110.8 | |
| Branch length (cm) | 62.7 ± 1.2 | 63.4 ± 0.6 | |
| Branch weight (g) | 55.0 ± 6.0 | 63.0 ± 6.6 | |
| No. of flowers / terminal 10 cm | 29.0 ± 3.2 | 27.3 ± 1.6 | |

Table 2 - Effect of the date of starting short-day treatment on bud appearance and development of wax flower cv 'Purple Pride' (1993/4)

| Starting short-day date | Bud appearance date[1] | Start of bud opening date[1] | Harvest date[1,2] | Advancement of flowering (days) |
|---|---|---|---|---|
| Aug 5 | Oct. 18 ± 4.3 | Dec. 12 ± 4.3 | Dec. 20 ± 4.3 | 65 |
| Aug 25 | Oct. 23 ± 1.2 | Dec. 10 ± 2.4 | Dec. 25 ± 2.5 | 60 |
| Sept 15 | Oct. 26 ± 3.3 | Dec. 9 ± 2.9 | Dec. 25 ± 3.0 | 60 |
| Normal days (cont.) | Nov. 28 ± 3.7 | Feb. 2 ± 3.5 | Feb. 23 ± 3.3 | - |

[1] ± Days
[2] 30% of buds are open

Table 3. Effect of short-day period (3,5 and 7 weeks) for two dates of starting shortening (Aug 5 and Sept 15) on flowering of cv 'Purple Pride' (1993/4)

| Short-day treatment (weeks) | Bud appearance date | Bud opening date | Harvesting date | Advancement of flowering (days) |
|---|---|---|---|---|
| *Short-day started on Aug 5* | | | | |
| 3 | Nov. 4±2.2 | Dec. 27±3.6 | Feb. 12±1.9 | 12 |
| 5 | Oct. 19±2.6 | Dec. 3±2.4 | Jan. 9±6.4 | 46 |
| 7 | Oct. 19±2.5 | Dec. 4±2.1 | Jan. 9±5.2 | 46 |
| Normal days (control) | Nov. 28±3.7 | Feb. 9±3.5 | Feb. 24±2.9 | - |
| *Short-day started on Sept 15* | | | | |
| 3 | Oct. 24±0.8 | Dec. 17±2.3 | Jan. 21±8.6 | 34 |
| 5 | Oct. 27±1.5 | Dec. 17±2.1 | Jan. 13±4.3 | 42 |
| 7 | Oct. 26±1.4 | Dec. 27±4.3 | Jan. 21±5.6 | 34 |
| Normal days | Nov. 28±3.7 | Feb. 9±3.5 | Feb. 24±2.9 | - |

Table 4 - Effect of the date of starting short-day treatment (5 weeks) on bud appearance and development in cv. 'Purple Pride' (1994/5)

| Starting short-day date | Bud appearance date | Start of opening date | Harvest date | Advancement of flowering (days) | No. of flowering branches/ plant | No. of flowers/ branch |
|---|---|---|---|---|---|---|
| Aug. 15 | Nov. 24±2. | Feb. 26±4.4 | Mar. 18±1.8 | 2 | 16.0 | 67.9±9.4 |
| Sept. 1 | Nov. 7±2.4 | Jan. 19±5.8 | Mar. 2±2.1 | 18 | 20.2 | 83.2±8.9 |
| Sept 15 | Nov. 10±1.2 | Feb. 10±1.3 | Feb. 28±1.0 | 22 | 16.0 | 67.9±9.4 |
| Normal days | Nov. 28±1.0 | Mar. 4±1.3 | Mar. 20±1.2 | | 23.8 | 62.7±11.0 |

Table 5 - Minimum-maximum temperatures in summer-autumn 1993. Under the black plastic the minimum temperature was 0.6°C higher.

| Month | Period (10 days) | Minimum (°C) Outdoors | Minimum (°C) Tunnel | Maxim (°C) |
|---|---|---|---|---|
| Aug | 2 | 20.3 | 21.0 | 33.1 |
| " | 3 | 20.3 | 20.9 | 30.0 |
| Sept | 1 | 18.1 | 18.8 | 31.0 |
| " | 2 | 18.8 | 19.6 | 31.8 |
| " | 3 | 16.6 | 17.3 | 29.7 |
| Oct | 1 | 15.8 | 16.2 | 28.5 |
| " | 2 | 18.8 | 18.8 | 32.2 |
| " | 3 | 16.9 | 17.2 | 31.5 |
| Nov | 1 | 13.7 | 14.0 | 26.7 |
| " | 2 | 9.1 | 9.9 | 22.1 |
| " | 3 | 11.8 | 12.6 | 23.8 |

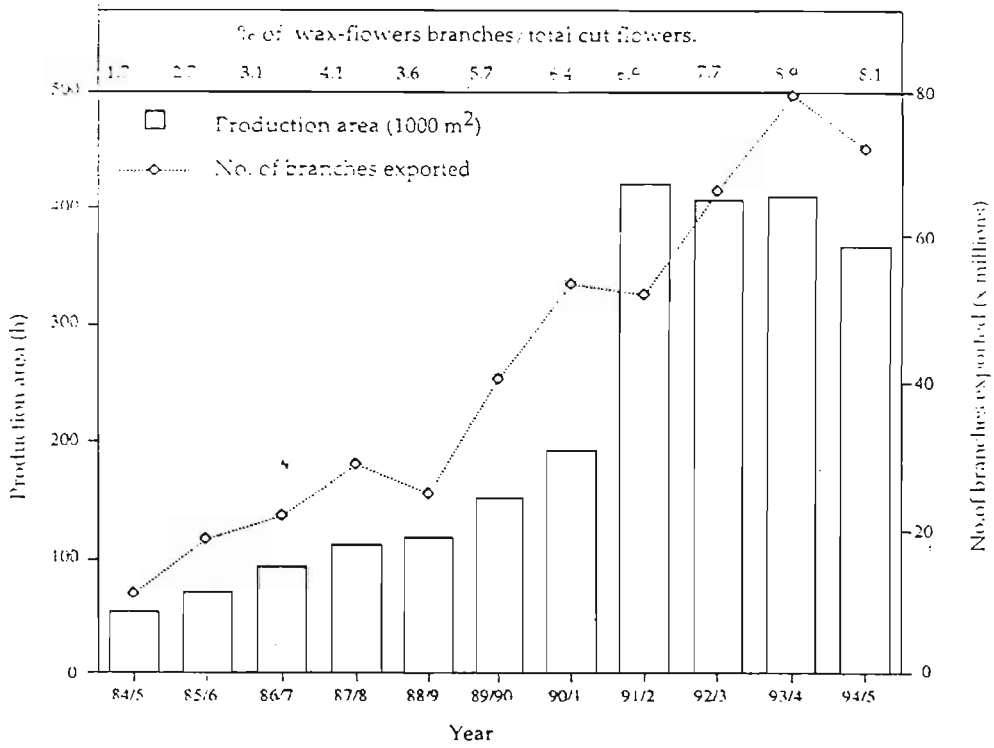


Fig 1. Facts about Israeli wax flower production. Reconstruction from annual diaries (1985-1995) of Israel association of commercial flower growers and the production and marketing board for ornamental plants.

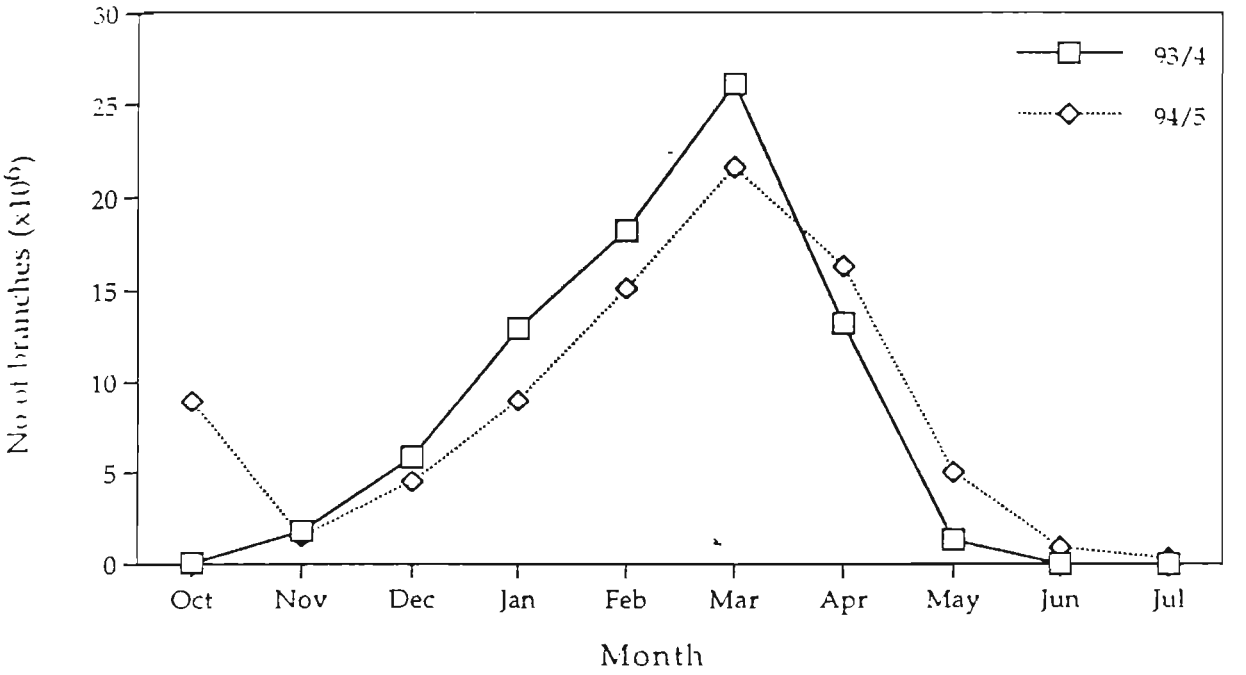


Fig. 2. Seasonal distribution of wax flowers exported from Israel in 1993/1994 and 1994/1995.

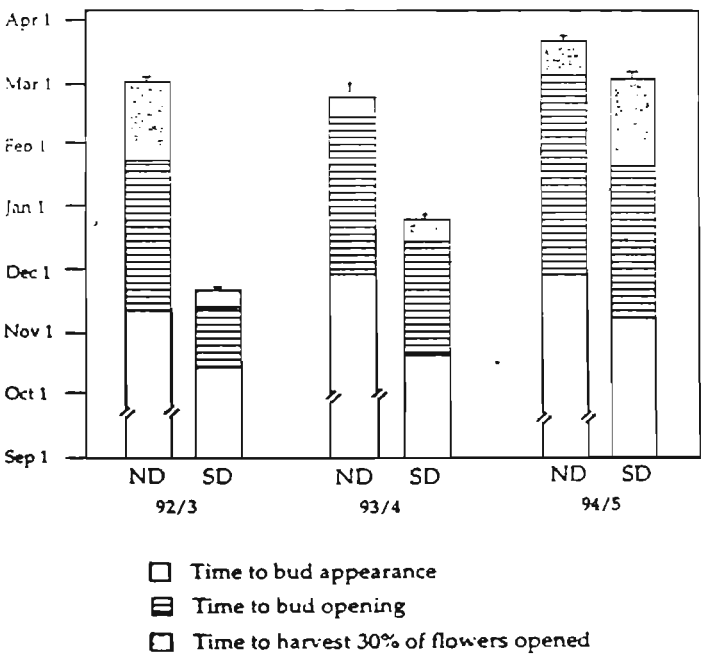


Fig. 3. Effect of short days (SD) on three years of flowering of wax flower cv. Purple Pride. SD started on September 1 (ND = normal days).

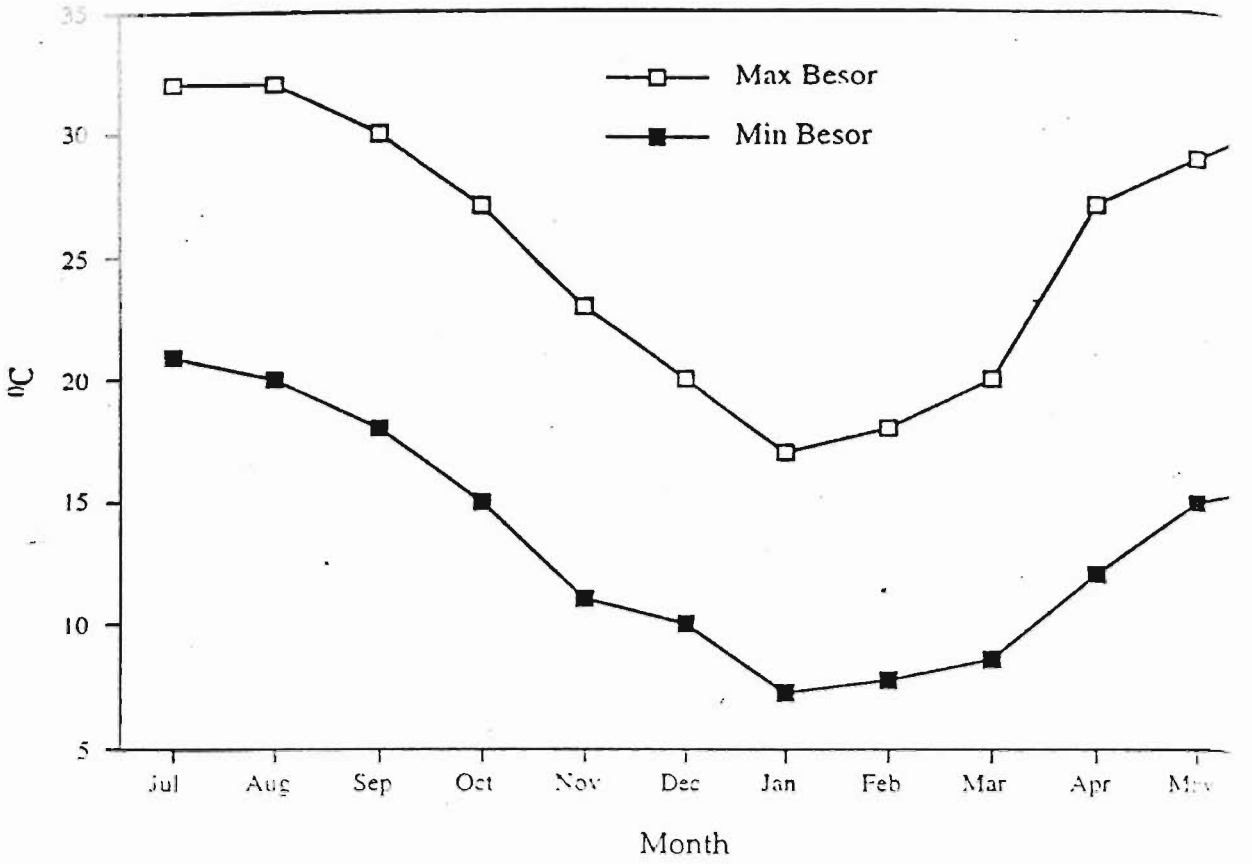


Fig. 4. Multi-Year average minimum-maximum temperatures at Besor experimental station.

# LIKELY TRENDS IN THE PRODUCTION OF WAXFLOWER AND OTHER *MYRTACEAE* IN WESTERN AUSTRALIA

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Abstract

The Australian export cut flower industry based on Myrtaceous species will face many challenges and opportunities in the next 10-15 years. There will be increased competition from other southern hemisphere producers and any downward pressure on prices will require efficiencies and innovation in all aspects of production and marketing.
If the industry is to continue past export growth, it will need to be at the forefront of developing new selections of various Myrtaceous species.

## 1. Introduction

Australia contains over 1500 species in the Myrtaceae family (Western Australian Department of Conservation and Land Management, personal communication) , with about 47% of these found only in Western Australia. The development of Myrtaceous species for cutflower or foliage production has been dominated by *Chamelaucium* (waxflower), followed by *Agonis* (ti tree), *Eucalyptus* and other miscellaneous genera.

Export of waxflower became important from Australia in the early to mid 1980's. The number of waxflower stems exported was 6.5 million stems in 1992, down from 11.7 million stems in 1991 (The Flower Export Council of Australia - FECA, personal communication). Some other Myrtaceous species harvested from Western Australia in 1993 are indicated in Table 1.

The Australian plant (wildflower) industry in Western Australia has two sectors: fresh and dried / processed. The fresh flower industry has recorded the greatest increase in production, from less than A$1 million in 1981/82 to over A$10 million in 1991.92 (Australian Bureau of Statistics, 1992). Approximately 76% of the fresh flowers are intensively cultivated. The dried and processed flower industry has grown from less than A$1 million in 1981/82 to about A$5.4 million in 1991/92. In contrast to fresh flowers, only about 30% of the dried and processed flowers are cultivated, with the majority coming from crown land and remnant bush stands on farms.

This paper will examine likely changes in the fresh wildflower industry based on species in the Myrtaceae family, with a special emphasis on waxflower production.

In analyzing the Australian wildflower industry, a major impediment is the lack of up to date and reliable information on production and the domestic market. Although export data is more reliable, it also suffers from some significant errors in flower categories. As indicated by Karingal Consultants (1994), industry needs to address as a high priority the requirement for better production and market data for wildflowers.

## 2. Domestic market

Information on the consumption of wildflowers in the domestic market is very limited. A survey by Karingal Consultants (1994) estimates that wildflowers have a 10 to 15% share in a domestic flower market valued at A$142 million. Analysis of market summaries suggests

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that wildflower market share has increased from almost nothing four years ago to its present level. Most of this increase is from bouquet sales though supermarkets.

There is a capacity for the wildflower industry to increase its share of the domestic market above its current level, with impulse buying at supermarkets and other convenient locations likely to increase in importance. Depending on the outcome of a proposal currently before government for a domestic flower levy, it could be expected that targeted promotion and advertising will increase domestic consumption of wildflowers, both in real terms and at the expense of 'exotic' flowers (carnations, roses etc.). Karingal Consultants (1994) suggest consumption of wildflowers in the Australian domestic market will increase by 2% per annum.

## 3. World cutflower market

The world cutflower market is growing at 6 to 9% per annum (Karingal Consultants, 1994). Most of the consumption is centered on the European Union, North America and Japan. Australia is a niche supplier of cutflowers, supplying less than 1% of the world cutflower market.

It is likely that some wildflower products e.g. waxflower may move from becoming a niche product to a 'mainline' product, albeit still at a low level. For waxflower, continuity of supply is critical to maintain its position on world markets.

For most other products, targeting a niche in the market place will require changes in product type and color, and having a wide range of different products available. FECA's policy of targeting auction markets, wholesalers and the major florist chain (JFTD) in Japan through promotions and displays is an important part of developing new markets, and maintaining or increasing market share. The color and uniqueness of other suitable Myrtaceae like *Verticordia* will be important in accessing these niche markets.

Increasingly, the world cutflower markets appears to be concentrating into vertical corridors of trade (Hayler, personal communication). Within the constraints of demand and returns, this may mean that Australia will increasingly focus on exports into Asia, especially Japan. The Japanese Cutflower Importers Association has forecast that imports of wildflowers into Japan can increase from A$12 million in 1993/94 to A$75 million by 2000 (FECA, personal communication).

## 4. Export considerations

With an emphasis on export, the industry needs to be focused on factors that affect this trade. Exporters surveyed by Karingal Consultants (1994) considered the major impediments to export growth was not demand, but airfreight supply and cost, quarantine issues and product quality. International factors affecting export growth include the A$ exchange rate and competition from other countries, especially those in the southern hemisphere.

In general, export to markets like the USA and Japan become more difficult when the A$ increases above US$ 0.75 and ¥ 80 (FECA, personal communication).

FECA is working with the Air Freight Export Council (AFEC) to resolve some aspects like quarantine and airfreight supply. The feasibility of a south east Asian transport hub for perishable products at Bali in Indonesia is being examined. This hub would assist in increasing the amount of airfreight available in the region. AFEC has also proposed methods to streamline demands and 'bids' for airfreight space. The possibility of committed freighter aircraft is not considered to be a viable option at this time (AFEC, personal communication). Karingal Consultants (1994) estimate that flower export growth will be limited to 10 to 20% per annum.

Growers and exporters in Western Australia and South Australia may become disadvantaged in that Brisbane (Queensland) and Sydney (New South Wales) in eastern Australia have been designated by the airlines as major export transshipment points. This is especially important given the focus of Western Australia growers on export with over 57%

of wildflower exports coming from this state (FECA, personal communication). In addition, airfreight costs are higher from Western Australia, with less space also available, than from Sydney or Brisbane. Currently, the cost of airfreight from Western Australia to northern hemisphere markets is A$3.50/kg compared to A$2.50/kg from Brisbane. Strategic planning by airlines in Australia is dictated by passenger rather than airfreight considerations (Karingal Consultants, 1994) with an apparently *ad hoc* and uncoordinated approach to meeting the needs of airfreight users.

The cost of airfreight is a limiting factor, and increases in cost have a major and negative impact on grower returns. In 1995, the average cost of airfreighting cutflowers to Japan and western USA from Western Australia was A$3 per kg (FECA, personal communication). High value lobster exports to Japan from Western Australia seriously affect the cost and availability of airfreight to other users from November to March. According to Karingal Consultants (1994), an increase of $1 per kg. in airfreight is worth about A$0.03 to A$0.04 per stem for waxflower.

Sea freight trials on waxflower from Western Australia to Japan have been done (Clarke, *et al* 1992), but the prospects appear limited due to other factors like the effect on price of large consignment of a limited product range arriving in one shipment at a single destination.

Various oncosts including desinfestation at some destinations, and inefficient internal transport systems, especially in Japan can have serious and negative impact on product quality and grower profitability. In the medium to long term, it is expected that some of these issues will be addressed. This will be done either by exporters bypassing these impediments where possible e.g. dealing direct with wholesalers and retailers in Japan, or minimizing costly overseas fumigation by considering the placement of quarantine officers from the importing countries in Australia during the busiest periods.

## 5. Competition

The main competition to Australian wildflower exports in the medium to long term will come from other southern hemisphere countries in southern Africa and southern America. These countries are lower cost producers than Australia and tariff preferences in many markets are provided to 'emerging' countries. Variable quality from some of these countries will provide only a short term buffer. Industry sources indicate that airfreight rates from southern America are 10 to 30% higher to Europe than Australia, and even higher into Asia, providing an estimated A$0.10 per stem buffer in Australia's favor (Karingal Consultants, 1994).

Overlap in waxflower production by northern and southern hemisphere countries is currently minimal and mainly at the margins, when supply is usually short. This may have a long term effect of modifying high prices received early and late in the season. Provided no significant breakthroughs in cost effective flowering manipulation are achieved, or out of season selections developed, it is likely that the complementary production from northern and southern hemisphere countries will continue in the medium term.

The world wide production shifts by other countries like Holland, USA and Israel to lower wage cost countries suggests that for Australia to remain competitive, any advantages in quality, continuity of supply, diversity or uniqueness of product must be exploited and further developed.

## 6. Diversity of production

The Australian wildflower fresh cutflower industry relies on only a few products in the volume export market, including waxflower, banksia and kangaroo paws (Anon, 1995). This is a potential disadvantage and leaves the industry vulnerable to aggressive competition in these products from other countries. There are large areas of natural stands of some Myrtaceae like *Agonis parviceps* in Western Australia which can be managed at very low cost, and which provide some protection against competition. However, the very nature of

these natural bush stands makes production of high quality and uniform bunches difficult. Most of the material from crown land or remnant bush on farms is harvested for the dried and processed market, although there is significant capacity for them to be grown for fresh flowers. In the long term, the harvest of material from bush areas may be limited as quality concerns become more important, or where the relevant species can be grown economically under cultivation (Sprigg and Webb, 1994). In addition, there is increasing pressure, especially in Western Australia, to limit the amount and range of material taken from the bush where the harvesting process is having a negative effect on species maintenance and regeneration.

There are a number of species being targeted in Western Australia as part of a rigorous selection program. It can be expected that over the next few years the results of this program will make new plant types and forms available to the local industry. This will fulfill part of the obligation of a niche marketer to constantly supply new products to the market.

Australia has a major advantage in having a range of latitudinal climatic zones, and the subsequent variation in flowering times for some wildflowers that can be achieved (Webb, 1994). However, these differences can be affected by climatic variations as in Western Australia in 1995 when early and mid season waxflower varieties were 4 to 6 weeks late in northern areas. Instead of a 16 to 18 week supply period from Australia, this was compressed to only about 12 weeks with problems with both freight space and market oversupply. The University of Western Australia and Agriculture Western Australia are currently testing new waxflower genotypes in a range of environments in Australia and overseas to determine the effect of location on the flowering of different genotypes, and to provide important information for a waxflower breeding program.

## 7. Selection and breeding

The future for the Australian wildflower industry is in being at the forefront of selecting and breeding its unique flora. Israel, Germany, Holland, Japan and New Zealand have all been active in examining Australian wildflowers, and in some cases, hybridizing material and selling it back to Australian producers.

The Australian and state governments, and to some extent the industry have been generally slow in promoting development of the flora, and may have been sidetracked by the wealth of endemic genetic resources. That position is changing quickly. There is now a national focus on the development of selected wildflower species supported by the Rural Industries Research and Development Corporation. The establishment of the Center for Australian Plants in 1995, and the recent appointment in Western Australia of two wildflower plant breeders should provide for the ongoing release of new varieties. Genera being targeted are those in the *Chamelaucium* alliance, including *Chamelaucium*, *Verticordia*, *Darwinia*, and the *Scholtzia* group. It is expected that while interspecific and intraspecific varieties will dominate, there is considerable capacity for intergeneric hybridization. There is a capacity for Australian institutions and industry to form collaborative breeding activities with other countries where the benefit back to Australia can be demonstrated. Internationalization of the Australian flora, backed by national and international plant breeders rights presents exciting challenges and opportunities to the Australian industry.

Currently, most of the activity is directed towards cutflower production. However, in the short term, that focus will be broadened to include the opportunities for various species and forms for the potplant market.

For waxflower, producers in Western Australia are targeting earlier selections that flower in June and July. There is also some interest in 'bud' lines, especially hybrids of *C. uncinatum* x *C. megalopetalum*, and varieties with terminal flowers. Purples and deep pinks are the most desired colors, with industry looking for varieties to fill in gaps in supply. Interestingly, these colors are the rarest in nature.

For other Myrtaceous species, various forms and varieties are being targeted that flower in seasons other than spring.

As most Australian Myrtaceae target the 'filler' market, it is likely that variations in flower size will also become important. The development in the 1980's of small flowering wax hybrids by Greg Lamont of New South Wales has provided an example of the variations that can occur. Not only will hybridization provide different colors and forms, for waxflower it can also result in increases in vase life greater than the combined vase life of the open pollinated parents.

As new selections and hybrids become available, it can be expected that the commercial life of plants in the ground will reduce, and growers will constantly replace sections of their plantings on an annual basis.

In the long term, the natural movement of producers to the most economic locations may mean that the capacity of the Australian industry to grow a particular line may be limited. However, if that line has been part of a local selection and breeding program, ongoing benefits in terms of royalty payments may provide some benefit to industry.

There are attempts being made by some state governments in Australia to provide for potential royalty payments on wildflower material taken for selection and breeding. This has followed from the Rio Conference on the World's Environment and the subsequent Convention on Biological Diversity (UNEP, 1992) and may have some impact on future breeding programs.

## 8. Quality

In the past, there has been criticism of the general quality of Australian wildflowers. This detracts from the excellent quality product presented by many growers and exporters. There are currently no agreed standards for Australian wildflowers on the domestic or export markets.

FECA and the Rural Industries Research and Development Corporation are currently working with Standards Australia to develop quality guidelines. It is likely that the Australian industry will develop an Industry Code of Practice, which may eventually lead to a quality assurance scheme.

There has been some concern by industry at the cost of introducing and complying with requirements of the International Standards Organization. If quality assurance is to be adopted by industry, there will have to be demonstrated benefits of participating, and costs will have to be reasonable. SQF 2000, a lower cost quality assurance scheme developed in Western Australia, and being examined in the eastern states of Australia, and New Zealand is suitable for this purpose.

## 9. Organizational structure

There is a considerable lack of unity in purpose and vision in the Australian wildflower industry at a policy and organizational level. The distances between production areas presents a real challenge in unifying industry. There are numerous regional groups servicing the industry, but only three truly national bodies, namely the Flower Industry Association of Australia which is a peak flower body, the Australian Protea Growers Association, and FECA. However, not all industry members or associations belong to these groups.

To provide a better focus for activities like promotion, quality assurance schemes and policy development, there will have to be a commitment by all participants to develop the industry in a structured way, and to provide for regional differences. It is likely there will be a greater emphasis on product specific associations operating both informally and formally.

## 10. Conclusion

Over the next ten to twenty years, the Australian cutflower industry, including that sector based on Myrtaceous species will face many challenges and opportunities. It is expected that prices received by growers will be under constant pressure and product quality will have to

constantly improve, and innovations in production and marketing become a priority. The regular introduction of new varieties will become a feature of the industry.

There will be increased competition from other countries, especially in the southern hemisphere. The extent to which local producers are able to meet this competition will depend on continued development of the industry and the impact of outside factors like currency fluctuations and airfreight cost and availability.

In Australia, any significant new plantings are likely to occur in those regions that have some timing advantage, or that are close to major airfreight transshipment centers, especially in Queensland.

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Table 1. Some Myrtaceous species harvested from Western Australia in 1993.

| Species | Number of stems (millions) |
|---|---|
| *Agonis parviceps* | 3.47 |
| *Agonis* sp. 'Coarse' | 1.52 |
| *Beaufortia sparsa* | 0.64 |
| *Scholtzia involucrata* | 0.30 |
| *Verticordia eriocephala* | 0.23 |
| *Agonis linearfolia* | 0.17 |
| *Verticordia nitens* | 0.16 |
| *Eucalyptus tetragona* | 0.14 |

Sources: Sprigg and Webb (1994) and Karingal Consultants (1994).

# SESSION C :
# GENETICS, BREEDING AND PROPAGATION

# NEW *BANKSIA* CULTIVARS FOR CUT FLOWER PRODUCTION

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Abstract

Selection and breeding of new *Banksia* cultivars concentrates on the cut flower species *B. coccinea, B. menziesii, B. hookeriana* and *B. prionotes*. Selection criteria include number of blooms per plant, time of flowering, stem length, inflorescence size, color and shape, rooting ability and tolerance to the root rot fungus *Phytophthora cinnamomi*.
Selection for bloom color is important for *B. coccinea* and *B. menziesii*. The predominant bloom color for *B. coccinea* is scarlet, but yellow, pink, orange and dark red variants have potential as new cultivars. For *B. menziesii*, the predominant color is pink, with yellow, apricot, red and bronze variants. Color stability is a problem with some *B. menziesii* variants, and only stable genotypes are included in the selection programme.
Techniques have been developed for root induction, and for screening roots for tolerance to *Phytophtora* infection. Future work will address grafting of banksias and the development of root rot tolerant rootstocks. Three cultivars have been registered from the programme so far. Waite Orange is a vigorous natural interspecific hybrid between *B. hookeriana* and *B. prionotes*. Waite Crimson and Waite Flame are both *B. coccinea* selections, with Waite Crimson a mid season dark red variant and Waite Flame an orange red early season cultivar.

## 1. Introduction

A *Banksia* selection and breeding programme has been underway at the University of Adelaide for approximately eight years. The main aims of the programme are to develop improved cultivars for the cut flower industry. This review will cover three main aspects of the work, emphasizing the areas of selection, propagation and hybridization.

## 2. Selection

The first stage of the programme is to select superior types from the genetic variability currently available. All existing plantings of *Banksia* cut flower species are seed-derived, with the inherent genetic variation expected in an outcrossing plant. This variability is a disadvantage to the grower, as it causes lack of uniformity in the crop, but is an advantage to the breeder as it provides material for selection of important characteristics. To date we have concentrated on four cut flower species *B. coccinea, B. menziesii, B. hookeriana* and *B. prionotes*. The selection criteria include yield, size of blooms, color of blooms, stem length, time of flowering, length of flowering period and foliage characteristics. Selection for bloom color is important for *B. coccinea* and *B. menziesii*. The predominant bloom color for *B. coccinea* is scarlet, but yellow, pink, orange and dark red variants have potential as new cultivars. For *B. menziesii*, the predominant color is pink, with yellow, apricot, red and bronze variants. Anthocyanins are responsible for the pink and red tones of the blooms of *B. menziesii*, and care must be taken in the time of year when selection assessments are made. In some genotypes the redness of the blooms increases as the temperature decreases (Bickford and Sedgley, 1994), and only color stable genotypes are included in the selection programme. It is important to select color stable cultivars, so the

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colour will not change depending on the environment in which the cultivar is grown.

Three selections have now been registered from the programme. These are Waite Orange a natural interspecific hybrid between *B. hookeriana* and *B. prionotes*, Waite Crimson a mid-season dark red selection of *B. coccinea* and Waite Flame an early-season orange-red selection of *B. coccinea*. All have been registered with the Australian Plant Breeders Rights Office (Sedgley, 1991; 1995a; 1995b).

We have not so far addressed the important aspect of rootstock selection, although this is a priority of the next stage of the project. Selection criteria will include soil type, salinity, pH and disease tolerance, graft compatibility with the scion selections and rooting ability.

## 3. Propagation

Research so far has concentrated on the production of rooted cuttings of the scion cultivars. *Banksia coccinea* shows a trend toward increased rooting as the indole butyric acid concentration is increased to 10 000 ppm, and most success is achieved in the cooler months of the year. Up to 80% rooting success is achieved with *B. coccinea*, *B. hookeriana* and *B. prionotes*, although some genotypes will not root. Success is much lower with *B. menziesii*, and more research is required to address this problem. *In vitro* propagation has been investigated, with shoot and root proliferation of juvenile *B. coccinea* tissue, but no success in hardening off plantlets for deflasking. Further research is needed in this area, in addition to application of the techniques to mature tissue.

Work has commenced on grafting of banksias, as rootstock development is an important part of horticultural production. The major problem is that the scion species are intolerant of variation in soil type, salinity, pH and disease tolerance, and interspecific grafting is required to extend the planting areas available for *Banksia* cultivation. Previous work has shown variability in graft compatibility between the species, and more work is required to clarify these problems. The main disease which threatens banksias is *Phytophthora cinnamomi*, and selection methods have been developed to screen potential rootstocks for tolerance to this fungus.

## 4. Hybridization

Interspecific hybridization is important in the development of most horticultural crops, and this has already been demonstrated in *Banksia* by the cultivar Waite Orange. We have developed hybridization methods for banksias, and have made artificial crosses between the parental species of Waite Orange, *B. hookeriana* and *B. prionotes*. Hybrids were produced only when *B. hookeriana* was used as the mother, and all hybrids were intermediate between the parents in morphological and molecular characteristics (Maguire, *et al.*, 1994). Successful interspecific pollen tube growth has also been observed in the species *B. prionotes* and *B. menziesii* (Sedgley, *et al.*, 1994), and interspecific hybridization involving the most popular cut flower species, *B. coccinea* is currently underway.

An important aspect of hybridization work is the investigation of breeding systems, so these can be exploited for optimum hybrid production. Our research has shown that banksias are protandrous and show partial self incompatibility, and this knowledge has been incorporated into the hybridization method.

## 5. Concluding remarks

There are three major achievements of the *Banksia* selection programme so far. The first is the selection of three superior cultivars with characteristics for the cut flower industry. The second is the development of vegetative propagation techniques via the production of rooted cuttings. The third is the development of hybridization methods for the production of new novel cultivars. Further work remains to be conducted in all of

these areas, in addition to the development of rootstock cultivars, and on interspecific grafting. One possibility to overcome the current graft incompatibility problems, may be to investigate interspecific rootstocks as well as interspecific scions.

Acknowledgments

The research was supported by the International Protea Association, and by the following Australian research funding bodies: the Rural Industries Research and Development Corporation, the Horticultural Research and Development Corporation, the Australian Research Council, the Australian Flora Foundation, the Society for Growing Australian Plants, New South Wales and the Playford Memorial Trust.

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# REVIEW OF THE FYNBOS GENEBANK PROJECT

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Keywords : genetic resources, horticulture, machia

Abstract

The uniqueness of the Fynbos Genebank lies in its aim to conserve the genetic diversity of fynbos plants with floricultural merit. The fynbos is a unique plant ecosystem found only within the world's smallest floral kingdom, the Flora Capensis. This plant ecosystem has been reported to be more threatened by mans activities and interference than even the rainforests. The aims of the Fynbos genebank are the following:

1. collection and acquisition of new samples,
2. regeneration and multiplication of samples,
3. maintenance of the genetic integrity of samples,
4. documentation and exchange of information on the samples maintained,
5. research on the most appropriate methods of conservation of the samples, and
6. controlled exchange of samples.

The problems facing the maintenance of this genebank center around sufficient funds to not only maintain it, but to improve the operations of the genebank to meet international standards.

## 1. Introduction

A genebank is a center which maintains collections of plant material with the aim of keeping them alive and preserving their characteristics for the present and future benefit of mankind (Painting, *et al.*, 1993). Many types of genebanks exist in the world, many of them large international concerns conserving the genetic resources of important commercial crops such as maize and wheat.

The uniqueness of the Fynbos Genebank lies in its aim to conserve the genetic diversity of fynbos plants with floricultural merit. The fynbos is a unique plant ecosystem found only within the world's smallest floral kingdom, the Flora Capensis. While ecosystems such as the rainforests receive much attention from genetic resource conservators, Wood (1992) emphasizes that priority should be given to strategies which protect, manage and increase the diversity of species with potential agricultural value. The fynbos is not only unique because it is home to over 8500 species of plants (Huntley, 1994), but 135 floriculture products are marketed from this ecosystem, many of them still harvested from wild stands. This unique plant ecosystem, the fynbos, has been reported to be more threatened by man's activities and interference than even the rainforests (Rebelo, 1992). The greatest threats come from the infestation of vast tracts of land by alien shrubs. While the immediate destruction of pristine fynbos by agricultural and urban expansion or fires is very obvious the insidious encroachment of land by alien plants often goes unnoticed until it is too late. Rehabilitation of land by removing alien plants can result in the rehabilitation of the natural fynbos (Richardson, *et al.*, 1992), which is not possible on agricultural land.

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With over 8500 flowering plant species growing within the fynbos one could argue that each specie must be represented within the genebank. This is neither feasible nor necessary. Mountain fynbos ecosystem and the specie diversity within this ecosystem is being fairly adequately conserved, except for very rare species growing in threatened localities (Rebelo, 1992). Genetic variability within species, especially those species with a wide habitat range and the lowland species that have been destroyed by expansion of agriculture, desperately need to be conserved. The conservation of the genetic variability can be justified purely on the grounds of conservation and preservation of biodiversity, but from an economic perspective this genetic diversity provides the raw materials for breeding and commercial crop development (Moss, 1994).

Floricultural plants of the fynbos and other similar ecosystems have demonstrated that individual plants within a specie will be more amenable to cultivation practices and therefore superior for commercial production (Sedgeley, 1995, Littlejohn, *et al.*, 1995). The breeding of hybrids, between and within species has been and will be the future pathway of development of floriculture crops from wild species, thereby attaining greater plant vigor and productivity under cultivation (Ford-Lloyd, 1990). The flowering plants of the fynbos which have featured most prominently in cultivation within the last 50 years are members of the Proteaceae family. Despite the richness of the Flora Capensis in the genetic diversity of these endemic plants, initial cultivation and breeding research on these plants was more advanced and progressive in other countries, such as Australia, which have similar soil and climatic conditions. The steps towards the creation of a genebank for the conservation of the unique and valuable genetic resources of the Proteaceae during the 1960s were progressive. The vast surveys undertaken by persons such as the legendary Dr. Marie Vogts led to a collection of not only a large number of species, but also genetic variants within the species (Vogts, 1982). This collecting was continued into the early 1980's, but in the case of Proteaceae has had to be scaled down due to financial constraints. Current collecting efforts concentrate on woody fynbos plants other than Proteaceae, which are still harvested in large quantities from natural stands. This includes species from the Bruniaceae, Rhamnaceae and Ericaceae families.

The Fynbos Genebank is maintained as an active (Tao and Engels, 1994), field (Painting, *et al.*, 1993) genebank. This means that each plant type representing a unique genetic variant is maintained as living plants in a plantation. The collection of plants is active in the sense that the evaluation of the plants for characteristics of importance for floricultural use and hybridization is done on the genebank plants. The evaluation procedure involves an accurate description of flowering time, aesthetic characteristics of foliage and flower, stem length, vigor after pruning and vase life of the flowers. Ideally a base collection maintained only for genebank purposes should be kept either as a field genebank and in some cases as seed, but constraints are both financial and practical. Little is currently known about storage requirements of protea seed, and even less about other woody fynbos plants.

While the bulk of the plants conserved in the genebank are species and variants within species, many unique interspecific hybrids, in many cases already released as superior cultivars, are maintained. Cultivars developed in other protea producing countries are also maintained. The emphasis on both collection and maintenance of plants is on those with floricultural worth, but many rare or endangered species are collected and propagated. These include the marsh rose, *Orothamnus zeyheri* and silver flame bush, *Mimetes argenteus*.

The aims of the Fynbos genebank are the following:

- collection and acquisition of new accessions,
- regeneration and multiplication of accessions,
- maintenance of genetic integrity of accessions,
- documentation and exchange of information on the accessions maintained,
- research on the most appropriate methods of conservation of the accessions, and
- controlled exchange of accessions.

2. Objectives of the fynbos genebank

A policy statement and progress report in each of these areas is presented.

2.1. Collection and acquisition of new samples

Decisions to collect new plant material are based on the following criteria:

- The species or variants have floricultural potential as cut flower or potplant, based on own opinion or collectively from the indigenous plant industry.
- The plant specie is endangered or rare or the habitat is threatened.

2.2. Regeneration and multiplication of samples

The genebank accessions for each of the Proteaceae genera are:

| | |
|---|---|
| *Protea* | 23 species represented by 425 accessions<br>186 hybrid accessions |
| *Leucospermum* | 26 species represented by 130 accessions<br>190 hybrid accessions |
| *Leucadendron* | 52 species represented by 493 accessions<br>181 hybrid accessions |
| Serruria | 4 species<br>60 hybrid accessions |

Regeneration of samples of woody plants is via clonal vegetative reproduction using semi-hardwood cuttings. Seed samples are not currently kept.

The woody fynbos collection includes:

| Bruniaceae | Species |
|---|---|
| *Brunia* | 6 |
| *Berzelia* | 5 |
| *Nebelia* | 3 |
| *Raspalia* | 1 |
| *Staavia* | 1 |
| Rhamnaceae | |
| *Phylica* | 20 |
| Ericaceae | |
| *Erica* | 41 |

Foreign woody plants with floricultural potential include: *Chamelaucium* (Geraldton Wax) of which 23 accessions are presently kept.

2.3. Maintenance of genetic integrity of samples

Clonal multiplication circumvents the problem of maintenance of genetic integrity.

2.4. Documentation and exchange of information

The results of evaluation, origin and any cultivation practices concerning the samples maintained is available from the researchers involved in the genebank activities. Popular and scientific publications are made from time to time.

2.5. Research on most appropriate conservation methods of samples

This is an area which needs to be expanded so that more cost effective conservation than field maintenance of all clones can be achieved. Rare species that are not of immediate use in the breeding programme due to failure of hybridization or some deleterious characteristic could be conserved as seed. This aspect requires more research on the success of self pollination of the plants, appropriate seed harvest methods, seed storage and seed germination methods.

2.6. Exchange of samples

Release of genebank material is only through licence agreement to not commercially propagate nor multiply the material via seed or vegetatively. The material is supplied as rooted or unrooted cuttings. The maintenance of a core collection (Haman, *et al.*, 1995), based on seed, of each of the commercially used genera would facilitate the exchange of material. Funding for this collection and the aquisition of material from this collection would be necessary.

3. Conclusions

The fynbos genebank conserves three types of material:

- species selections with unique genotypes,
- rare and endangered species, and
- cultivars.

The problems facing the maintenance of this genebank center around sufficient funds, to not only maintain it, but to improve the operations of the Fynbos Genebank to meet international standards. It is a Catch 22 situation in which funds are required to get the genebank to operate in an internationally recognized manner, with the maintenance of long term storage of germplasm and duplicate collections, but without these operations already in place the standing of the genebank is low and will have trouble attracting international funding. According to Article 21 of the Rio Convention on Biodiversity the conservation of genetic resources is a government of the day responsibility, both financially and operationally (Moss, 1994), however as a developing country South Africa lacks funds to plough into conservation of genetic resources. Blixt (1994) contends that the terms of the Rio Convention imply that developed countries should financially support the development and maintenance of germplasm in developing countries, and especially support the ongoing conservation efforts of genebanks. While *in situ* conservation of the fynbos will conserve much of the specie diversity and hopefully most of the diversity in ecosystems present in the fynbos biome, the *ex situ* conservation of the genetic diversity within species is necessary to preserve the biodiversity of the Fynbos and to provide a base collection from which commercial products for floriculturists of today and tomorrow can be developed.

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# EFFECT OF THE POSITION OF CUTTINGS ALONG THE MOTHER STEM ON THE RHIZOGENESIS AND THE RAMIFICATION IN SOILLESS CULTIVATION

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Abstract

The main aim of this study was to understand the cutting position effect on the rooting and the future development of genus *Protea* plants. Cuttings from *P. eximia / P. susannae* cv. 'Sylvia' and cv. 'Cardinal' were carried out from Autumn 1994 to Spring 1995. An important variation of rooting ability depending on stem development state and cutting position was revealed. The best results were achieved for median positions on flower bud stems. In the same way, the effects of different growth regulator concentrations and dipping times were explored. Increased IBA concentration improved the rooting percentage, whereas the increase of dipping time had little effect on the auxin absorption rate. The observation of the rooted cuttings' development showed us that the branching ratio is especially affected by cutting vigor, i.e. the diameter and weight. A better choice of propagation material according to plant physiology and the control of cultivation conditions should conciliate growers' requirements with hard to root and to cultivate species.

## 1. Introduction

The big demand for exotic flowers on the European market as well as the fact that Mediterranean climatic conditions are very similar to those prevailing where they grow naturally, have led growers in the South of France to cultivate Proteaceae along the French Mediterranean coast. The low winter temperature and the calcareous soils means growing *Protea* under shelter and in soilless conditions, so as to obtain optimum growing conditions.

The first trials enabled us to define the branching and flowering processes of different species and to deduce which growing techniques were best adapted to the characteristics of each (Allemand, Le Bris, Montarone, 1993). The results of these trials led to fertigation adapted to the specific requirements of these plants. However, as seedlings give a heterogeneous production and as it is important to produce flowers quickly, we chose vegetative propagation i.e. by cuttings. In the case of most perennial woody plants, rooting is heterogeneous and depends on the position of the cutting on the mother-stem, probably owing to the age of the stem tissue.

During our study, we first determined the effect of the cutting's position on its rhizogenesis as well as its interaction with various morphophysiological factors. We then observed the effect of the cutting's position on morphogenesis of the plant itself as well as the possible links between rooting and branch development. Margara (1982) pointed out that further research into rhizogenesis was necessary in order to improve vegetative propagation techniques.

According to Chadwick in Jacobs (1990) "the successful vegetative propagation by cuttings depends on internal, anatomical and physiological factors as well as external and environmental factors". Leaves and buds play an important role. Favre (1977) noted that the stimulus originating from leaves or buds increased the number of rooted cuttings. It has long been known that there are big differences in rooting capacity between species,

Proc. Fourth Int. Protea Symp.
Eds. G.M. Littlejohn, H. Hettasch
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cultivars and clones, even though the physiological explanation has not been established. For example in his work on Leucospermum, Brits (1986) demonstrated a difference in rooting of 28 % between 2 cultivars 'Caroline' and 'Vlam'. Finally Jacobs (1981) proved there was a high degree of heterogeneity in the rooting capacity of different clones of *Protea repens*. This may be linked to the age of the mother plant, the position of the stems or cuttings on the mother plant, to the type of cutting taken, to hormone treatment, to the substrate, the climatic conditions, to damaging of plants or to phytosanitary problems.

## 2. Material and methods

To carry out our trials we used the following mother plants : *Protea eximia* produced from seeds, *P. eximia* x *P. susannae* cvs 'Sylvia' and 'Cardinal' from cuttings. The *P. eximia* plants were 5 years old, the 'Cardinal' cv 4 years old and 'Sylvia' cv 2 years old.

### 2.1. Containers and substrate

The 'Cardinal' and 'Sylvia' mother plants were grown on volcanic lava in plastic containers measuring 55 liters for 'Cardinal' and 4 liters for 'Sylvia'. The *P. eximia* mother plants were grown on Esterel porphyry in polypropylene benches measuring 470 l with a density of 2.2 plants per $m^2$.

### 2.2. Feeding

Earlier research had led to the defining of a nutrient solution adapted to Proteaceae composed as follows: 1 $me.l^{-1}$ of nitrogen, ($NO_3$ = 0.6 me, $NH_4$ = 0,4 me), 0.1 $me.l^{-1}$ of phosphorus, 1 $me.l^{-1}$ of potassium, 1 $me.l^{-1}$ of calcium, 1 $me.l^{-1}$ magnesium : These last two elements were supplied by deionized water. Iron was obtained as chelate at a concentration of 800 $\mu g.l^{-1}$. Oligo-elements were added by means of a commercial solution.

### 2.3. Cuttings

Cuttings were taken from floral stems for trial 1 and from floral and vegetative stems for trial 2. The cutting is a flush. The cutting technique used is slightly different from the traditional one as the base of the cutting is beveled.

About 5 of the basal leaves were taken off to avoid rot and necrosis ; then the cuttings were dipped for 30 sec. in an alcoholic solution of IBA (2000 ppm), washed for 1 minute with deionized water and dipped in a fungicide (Benomyl $2g.l^{-1}$) before planting in a humidified mixture composed of peat and polystyrene balls in a ratio of 50/50 (in volume). A relatively high moisture level for the leaves and substrate was maintained by means of a mist system.

The climate inside the greenhouse was managed by a computer. In the propagation greenhouse, day and night ground temperatures were 20°C, up to a maximum of 25°C during the whole rooting period.

When the roots reached 3 to 4 cm, the rooted cuttings were placed in 4-litre plastic pots containing volcanic lava (pouzzolane). Such plants require 3 days acclimatization in the propagation greenhouse before being moved to their cultivation greenhouse ; then the pots were placed on tables and fed the same nutrient solution as the mother plants by means of 2 drips delivering 2 liters/hour. For this greenhouse, the temperature was maintained between 5°C and 23 °C.

Three types of tests were carried out on Protea cuttings :

- Test no 1 : the effect of the flush's position on its rhizogenesis capacity as well as on branching, from stems taken at similar physiological stages, for *P. eximia* (in autumn).
- Test no 2 : the effect of the flush's position on its rhizogenesis capacity as well as on branching for *P. eximia* and *P. eximia* x *P. susannae* cv. 'Sylvia' (spring).
- Test no 3 : the effect of the cuttings' position and hormonal treatment on its rhizogenesis and branching for *P. eximia* x *P. susannae* cv. 'Cardinal' (spring).

2.4. Records of experimental observations

2.4.1. Vegetative material

As mentioned above the cutting is a flush, each stem consists of a series of flushes numbered from1 to X from the floral bud, i.e. UC1, UC2, UC3, etc. For nonfloral stems, the flushes were called UC1*, UC2*, UC3*, as it is impossible to know if UC1* will in fact produce a flower. (Fig. 1).

- Test no 1 : For *P. eximia* : position's effect on rooting potential of the stem flushes in autumn.
- Test no 2 : For *P. eximia* and cv 'Sylvia' : to show the effect of cutting's position on its rhizogenesis in spring.
- Test no 3 : we tested three concentrations of I.B.A. i.e. 500, 1000 and 2000 ppm and 2 dipping times, 30 and 60 seconds on cv. 'Cardinal'.

2.4.2. Observations made before rooting

- Physiological stage and weight of floral bud if any
- Position of the cutting on the stem and the plant
- Number of leaves left on the cutting
- Diameter and weight

The rooting was observed every two weeks, once roots began to appear. Observations of cutting's root systems made before planting were as follows :

- Number of roots
- Length of root system
- Estimation of the callus on a scale from 0 to 5 (0 is a total absence of callus and 5 means the scar area is covered).

As soon as the cutting has enough roots, it is placed in pots full of lava (Tuff).

2.4.3. Observations made during development

- Number of branching every two weeks per plant
- Number of flushes per new branch
- Length of fully grown flush
- Diameter growth of each flush

2.5. Statistical data-processing

The data collected were analyzed by the Statview software according to the following statistical methods.

- The $\chi^2$ test
- Variance analysis
- Comparison of means by Scheffe's test
- Correlations and regressions

In all the histograms shown, 2 different letters correspond to significant differences with $P < 0,05$. The abbreviations used are as follow : me = milli-equivalent, T = total, UC = Flush or growth unit, ppm = part per million.

## 3. Results and discussion : rhizogenesis

A cutting's quality is defined in terms of its rooting capacity. Cuttings remained dormant for differing lengths of time. This length of time is a second criterion taken into account in judging cutting quality.

### 3.1. Cutting's rooting capacity and origin

The rooting capacity of the cutting was measured in terms of its origin (mother plant) and its position on the stem.

#### 3.1.1. Influence of the mother stem

Fig.2 shows the influence of the mother plant, whether from seedlings or cuttings. For *P. eximia*, 'Cardinal' and 'Sylvia', the influence of the mother plant on rooting capacity was observed to be very significant at all stages of development. Two reasons may be proposed:

- The genetic factor which plays an important role in some *P. eximia* species, clones and cultivar : Brits (1986) also observed a great variability in rooting capacity among *Leucospermum* cultivars.
- The effect on the mother-plant of growth, climatic and feeding conditions.

It has often been observed that a cutting's rooting capacity is influenced by environmental conditions (Andersen, 1994) and Nitrogen-rich nutrition (Lemaire, 1989) on the mother-plant

#### 3.1.2. Influence of the development stage of the mother stem when the cutting is taken.

In tests 2 and 3, in which we took both floral and vegetative cuttings, the rooting capacity was seen to be significantly two or three times greater for floral stems ; this is due to the fact that the tissues of the vegetative stems were insufficiently mature.

At all development stages of the mother plant, the rooting potentiality of the species studied can be classified as follows: ***P. eximia*** > **'Sylvia'** > **'Cardinal'**. It is however important to bear in mind the fact that the cuttings of this species and its two hybrids were not taken in exactly the same climatic conditions.

#### 3.1.3. Influence of the cutting's position

In the case of vegetative stems, the extremity corresponding to UC1* never produced roots ; in the case of other positions, there was a positive acropetal rooting gradient whatever the cutting period, as shown in Fig.4. The total failure of the growing flush to produce roots confirms the theory that this tissue was still immature (herbaceous). The full-grown flushes were sufficiently mature to allow rhizogenesis : therefore, the best rooting can be expected from a cutting taken just below the growing flush, as we may presume that its cambium is sufficiently mature to allow rooting. In the case of mature

floral stems, rooting in terms of position appears to vary according to the cutting period as suggested in Fig. 5.

- For a cutting taken in March there was a clear positive acropetal gradient for 'Sylvia' but not for *P. eximia* ; on the other hand, for April cuttings, this gradient was only observed for positions 2, 3, 4 and the rooting percentage of the extremity was significantly lower than for flush 2.
- For autumn cuttings, the gradient showed increased rooting for the lowest flush.

3.2. Rooting capacity and hormonal treatment

Both concentration and dipping time were taken into account.

3.2.1. Concentration

A stronger IBA solution improved rooting capacity significantly. There is a positive gradient for rooting capacity for doses from 500 ppm to 2000 ppm as shown in Fig. 6.

3.2.2. Dipping time

The dipping time had no significant effect on rooting whatever the concentration used : however it appeared to have more effect when the IBA solution was weaker. For example increasing the dipping time by 30 seconds improved rooting by 7 % for 500 ppm, by 4 % for 1000 ppm and by only 2 % for 2000 ppm. Prolonging the dipping time results in quick absorption of auxin by stem tissues as observed by Jacob (1990). There is however a limit to this increased rooting, as after a short period of time auxin absorption by the cutting would be very low. Thus it is more judicious to represent the results obtained in terms of concentration x time. We obtained a curve of points similar to those describing the variation of enzymatic reaction speed, or the absorption of a dissolved substance. The rooting percentage appears to level off when the concentration x time = 2000 ppm.min. Therefore if C x t = 4000 ppm/min or more the rooting is no better. This confirms the theory that above a certain quantity of auxin, the concentration has no effect on rooting. In other words, the tissue maturity of the cutting seems to be the main limiting factor for rooting.

3.3. Influence of cutting's morphological features

Each cutting also has varying quantitative characteristics which may have an effect on rooting.

3.3.1. Number of leaves per cutting

Rooting versus the number of leaves indicated that number of leaves had a positive effect but there could also be the influence of solar radiation linked to the leaf area.

3.3.2. Diameter and weight

The diagrams drawn plotting rooting against the cutting's diameter were similar to more or less symmetrical Gaussian curves, the top of the curve indicating the diameter value for maximum rooting. This value varies according to the species, in the case of woody cuttings, weight has the same influence as diameter. Figures 8 and 9 illustrate these results for 'Cardinal'; *P. eximia* and 'Sylvia' show the same variations.

3.4. Latency

This was observed in trials 2 and 3 in which rooting was measured in terms of time. Rooting was measured every two weeks

3.4.1. Influence of cutting's position on average latency

In test 2 no significant difference in latency was observed. It was between 80 and 90 days for all positions with a minimum of 70 days for position 2. Test 3 carried out on 'Cardinal' showed a much shorter latency in the case of UC2, 3 and 4 : about 60 days, compared with UC1 which had an average rooting time of 85 days for all positions. As in the case of rooting capacity in the same position, latency seems to vary according to the cutting period.

3.4.2. Influence of position on earliness of rooting

In all trials UC2 was seen to be the earliest to develop rooting. Two of the 3 diagrams indicate the rapid growth of the percentage of cuttings rooted during the first month after the first roots appeared. In the case of *P. eximia* and 'Cardinal' rooting leveled out in June and increased again at the beginning of July. For cultivar 'Sylvia', Fig.10 shows a regular increase in rooting percentage.

4. Results and discussions : branching, development

4.1. Influence of position

No link was observed between position and the appearance of axillary buds, which started to swell after 40 days for all positions and species. There was a negative correlation between bud swelling and root length when the cutting was planted for 'Cardinal'. This relation can be expressed as follows : $Y = -3.17x + 55.3$ ($R^2 = 0,45$). It is however important to bear in mind that these measurements may vary according to the seasons and the substrate used. Furthermore, signs of stress may be observed and vary according to the type of plant.

4.2. Branching flush

Axillary budding is produced by flushes in the same way as on the mother plant (Fig. 11). The branching is obtained on the topmost part of the cutting as seen in Leuwenberg's model (Le Bris, 1993). From 0 to 20 % of cuttings produced delayed budding but the last branch always appeared on the cutting within 2 weeks after the first bud. The cutting position did not have a significant effect on branching potentiality, which was 3 or 4 branches per cutting. The strength of the cuttings was measured by its diameter and its weight when it was taken. There was a positive correlation between the diameter, the weight and number of branches growing in the case of 'Sylvia' UC2, UC3, UC4 ; the correlations obtained are as follows :

| | |
|---|---|
| Number of branchings and diameter | UC 2 $Y = 0.69X - 2.36$ $R^2 = 0.68$ |
| | UC 3 $Y = 1.26X - 7.72$ $R^2 = 0.69$ |
| | UC 4 $Y = 0.21X + 1.29$ $R^2 = 0.82$ |
| Diameter and weight | UC 1 $Y = 3.09X - 4.96$ $R^2 = 0.68$ |
| | UC 2 $Y = 4.23X - 15.44$ $R^2 = 0.89$ |
| | UC 3 $Y = 5.06X - 29.57$ $R^2 = 0.90$ |
| | UC 4 $Y = 3.24X - 14.42$ $R^2 = 0.82$ |

| | |
|---|---|
| Branching and weight | UC 2 $Y = 0.163X + 0.22$ $R^2 = 0.75$ |
| | UC 3 $Y = 0.30\ X + 0.015$ $R^2 = 0.65$ |
| | UC 4 $Y = 0.068X + 2.19$ $R^2 = 0.94$ |

For UC1 no correlation was established ; similarly for *P. eximia* and 'Cardinal', there was no relationship between diameter and number of branchings on the one hand, and weight and number of branchings on the other. In view of the fact that 'Sylvia' cuttings were taken from branching orders 1 and 2 on plants 2 years old, whereas for 'Cardinal' and *P. eximia*, they were taken from branching order 4 and 5 on plants 5 years old, it could be supposed that the branching strength of the cutting was proportional to the age of the mother plant. Thus, when the mother plant is young, its cuttings produce vigorous branchings, whereas cuttings taken from older plants, produce unpredictable branchings (strength no longer plays any part).

Several important criteria for rooting cuttings of *Protea* are derived from the results of this study, for the future application in soilless conditions in the South of France :

- the mother plants must be young
- the stems chosen for cuttings should be floral
- UC2, UC3 and UC4 give the best rooting and branching

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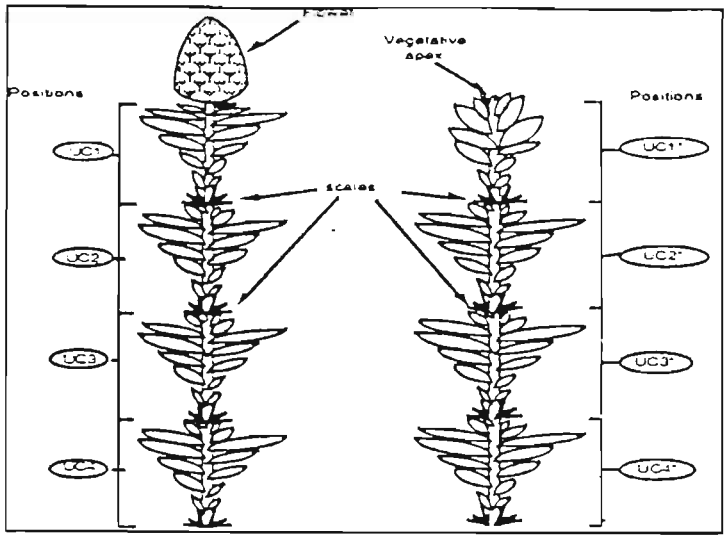


Fig. 1: Positions of the cuttings on the floral stem, and on vegetative stem

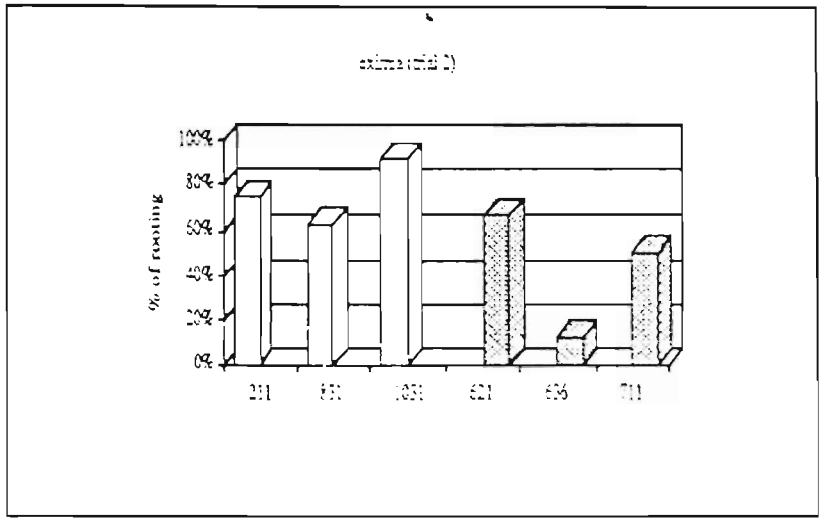


Fig. 2 : Rooting variability according to the mother-plant : ex. *P. eximia*

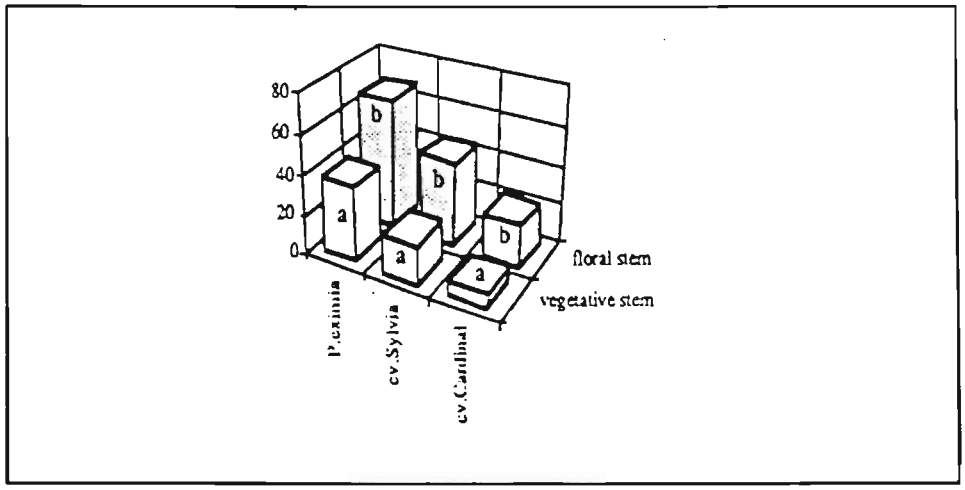


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Fig. 3 : Effect of the physiological stage of the mother stem

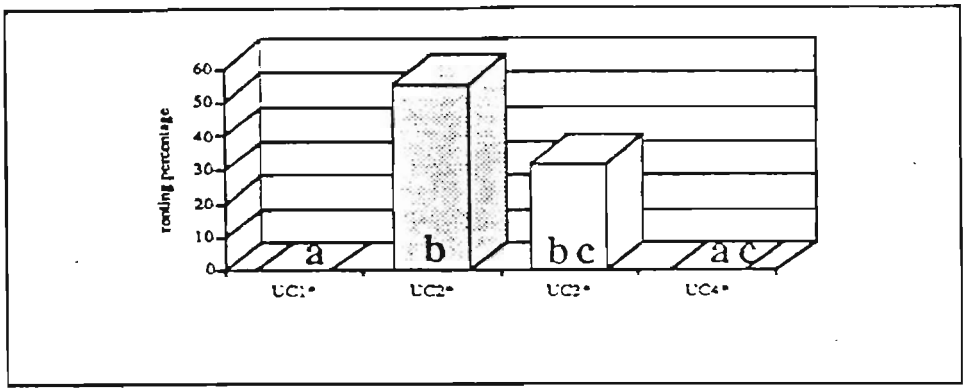


Fig. 4 : Vegetative stems : effect of the cutting position : ex cv 'Sylvia'

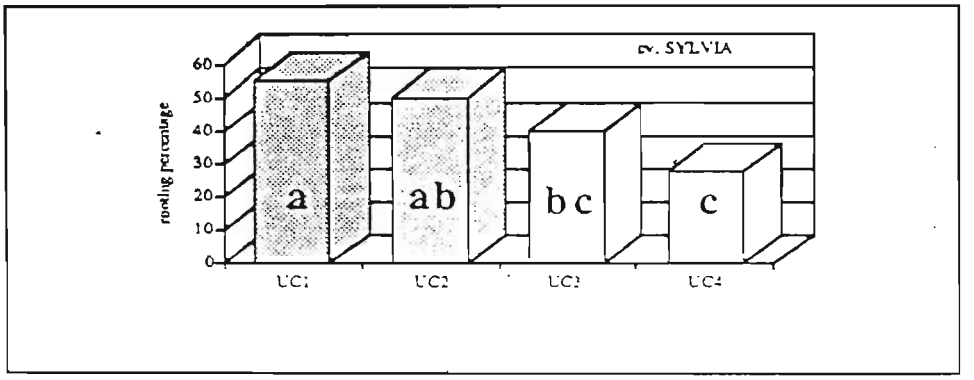


Fig. 5 : Floral stems : effect of the cutting position

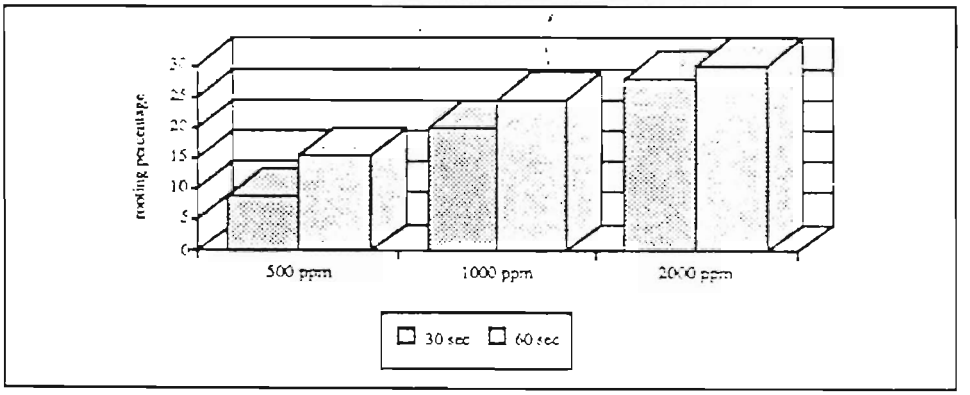


Fig. 6 : Effect of IBA concentration and dipping time

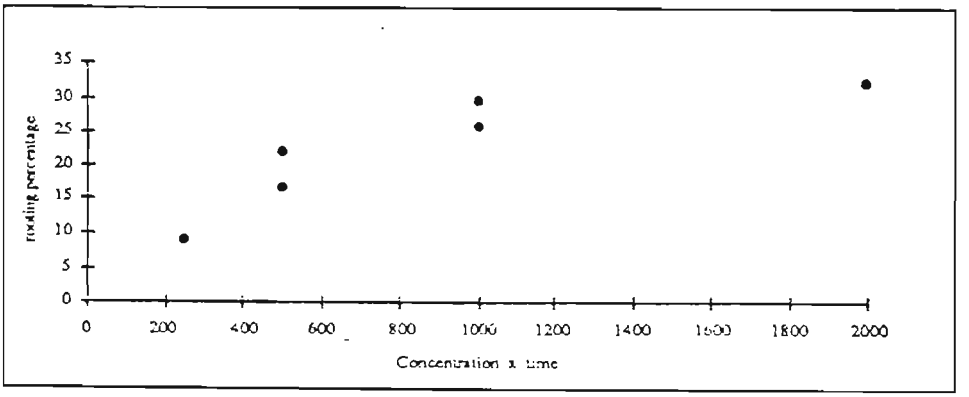


Fig. 7 : Interaction concentration x time (ppm/mn)

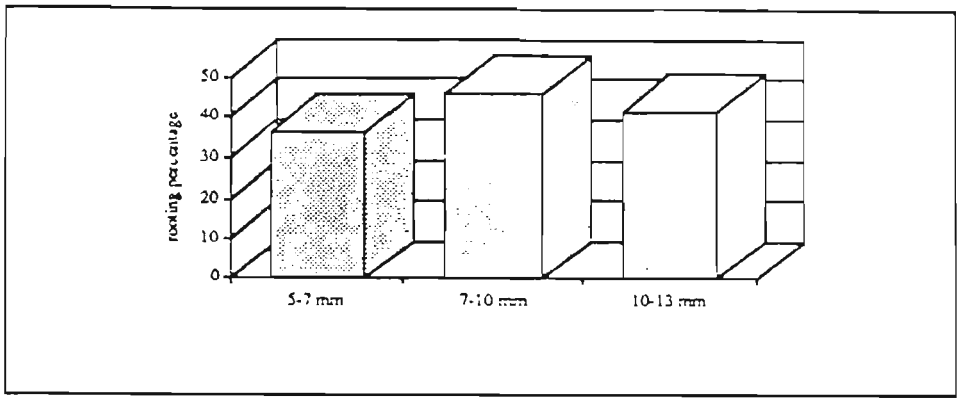


Fig. 8 : The rooting according to cutting diameter : ex cv 'Sylvia'

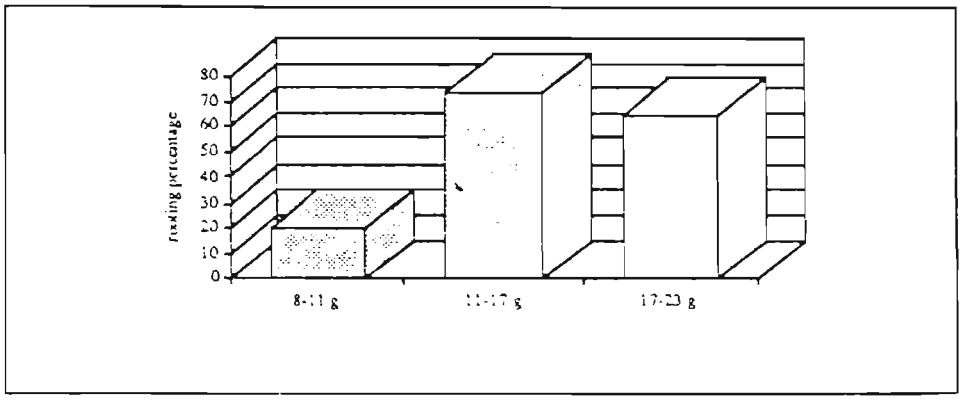


Fig. 9 : The rooting according to the weight of the cutting : ex *P. eximia*

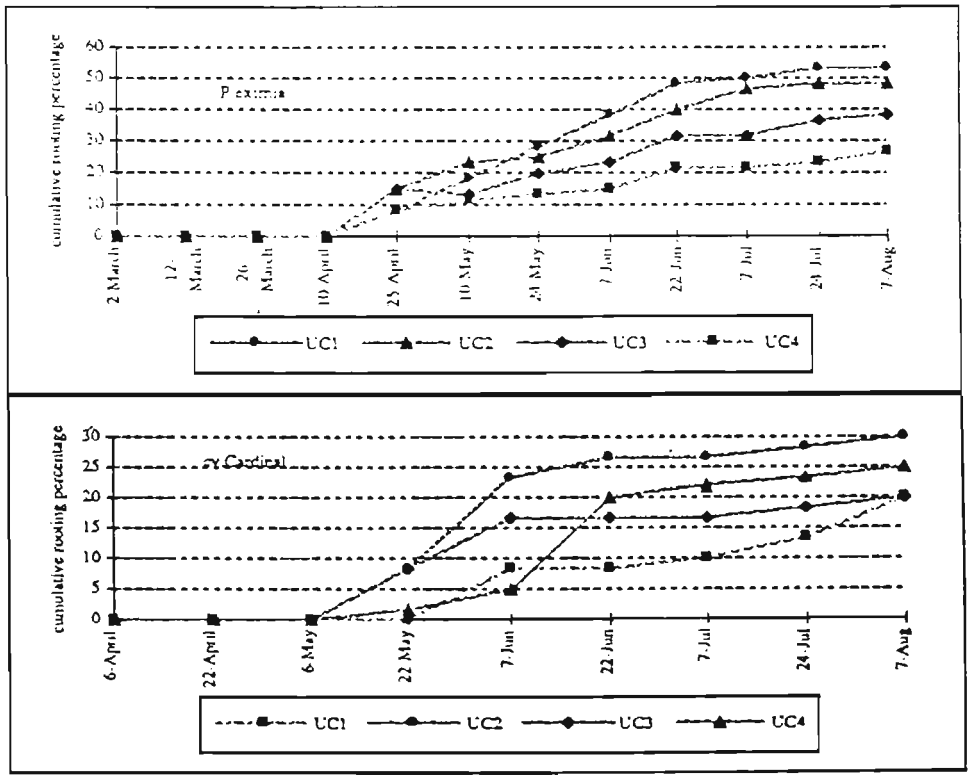


Fig. 10 : Rooting course according to the time : ex *P. eximia* and cv 'Cardinal'

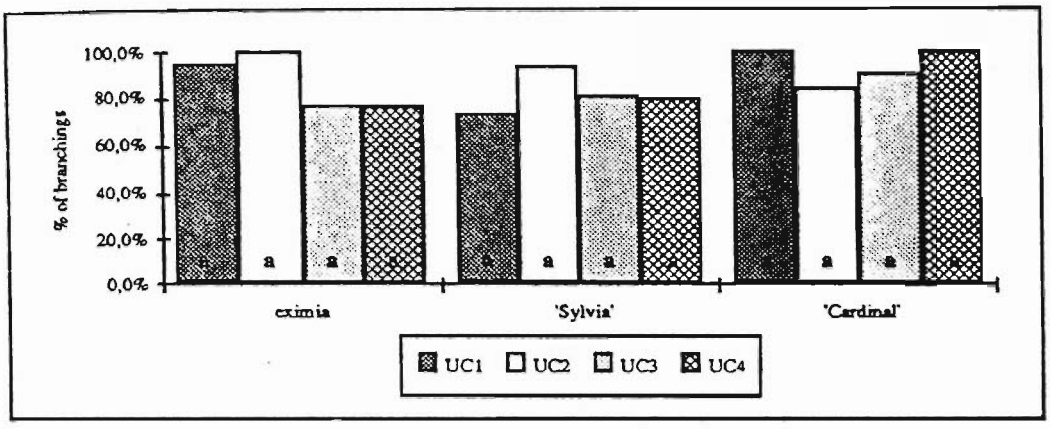


Fig.11 : Flushes of branching : *P.eximia*, cv. Sylvia , cv. Cardinal

# BREEDING OF *ANIGOZANTHOS MANGLESII*

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Abstract

In a breeding programme of *Anigozanthos manglesii* the first step was selection for parent plants with good horticultural traits. The parents were crossed to obtain experimental hybrids. Four of the hybrids have been propagated and released as new varieties. In the next step selection for seed germination of hybrids should be done for producing seed-propagated varieties.

## 1. Introduction

Haemodoraceae is a plant family of the southern hemisphere of which *Anigozanthos* is the most well known common genus. *Anigozanthos* is an endemic genus of South West Australia that includes 11 species. It has horticultural importance as a garden plant, pot-plant and cut-flower plant. Selected interspecific hybrids of *Anigozanthos* are available as cultivars, as well as selections from natural populations. Plant multiplication is generally by tissue culture. *Anigozanthos* is bird (open) pillinated in its natural habitat and a rich variety of exotic forms and colors are found within the species.

Anigozanthos has been grown in Israel for 14 years. Since winter is the main flower export season from Israel, early varieties are wanted by the growers. The major cut flower variety has for many years been an *A. manglesii* / *A. humilis* hybrid, while the A. manglesii selections were not popular as they flower too late.

Considering the horticultural potential of *A. manglesii*, a breeding programme was established, looking initially for early flowering plants, with the final goal being seed multiplied hybrid varieties (Shchori, *et al.*, 1984).

## 2. Material and methods

Early flowering plants were selected from a seed population obtained from the wild. These were crossed with selected plants from other commercial varieties. The offspring were intercrossed or backcrossed to the parents. Several good quality early flowering plants were selected and used as parents for a further round of production of experimental hybrids. From these hybrids selections were made and released as cultivars. Additional series of experimental hybrids were produced for the purpose of testing seed set and seed germination.

## 3. Results and discussion

Four good quality and early flowering hybrids were selected and released as cultivars: Fira Vol., Ohir Vol., Shani Vol. and Chen Vol. from the offspring populations developed by intercrossing early hybrids.

Seed set and seed germination rates differed between different crosses produced to test these parameters (Shchori, *et al.*, 1995).

Inclusion of the seed yield and germination rate as selection parameters in addition to the desirable ornamental characteristics of the hybrids should result in the production of seed-propagated F1 hybrids in the near future.

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# SEED GERMINATION OF SPONTANEOUS HYBRIDS OF *LEUCOSPERMUM*

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Abstract

In hybridization of *Leucospermum patersonii* x *L. conocarpodendron* the hybrids obtained were resistant to high pH soils. Additional resistant hybrids were sought by screening spontaneous hybrids of different varieties. In the first step, germination rate of the seeds obtained by open pollination of different varieties was measured. Potential hybrids were screened among the seedlings.

## 1. Introduction

*Leucospermum* species introduced to Israel were found sensitive to the high pH of Israeli soils. Only *L. patersonii* was found to be tolerant to these soil conditions. A breeding program for resistant cultivars and rootstocks of *Leucospermum* is in progress at Bet-Dagan.

## 2. Materials and methods

In the breeding a cross of *L. patersonii* with the pH sensitive but vigorous *L. conocarpodendron* gave F1 hybrids completely resistant to the adverse soil conditions. Five plants of the F1 hybrid population were selected. Four of them ('Udi', 'Shai', 'Nir' and 'Miriam') as flowering cultivars and one ('Carmeli') as a rootstock (Shchori, *et al.*, 1995). In addition spontaneous hybridization occurred in the experimental plantation at Bet Dagan, in which different *Leucospermum* species are flowering close to one another. There is a good chance that interspecific hybrids could be found among the offspring.

The percentage germination of seeds from different mother plants in the Bet Dagan plantation was tested. Seeds were treated according to Brits (1989).

## 3. Results and discussion

Seed germination rate is presented in Tables 1 and 2.

It was noted that a high germination rate appeared in seeds taken from one *L. patersonii* x *L. conocarpodendron* hybrid.
Other hybrids and cultivars showed lower germination rates.

Seedlings are being tested now for soil adaptability and horticultural traits.

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Shchori Y., Ben-Jaacov, J., Ackerman, A., Gilad, S. and Mechnik, B. 1995. Horticultural characters of interspecific hybrids of *Leucospermum patersonii* x *Leucospermum conocarpodendron*. Acta. Hort. 420: 135.

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Table 1: Germination rates of seeds collected from hybrids of *L. patersonii* x *L. conocarpodendron* at Bet Dagan.

| Hybrid Parent Plant | Seed No. | Germination rate (%) |
|---|---|---|
| 7/2 | 91 | 64 |
| 7/3 | 130 | 31 |
| 6/3 | 130 | 25 |
| 6/4 | 13 | 23 |
| 7/1 | 48 | 21 |
| 1/4 | 320 | 18 |
| 7/4 | 156 | 14 |
| 9/3 | 78 | 14 |
| 8/12 | 65 | 12 |
| 1/1 | 195 | 11 |
| 8/11 | 154 | 5 |
| 9/12 | 65 | 5 |
| 1/3 | 78 | 5 |
| 9/11 | 66 | 0 |
| 8/13 | 78 | 0 |

Table 2: Germination rates of seeds collected from different cultivars at Bet Dagan.

| Parent Plant | Seed No | Germination rate (%) |
|---|---|---|
| Tango 2 | 290 | 35 |
| Tango | 78 | 28 |
| *L. Patersonii* S.N. | 65 | 25 |
| Spider 211 | 78 | 21 |
| *L. patersonii* | 26 | 19 |
| Spider | 65 | 18 |
| *L. patersonii* | 208 | 15 |
| Helderfontein | 39 | 15 |
| Sunrise | 143 | 13 |
| Ballerina | 780 | 4 |
| Setaria | 300 | 4 |
| Ballerina | 780 | 4 |
| Setaria | 300 | 4 |
| TP 52 | 40 | 3 |
| Tomer | 202 | 2 |
| *L. fulgens* | 55 | 2 |

# DEVELOPING YIELD EVALUATION PROCEDURES FOR *LEUCOSPERMUM*

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Abstract

A block of 50 *Leucospermum* accessions in the fynbos field genebank, planted in a randomized block were harvested for three consecutive seasons, from two years of age. Significant variation for total stem yield only became apparent at four years of age. There were no significant differences between the means of the *L. cordifolium* accessions, the *L. cordifolium* hybrids and the multiple head types. The *L. lineare* hybrids as a group gave significantly higher marketable yields in the third harvesting season. *L. reflexum* consistently performed well over the three seasons. The percentage of 1st grade stems produced during the second harvesting season was correlated with the percentage produced in the third harvesting period. The yield of the accessions was not correlated with the duration of flowering. The majority of accessions showed an increase in total stem yield over the three seasons, but exceptions which did not recover well from pruning were observed.

## 1. Introduction

The Fynbos Genebank currently maintains 123 species accessions and 197 hybrid accessions of *Leucospermum*. Many of these accessions were originally selected on the basis of specific characteristics such as flower color, flowering time or purported ability to grow on atypical soils or under atypical conditions. These accessions need to be carefully assessed before use in a controlled breeding programme. Two criteria need to be established, i.e. the heritability of the characteristic for which they were originally selected and their performance against other accessions under equivalent conditions. Armed with answers to these two questions hybridization programs can be planned to combine the best characteristics of the parental lines. While adaptability of the accessions cannot be assessed by planting only at one locality, preliminary yield and aspects of yield can by analyzed. Total flowering stem yield of *Leucospermum* cultivars have been reported (Ackerman, *et al.*, 1995; Brits 1986a, b), but an assessment of traits contributing to yield has not been reported. This paper deals with the yield evaluation and comparison of types of *Leucospermum* accessions in the field genebank under standardized conditions.

## 2. Material and methods

Fifty accessions, ten rooted cuttings of each, were planted on a south east facing slope on Hutton soil at the Elsenburg Experimental Farm, Western Cape, South Africa during 1991. The plants were established, 1m within rows and 3m between rows, using black plastic mulch and were irrigated regularly during the dry summer months. Commercially registered insecticides and fungicides were used as necessary to control insect and disease damage. At a year old (1992) the plants were pruned back without harvesting flowering stems. At two, three and four years after planting the of flowering stems were harvested over the duration of the flowering period. The harvest of 1994 was divided into 1st grade and unmarketable stems. 1st grade stems were defined as longer than 30 cm, straight stems with the inflorescence straight on the end of the stem. The 1995 harvest was subdivided into 1st grade as in 1994 and 2nd grade which consisted of longer than 30 cm stems but the

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inflorescence or the stem was not perfectly straight. The stems that were too crooked or short were classed as unmarketable.

The data was subject to standard techniques applicable to continuous scale scores measured on an interval scale (mean, variances, analysis of variance) after careful scrutiny for normality. The yield data was grouped according to type of accessions for the statistical analyses, i.e. *L. cordifolium* accessions (15 accessions), *L. cordifolium* hybrids (14), multiple head types (9), *L. lineare* hybrids (10) and *L. reflexum* accessions (2).

## 3. Results and discussion

The parameter total stem yield per plant, could be interpreted as normally distributed based on the normal probability plot, residual plot and fit of a normal curve to the frequency histogram of the yield data. Analysis of the data revealed the following:

- Significant differences between the total stem yields of the four accession types was only observed for the 1994 and 1995 harvests. The proportion (%) of 1st grade stems harvested in 1994 was correlated (Correlation coefficient = 0.79, R5 = 63 %) with the proportion of 1st grade stems harvested in 1995. In the first harvest no significant differences between types of accession were observed and the 1st grade first year harvest was poorly correlated with second and third year 1st grade harvests.
- Neither the total stem yield of 1994, nor that of 1995 was closely correlated with the total stem yield of 1993 (correlation coefficient = 0.56 and 0.22 respectively), indicating that the stem yield of young plants is not a good indication of mature plant flower yield.
- No significant differences for 1st grade stem yield were observed between the four accession types for the 1994, nor the 1995 harvest.
- Second grade stem harvest for 1995 showed significant differences between groups, with the *L. lineare* hybrids producing a high average number of second grade stems, and the multiple head group and *L. reflexum*, few.
- No correlation between 1st and 2nd grade stems was observed for the 1995 harvest, nor between 1st or 2nd grade stems and total yield. This indicates that the practice of counting the total number of blooms and using it as a prediction of stem harvest would have been inaccurate in this trial.
- Although only two entries of *L. reflexum* were grown in the trial, these accessions consistently performed well. The proportions of 1st grade stems was also consistently high.
- The *L. cordifolium* hybrids as a group did not outperform the *L. cordifolium* specie accessions as a group. The *L. cordifolium* specie accessions showed large variation between genotypes, with two of the accessions not producing any marketable yield until the third harvest. There was less variation between the *L. cordifolium* hybrids and no significant differences for stem yield between the *L. lineare* hybrid accessions.
- The *L. lineare* hybrids as a group gave the significantly highest marketable yields (1st + 2nd grade stems).
- The earliest flowering accession was in early August, the latest flowered in November. Flowering periods varied within groups and between groups. The *L. cordifolium* accessions took from two to 14 weeks to complete flowering, the *L. cordifolium* hybrids from one to ten weeks, the *L. lineare* hybrids from three to 15 weeks, the *L. reflexum* 11 weeks and the others varied from three to eight weeks.

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# SESSION D :
# AGROTECNIQUES AND MORE

# THE ECOLOGY AND DEVELOPMENT OF *CONOSPERMUM*

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Abstract

The genus *Conospermum* is a member of the Proteaceae family. They are restricted to Australia and comprises over 36 species of which 29 occur in Western Australia. Flowers of several *Conospermum* spp. are presently picked from natural populations and exported fresh and dried to Japan, Europe and the USA. However, most species, especially those with horticultural potential, have proved difficult to propagate and cultivate.
The plants, commonly called 'smokebush', occur as small shrubs (0.5 m) to large bushes (2m to 3 m) in sandy heath woodland on soils with a pH ranging from 4.5-5.5 (1:5, $CaCl_2$). They naturally colonize disturbed ground and some species regenerate from seed while others re-sprout from substantial tubers. Flower color included white, cream, pink, and blue. Flowers were either arranged in clusters as in *C. eatoniae* (blue smokebush), panicles as in *C. triplinervium* (tree smokebush) and *C. incurvum* (plume smokebush) or corymbs as in *C. crassinervium* (tassel smokebush).
From natural populations in Western Australia, genotypes of *Conospermum* spp. were selected which exhibit desirable horticultural characteristics including long stems, different flower colors and a range of flowering times. Various techniques were used to propagate different *Conospermum* spp. including vegetative, tissue culture and germination from seed.
*C. eatoniae* was planted in November 1994 at Perth, Western Australia and at Mt Barker, 350 km south east of Perth, and have responded positively at both sites to intensive management and applied irrigation. The plants flowered from July to September 1995 and produced a mean of fifteen marketable stems per plant.

## 1. Introduction

The Australian cut flower industry, based on indigenous plants, is currently worth $25 million (Anon, 1995). The industry is based on cultivating and selling Geraldton waxflower (Myrtaceae, *Chamelaucium* spp. Schaer), banksia (Proteaceae, *Banksia* spp.) and Kangaroo Paw (Haemodoraceae, *Anigozanthos* spp.) (Anon, 1994).

The genus *Conospermum* (Proteaceae) is restricted to Australia and comprises 36 species of which 29 occur in Western Australia (Wrigley and Fagg, 1992). Selections from this genus are being developed in Western Australia as a potential new cut flower (Seaton, 1995).

The aim of this study was to evaluate the cut flower potential of *Conospermum*. This involved the selection of suitable plant forms and determining suitable propagation, establishment and cultivation techniques.

## 2. Material and methods

### 2.1. Field surveys and plant selection

Plants were surveyed in natural populations over a distance of 800 km in Southern Western Australia from 35° lat. S to 27° lat. S, from north of Kalbarri to Esperance in the south-east. The soil type, topographical conditions, plant growth habit and flowering time

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were noted. Suitable plants with desirable cut flower characteristics were selected for cultivation trials. Species were propagated by tissue culture or cuttings using IBA 3 mg/l as a liquid and propagated in peat: sand (coarse): perlite as 1:2:4 or peat: sand (course). Cuttings were placed in a high humidity propagation house, with a temperature range of 15 -28 °C and a bed heating temperature of 20 °C.

### 2.2. Cultivation trials

Plantings of *C. eatoniae* were made in November 1994 at Medina, 50 km south of Perth with rainfall (880 mm) mainly in winter and yearly mean maximum/minimum temperature range of 23/13 °C, and at Mount Barker, 350 km south of Perth with annual rainfall of 651 mm and a mean temperature range of 20/10 °C. The species *C. crassinervium, C. floribundum* and *C. triplenervium* were planted in 1994 and *C. incurvum* at both sites. *C. crassinervium* was planted in 1995 but only at Medina. Plants were spaced in rows 3 m apart and 2 m between plants in a row. Each plant was supplied daily with water via 4 l/h pressure compensated drippers (Netafim®). Prior to flowering, stems of *C. eatoniae* were trained through 900 mm wide 'carnation mesh' (Cyclone®) with a grid size of 150 mm square, and located 300 mm above the ground. Measurements were made of plant height and width, number of stems and appearance of first and last flowers and when flowers were 50% open. Following flowering stems were cut back to 200 mm above the ground surface.

## 3. Results

### 3.1. Potential *Conospermum* spp. cut flower types

Smokebushes occur in sandy heath woodland in deep sand or sand over laterite or limestone and in soils with pH ranging 4.5 to 5.5 (1:5, $CaCl_2$). They occur in rainfall isohyets from 200 to 900 mm. Some are low shrubs, 450 mm high while others are small trees 2-3 m high. Five *Conospermum* spp. were identified for their cut flower potential in terms of flower color, stem length, flower display and time of flowering (Table 1.). Those species evaluated were *C. eatoniae, C. crassinervium, C. floribundum, C. incurvum* and *C. triplinervium*. Flower color of *C. eatoniae* is blue, *C. floribundum* blue/white and white for the other species. Stem production of *C. floribundum* and *C. triplinervium* and *C. triplinervium* were highest of all species with stems of *C. floribundum* short compared to other species. *C. eatoniae* and *C. incurvum* stem production was medium with stem length of *C. eatoniae* longer than for *C. incurvum*.

### 3.2. Performance of *Conospermum* spp. in cultivation

#### 3.2.1. Growth

Growth of stems of *C. eatoniae* was rapid over the summer months and reached a maximum length of 48.2 ± 4.2 cm in August at Medina and 41.6 ± 6.4 cm in June at Mt Barker. Stems of *C. eatoniae* reached 70 cm 7 months after planting. Stems of *C. triplinervium* elongated rapidly after June to nearly 60 cm by September, while stem elongation of *C. floribundum* was low with stems reaching nearly 40 cm by November. Stem multiplication of *C. eatoniae* and *C. triplinervium* was low with 15 and 11 stems respectively, while stem multiplication of *C. floribundum* was high producing 30 stems by October. Following flowering and cutting back plants in August plants of *C. eatoniae* recovered quickly with rapid elongation of stems to 50 cm within 3 months. Following cutting back, stem elongation of *C. triplinervium* and *C. floribundum* was less than for *C. eatoniae*.

3.2.2. Flowering

*C. eatoniae* grown at Medina flowered in spring (early August) in their first year (Table 2), while flowering occurred approximately 1-2 weeks earlier at Mt Barker. *C. floribundum* and *C. incurvum* flowered in September and *C. triplinervium* flowered in early October at Medina. The estimate of the flowering time of *C. incurvum* was made from field observations of natural population as plantings of this species were made after spring 1995. *C. cassinervium* flowered in February.

3.2.3. Trellising

*C. eatoniae* stems became quite heavy with flowers and were not sufficiently strong to maintain an upright position. Plant left without support were found to be damaged by wind, which twisted the plants causing the plants to be pulled out of the ground. Wire trellis or 'carnation mesh' was necessary to train the plants at an early stage (i.e. when plants were 15-20 cm high or 2-3 months after planting). The square mesh anchored the plant by the lateral branches of the new stems which pushed against the mesh and encouraged the development of straight stems.

## 4. Discussion

With the large variation in the genus *Conospermum* in flower color, flowering time, and stem form, there is considerable potential to develop fresh and dried cut flowers for the export industry. There are many unknowns in the cultivation of this plant and propagation for many species is extremely difficult. Given the early results of this project it appears possible to successfully cultivate *C. eatoniae*. Field evaluation trials are continuing to define the full cut flower potential of this and other *Conospermum* spp. Plants appeared to grow best under warmer condition (19-30°C day and 10-19 °C night temperatures), in sandy soils with slightly acid pH and grown using trickle irrigation. The *Conospermum* spp. studied exhibit the ability to respond to increased temperature and light in spring, which promotes rapid stem elongation. For *C. eatoniae* the stem framework for flower production is produced several months before flowering, while for *C. triplinervium* flowering shoots rapidly elongated approximately one month before flowering. *C. floribundum* appears to continually produce flowering stems over the year with little rapid elongation of stems at flowering.

Management practices such a the use of "carnation mesh" appear necessary to support and produce straight stems in *C. eatoniae*.

## Acknowledgments

This research was done with the support of Rural Industries Research and Development Corporation and Agriculture WA. The technical assistance of Mr. J. Berston is acknowledged.

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Seaton, K. A. (1995). Introduction of new wildflowers into cultivation. J. West. Aust. Wildflower Producers Assoc. Sept. 1995 p8.

Wrigley and Fagg, (1988). Australian Native Plants; A Manual for their Propagation, Cultivation and use in Landscaping'. Collins: Sydney.

Table 1 - Cut flower characteristics of *Conospermum* spp. from surveys of several naturally occurring populations for each species.

| Species | Flower colour | Average stem production per plant* | Range of stem lengths (cm) | Growth habit | Flowering time |
|---|---|---|---|---|---|
| *C. eatoniae* | blue | medium | 50-60 | spreading | July to September |
| *C. floribundum* | blue/white | high | 7-15 | upright | July to October |
| *C. incurvum* | white | medium | 20-35 | upright | July to October |
| *C. triplinervium* | white | high | 20-50 | upright | June to November |
| *C. crassinervium* | white | low | 80-90 | upright | December to February |

* Low < 25 stems, medium 25 - 50 stems and high > 50 stems per plant.

Table 2 - Time of 50% flowering of *Conospermum* spp. at Medina.

| Species | *C. eatoniae* | *C. floribundum* | *C. incurvum* | *C. triplinervium* | *C. crassinervium* |
|---|---|---|---|---|---|
| Time of flowering | early August | late September | mid September | early October | mid February |

# SOME MANAGEMENT STRATEGIES FOR GROWING *BANKSIA BAXTERI*

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Abstract

*Banksia baxteri* blooms have been commercially harvested for over twenty years from unmanaged bush stands east of Albany on the south coast of Western Australia. Decline of natural bush and a trend toward managed stands has required landholders to investigate management strategies to improve yield and quality of flowers of selected species. In this experiment, the effects of pruning old *B. baxteri* plants and of transplanting and fertilizing postfire bush seedlings were examined.

Light pruning of eleven year old plants, cut back from the stem tip down to a stem diameter of 7-10 mm produced an increase in total bloom production and a significant increase in the percentage of commercial blooms when compared with unpruned plants in the second year after pruning. Medium and heavy pruning of stems back to a diameter of 14 - 30 mm (or greater) resulted in a 70 % death rate.

Postfire seedlings transplanted from natural bush into cleared open ground produced on average 34.3 times more leaves than those plants remaining in bush after two years. Application of fertiliser was found to further enhance the advantage of the transplanted seedlings. A rate of 8.33 gm of NPK fertiliser (15:2.2:16.6) applied every six months near the base of the plant was optimal in increasing plant growth.

## 1. Introduction

*Banksia baxteri* occurs naturally in sandy soils supporting scrub heath over a range of 250 km east of Albany along the south coast of Western Australia. For almost 20 years *B. baxteri* blooms have been commercially harvested from wild populations on both crown and private land. The flowers have been sold domestically, but most are exported with a total of 560,000 stems exported in 1991 (Robinson, 1991). *B. baxteri* flowers from late January to mid April.

Serious decline of the remnant stands due to increased commercial and recreational exploitation of coastal reserves, compounded by fungal disease, has resulted in all *B. baxteri* flowers now being picked from private land. Picking of *B. baxteri* on crown land was banned in 1992, resulting in a greater interest in better management of *B. baxteri* on private land.

In the past there have been large natural populations on private land which have been of suitable age and plant structure to facilitate flower picking. These were plants from five to ten years old which had germinated following wildfires. Fire triggers the immediate release of canopy stored seed (i.e. serotiny) Lamont (1991) which germinates in the next rains. Flowers may be harvested from plants about 1 m tall in the fourth or fifth year after fire depending on the variability of the intervening growing seasons. The plants continue to grow and around ten or eleven years will reach about 3 m tall and 3-4 m across the dense prickly canopy. At this stage plants are difficult for pickers to harvest and flower stems become shorter and more curved than on younger plants. Many of the previously harvested wild populations have now reached this relatively non commercial mature stage and landholders are faced with the prospect of having to rejuvenate them by burning. It would then take at least five years for plants in these locations to become productive again.

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s banksias normally produce vigorous new shoots just below the cut made taking the previous year's bloom, a trial was established to test the practicality of pruning large old plants as an alternative to burning. This was done to determine if the plants could be rejuvenated to produce more commercial flowers whilst improving the accessibility by canopy reduction. Rohl. *et al* (1994) found that *B. baxteri* produced half its blooms on two year old shoots and half on three year old shoots and consequently a pruning exercise would lose at least one season's flowering.

As an alternative to pruning old plants the possibility of accelerating the postfire growth by translocation of seedlings into more accessible rows on cleared, unirrigated land was investigated. The application of fertiliser to translocated seedlings was also tested.

## 2. Material and methods

### 2.1. Pruning trial

Thirty even sized plants were selected from an extensive bush stand of eleven year old *Banksia baxteri* at Wellstead (80 km east of Albany) that had previously been heavily picked. These plants were considered by the pickers to have reached an unmanageable size with few flower stems of commercial length. Pruning treatments by cutting back from the stem tip into either 1-2 year old wood (light prune), 4-6 year old wood leaving eight leaves (medium prune) or 4-6 year old wood leaving four leaves (heavy prune) were conducted on ten randomly selected plants per treatment in June 1993.

In June 1995 the total number of 1995 flowers (i.e. first flowering for pruned plants) per pruned plant and on ten unpruned plants was recorded and the number of commercial stems (>300 mm and straight) measured. The quality of the inflorescence formation was not assessed as this is determined by weather conditions at and just prior to flowering and not by severity of pruning. The diameters of ten cut stems per pruned plant were also recorded.

### 2.2. Seedling trial

An area of older *B. baxteri* plants growing on a low sand rise (pH 4.2 in $CaCl_2$; P < 2 ppm in $HCO_3$; K 26 ppm in $HCO_3$) was burnt in March 1993. Seedlings germinated from the subsequent seed release were transplanted in June 1993 into rows (3 m between plants and 5 m between rows) adjacent to the burnt bush block on the same sand ridge that had previously been cleared. Fifty transplanted seedlings were randomly selected and NPK (15: 2.2: 16.6) fertiliser was applied twice per year at rates of zero, 4.2 gm, 8.3 gm and 16.7 gm and ferrous sulphate was applied at 6.3 gm twice per year. Growth rates were measured by counting the number of leaves and branches of transplanted seedlings and compared with leaf counts made on seedlings remaining in the remnant bush.

## 3. Results

### 3.1. Pruning trial

Although the pruning treatments were intended to be of substantially different stem thickness, there was actually little difference in the average thickness of pruned stems between the heavy (20.21 mm) and medium (19.23) pruning treatments. Only 6 of the 20 plants in these pruning categories survived, and only 3 produced flowers. Several of the heavy to medium pruned plants produced coppiced shoots on the main trunks but no shoots immediately below the pruned cut. Many of these shoots eventually died. The relatively few flowers produced on the medium pruned plants were all of commercial stem length. All plants lightly pruned (average cut diameter 8.3 mm) survived, produced shoots immediately below the cut and produced more flowers per plant with a greater percentage of commercial length stems than the unpruned controls.

Table 1. Effect of pruning on flower production of *B. baxteri*

| Treatment | Heavy prune | Medium prune | Light prune | Unpruned |
|---|---|---|---|---|
| Mean diameter of cut (mm and range) | 20.2 (se 1.6) | 19.2 (se 1.5) | 8.4 (se 0.3) | not applicable |
| Number of plant deaths | 8 | 6 | 0 | 0 |
| Total blooms | 0 | 36 | 307 | 209 |
| Total commercial blooms | 0 | 36 | 187 | 101 |

3.2. Seedling trial

Thirty postfire seedlings remaining in unfertilized bush had produced an average of 8.2 (± 0.6) leaves per plant, with a range of 4 to 19 leaves. No branching was observed. Transplanted seedlings (Table 2.) performed 34 times better than bush seedlings without fertiliser and 55 times better with 8.33 gm of NPK fertiliser. Five of the 10 seedlings receiving the higher rate of 16.67 gm NPK per plant died. Application of ferrous sulphate to transplanted seedlings decreased average leaf production relative to unfertilized transplants.

Average branch counts on the live transplants were 11.9 ($FeSO_4$), 14.6 (zero fertiliser), 16.7 (4.17 gm NPK), 23.6 (8.33 gm NPK) and 18.2 (16.7 gm NPK). This included primary, secondary and tertiary branches.

4. Discussion

Pruning of old *Banksia baxteri* plants down to 7 to 10 mm diameter wood (1-2 years old) provided an advantage in total flower production and encouraged the growth of longer flower stems, relative to the older unpruned controls. The loss of one season's flowers in 1994 from the lightly pruned plants was almost compensated for in the first harvest in 1995 by the increase in average number of commercial length stems to 18.7 relative to the unpruned average of 10.1 commercial flowers per plant. It is expected, as per Rohl, *et al.* (1993), that the pruned plants will produce a similar number of flowers in 1996 on the three year old wood, as on two year old wood in 1995. The loss is of one harvest will be more than compensated, with the added convenience of more easily reached blooms and a lower harvest cost per stem.

Plants pruned down to 4-6 year old wood of 14.1 to 30.4 mm diameter were pruned too hard as expressed in their high death rate and poor flower production. This high death rate in the hardest pruned plants may have been exacerbated by the weather conditions which have effected this trial since its beginning. Immediately following the pruning event the area adjacent was flooded by unseasonably heavy rains, which severely stressed many plants. This was followed by a very dry year with rainfall to September 1994 only 40% of the 40 year average (Agriculture WA, unpublished data). It is suggested that in a more normal season pruning back to more than 10 mm stem diameter into 2-4 year old wood may also stimulate successful rejuvenation of the old *B. baxteri* plant without plant death.

Transplanting of seedlings of *Banksia baxteri* from burnt bush into a cleared area of the same soil type proved to be successful without fertiliser and even more successful with application of low and medium rates of NPK. The higher rate of fertiliser appeared

[illegible] rate in the ten transplants treated. Although, the high rate of [illegible] cannot be totally blamed for the deaths due to a small sample size, it is likely that [illegible] of plant death.

[illegible] branching in the absence of competition when transplanted, and [illegible] fertiliser should ensure significantly increased flower production, several years [illegible] plants remaining in the bush. Planting out of the bush situation in rows will make other management practices such as irrigation, pruning, spraying with fungicide and [illegible] more practicable, which will further increase the productivity relative to the [illegible] *Banksia baxteri*.

Acknowledgments

This research was supported by funding provided by Rural Industries Research and Development Corporation. Greg and Jenny North, and Robert and Caroline Davy generously allowed unlimited access to *Banksia baxteri* stands on their properties at Wellstead. Max Crowhurst and John Gladman provided technical assistance.

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Table 2. Leaf count of *B. baxteri* seedlings

| Fertilizer treatment | Total number of leaves | Live average | Standard error |
|---|---|---|---|
| 6.25 g/plant $FeSO_4$ | 1380 | 172.5 | 50.9 |
| Zero fertilizer | 2434 | 281.6 | 38.9 |
| 4.17 g/plant NPK | 2671 | 333.9 | 70.8 |
| 8.33 g/plant NPK | 3604 | 450.5 | 74.9 |
| 16.67 g/plant NPK | 1446 | 289.2 | 79.9 |

# FLOWER PRODUCTION OF *PROTEA EXIMIA* IN SOILLESS CULTIVATION

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Abstract

*Protea eximia* plants grown from seed were grown under soilless cultivation in a greenhouse for cutflower production. The vegetative pattern and flower production were studied over six years.
Using different methods to pinch and prune the plants, the evolution of various parameters was followed : vegetative and flower production periods, ratio of branching and floribundity of the different orders of branches, the number of growth units, and the length, diameter and straightness of the flower stem.
The main results show that the vegetative and floral rhythms are not affected by the pruning and pinching system used, but the earliness of the first flowerings and the ratio of branching of the young plants are influenced by this. Consequently, the potentials of the further yields are significantly different. The number of growth units (flushes), and consequently the length of the flowering stems, are also influenced by the different treatments of pinching and pruning, whereas the stem diameter is not altered significantly.
Finally, the pruning of the weakest branches during the vegetative period does not modify the degree of straightness of the flowering stems obtained.
The results of this study enable us to suggest, for the proteas species and varieties with similar development to *P. eximia* (i.e. proteas with sub terminal branching), a development and growth system for the soilless cultivation under greenhouse. This system should lead to the production of better yields, and to an increase of the commercial quality in the flower stems. (i.e. length and straightness).

## 1. Introduction

The growth of Proteaceae for cut flower production in the French Mediterranean area is possible only in a greenhouse and under soilless conditions on account of low winter temperatures and calcareous clay composition of the great majority of French Mediterranean soils.

The main aim of the first trials was the adjustment of the nutrient solutions suitable for the particular needs of the major species grown for cut flowers. The trials studied the influence of this mode of cultivation on the growth and the morphogenesis of several species with acrotonic branching which is the main type of growth of the majority of protea species grown for cut flower production.

Concurrent to these morphogenetic studies, the floral production was studied over a six year period, observing the vegetative and reproductive rhythm sand, the quantitative measures of quality resulting from various types of training and pruning of the plants.

For the growth, it is difficult to separate the vegetative and floral aspects, the first leading to the second. So we will speak about the floral aspects according to the vegetative aspects which lead to them.

Proc. Fourth Int. Protea Symp.
Eds. G.M. Littlejohn, H. Hettasch
Acta Hort. 453, ISHS 1997

## 2. Material and methods

### 2.1. Material

The species used for this study was *Protea eximia*. It was multiplied in January by sowing seeds from South Africa in a temperate greenhouse (15°C). The seedlings were transplanted as to 3 weeks to 1 month into small pots (diameter : 8 cm), then installed in a greenhouse at the beginning of June. The greenhouse plantation was established in polypropylene trenches of 20 cm of depth, with a density of 2.2 plants/m$^2$ grown, in a substrate made of porphyry of Esterel Mountains (Rhyolitic stone) with a granulometry varying between 5 and 8 mm. The nutritive solution was supplied by dripper 2 or 3 times a day varying with the seasons, and the amount supplied was 0.5 liter/plant/watering. Its basic composition is indicated in Table 1. Calcium and magnesium were used as found in the water supplied by the city. Micro nutrients come from a commercial solution and iron from chelating agents.

The temperature was regulated to a minimum of +5°C during the winter and the day ventilation was regulated at +20°C.

### 2.2. Methods

Plants of *P. eximia* were arranged into 12 blocks, according to Fisher, with 6 plants per block. There were 3 treatments : T1 = the plants have only one axis (order 1) until the first flowering after which they are pruned at the top of the 5th growth unit (GU) or flush : T2 = the plants are pinched on the axis of the 1st order after the 3rd GU : T3 = the plants are pinched on the axis of the 1st order after the 5th GU (Figure 1). For T2 and T3, the axis of 2nd order obtained by pinching the 1st order were disbudded when necessary. The plants of treatment 1 could be compared to those of treatment 3 on their branching potentialities when, after flowering of the main axis (order 1), they were pruned back on the top of the fifth flush. The treatment 3 was pruned at the autumn of the fourth year for homogenization after measures of water status and dry matter. Lastly, during the last time of production (autumn of year 5 to spring of year 6), the weakest stems of half the plants of each plot were taken out to determine the influence of this pruning on the straightness of the floral stems.

### 2.3. Measures

The vegetative and floral rhythms were observed simultaneously over the 4 first years. The number of axes of the different orders, the number of flushes completely developed, the number of flowers from the emergence to the full flowering, (after which they are harvested), were recorded each month.

From the 4th year, the number of harvested flowers and their length and position on the branching were recorded. Lastly, during the last period of flower production (autumn of year 5 to spring of year 6), the diameter, straightness and total number of growth units of the axis on which the flower developed were also recorded.

## 3. Results

### 3.1. Vegetative aspects

The vegetative activity is conditioned by season (light and temperature) and endogenous rhythms of the plant. The growth of axes of *Protea eximia* is rhythmic and proceeds from successive growth units separated by a break time, more or less important according to the seasons. These vegetative rhythms were characterized by means of 3 different criteria to determine the most representative:

- the percentage of plants in active growth, i.e. the plants which have one vegetative axis (this data is represented by PL),
- the number of growing axes per plant (this data is represented by AX),
- the number of growth units per plant fully developed during the last month (this data is represented by GU).

Figure 2, uses treatment 3 as an example to show, the relative monthly variation of these 3 criteria over the first four years. The percentage of vegetative plants (PL) is the one showing the greatest range of seasonal variation but it does not show, as the two others (AX end GU), the quantitative evolution of the plant activity over time. The number of vegetative axes (AX) and the number of fully developed growth units per plant (GU) have a similar variation, but with larger range for AX. This criterion (AX) is important for the comparison of vegetative and reproductive rhythms.

Figure 2 shows that under these conditions of cultivation, the plants have the main vegetative growth during the hotter months, from April to October.(N Hemisphere)

If we consider now the potential of branching of the plants according to the treatments, potential which can have an influence on the further floribundity of the plant, we see (Figure 3) that the treatments have an influence more or less important on branching according to the considered order of branching. For example, if the branching coefficient of the main axis (order 1) showed the trend T1>T3>T2, for the second order we have T2>T3>T1 and T3>T2>T1 for the third order.

3.2. Vegetative and generative rhythms

Figure 4 shows the behavior of the plants over the first 4 years following the 3 treatments. In each case the minimum vegetative activity is 1 to 2 months before floral production. In the same way, the maximum vegetative activity is 3 to 4 months later than the maximum of floral production. We note that the more spread the period of flowering is, the smoother the peak of vegetative activity becomes. For instance, in the 3rd year, the treatment 1 which is flowering from February to August, shows a curve of growth activity smoother than that of treatment 3 which has the main flowering between February and May. Treatment 2 shows behavior intermediate to the other 2 treatments.

3.3. Floral aspects

The floral production changed quantitatively in a similar way between each of the three treatments (Figure 5.a). For the cumulative annual production (Figure 5.b), the treatment 3 yield is significantly greater than treatment 1 for years 3, 4 and 6, and than treatment 2 for the years 4 and 6 ; Yield of T2 is significantly greater than T1 in year 4 only. The very low production of T3 in year 5 could be from the pruning for homogenization of the plants of this treatment in September of the year 4. While T1 gave a weak floral production in the second year of cultivation, its total production over the whole cultivation period is lower than either of the other two treatments.

On the influence on the floral stem, we noted:

- there was a significant difference between the treatments in the number of growth units till the order 3. From the order 4 the treatments gave the same results. On other hand, taking the treatments separately, we noted a significant decrease in the number of flushes according to the order, but this decrease was not characteristic for the treatment 3 (Table 2).
- the length of the growth units was significantly different between the treatments for the order 2 only. In addition, there was an increase in the length of the flush according to the order but with different levels of significance (Table 3).

- the length of stem was different between the 3 treatments for the 2nd order only. In order 3 the trend was T1=T2>T3. From the 4th order, there was no significant difference. Into each treatment the differences followed the same variation as the flushes (Table 4).
- the diameter of floral stems showed significant differences according to the order or the treatment (Table 5).
- lastly, after the pruning of the weak branches, we noted an influence of this pruning on the straightness of the floral stems (Table 6). However, if we study the evolution of this straightness over all the cropping period, we note (Figure 6) that the percentage of straight floral stems decreased progressively till the end of the cropping period. For instance, if at the beginning of the cropping period we had 100% of straight stems, this value fell down 40% for the last harvests (mean value of the 3 treatments).

## 4. Discussion

### 4.1. "Building" of the plant

The different types of pinching or pruning applied to a seedling showed that the later the pinching or pruning was done, the more branches the seedling produced on the main axis. The number of structural branches (order 2) being more important, we would can think that the potential of further floral production would be increased. But during the following vegetative period, the branches of 2nd order were more ramified if the seedling was pinched at a young stage (3 flushes). The following year, for the 3rd order, the middle treatment (T3) gave the best branching coefficient.

However, the total number of branches per plant (until order 4) was: T1 : 10.75, T2 : 14.87 and T3 : 18.74. The total number of branches produced is greatly affected by the stage of vigor and development and the regularity of growth: if at the beginning we cause an important branching for the plant, it produces less afterwards (T1), whereas if we cause a low branching at an early stage of the plant, it produces an important branching for the 2nd order and for the following orders we note an important decrease of branching (T2). For a better floral productivity for a long time, the best solution is the pinching of the seedling on the 5th growth unit because it leads to a luxuriant and regular branching during all the growth of the plant.

### 4.2. Development and flowering rhythms

The initial treatments of training the plants did not seem to have an influence on the vegetative and floral stages since in each case the behavior of the plants was similar. The noted decrease of vegetative activity from July came from the formation of flower buds which will flower the next spring. The contour of the graph of the vegetative stage, seems linked to the spread of the crop. For instance, in the Figure 4, the contours of the vegetative activity of the 2nd year are more and more pronounced from T1 to T3. If the annual productivity increases from T1 to T3, the time of cropping decreases from T1 to T3 on the contrary : T1 is flowering from January to August (8 months), T2 mainly from January to June (6 months) and T3 mainly from February to May (4 months). The vegetative contour could be an indicator of the length of the cropping period.

### 4.3. Productivity and quality

The pinching of seedlings on the 5th growth unit gave plants with a floral production always higher than the two other treatments. This follows the same trend as the vegetative activity, and seems to be the best method of training for quantitative aspects.

On the qualitative aspects, and specially on the length of floral stems, the treatment 3 gave shorter stems than the two others treatments, at least for the 2nd and 3rd order, while from the 4th order there was no significant difference between the 3 treatments. These short

stems decrease the quality of the cropping only the two first years since, from the 4th order, the freak disappears. On the other hand, this freak seems to appear only on the plants from seeds, and this multiplication is less and less used for a cultivation of quality.

At least, the pruning of the weak stems do not lead to a better straightness of floral stems. So it is not necessary to propose this practice in the cultivation.

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Table 1 - Composition of the nutritive solution

| | N | P | K | Ca | Mg |
|---|---|---|---|---|---|
| Concentration ($mM.l^{-1}$) | 0.6 | 0.1 | 0.4 | 2.9 | 1.9 |

Table 2 - Mean number of growth units of the floral stems according to the orders of branching

| Treatments | Order 1 | Order 2 | Order 3 | Order 4 | Order 5 |
|---|---|---|---|---|---|
| T 1 | 10.00 d | 6.67 e | 5.44 f | 5.14 f | - |
| | | a | b | NS | |
| T 2 | - | 7.25 d | 6.33 e | 5.11 f | 4.79 f |
| | | a | a | NS | NS |
| T 3 | - | 5.20 d | 4.28 e | 5.04 d | 4.67 ed |
| | | b | c | NS | NS |

Table 3 - Mean of the length of growth units of the floral stems according to the orders of branching

| Treatments | Order 1 | Order 2 | Order 3 | Order 4 | Order 5 |
|---|---|---|---|---|---|
| T 1 | 11.5 ef | 13.3 df | 13.7 d | 14.5 d | - |
| | | a | NS | NS | |
| T 2 | - | 10.3 f | 13.1 e | 14.8 d | 14.9 d |
| | | b | NS | NS | NS |
| T 3 | - | 11.0 e | 12.4 e | 15.0 d | 15.3 d |
| | | b | NS | NS | NS |

Table 4 - Mean of the length of the floral stems according to the orders of branching

| Treatments | Order 1 | Order 2 | Order 3 | Order 4 | Order 5 |
|---|---|---|---|---|---|
| T 1 | 58.0 NS | 68.0 NS<br>a | 60.3 NS<br>a | 57.5 NS<br>NS | - |
| T 2 | - | 54.1 e<br>b | 67.4 d<br>a | 60.9 e<br>NS | 56.6 e<br>NS |
| T 3 | - | 33.7 e<br>c | 41.0 e<br>b | 60.4 d<br>NS | 56.0 d<br>NS |

Table 5 - Mean of diameter of the floral stems according to the orders of branching

| Treatments | Order 3 | Order 4 | Order 5 |
|---|---|---|---|
| T 1 | 8.84 NS | 9.38 NS<br>NS | - |
| T 2 | - | 8.84 NS<br>NS | 9.13 NS<br>NS |
| T 3 | - | 9.06 NS<br>NS | 9.08 NS<br>NS |

Table 6 - Percentage of straightness of the floral stems

| Treatments | Order 3 | Order 4 | Order 5 |
|---|---|---|---|
| T 1 | 65.8 NS | 80.9 NS<br>NS | - |
| T 2 | - | 71.5 NS<br>NS | 89.7 NS<br>NS |
| T 3 | - | 75.8 NS<br>NS | 75.3 NS<br>NS |

The numbers followed by a same letter are significantly different at 95% (Schéffé Test) ; on the right of the number, analysis according to the treatments ; under the number, analysis according to the orders ; NS= No Significant

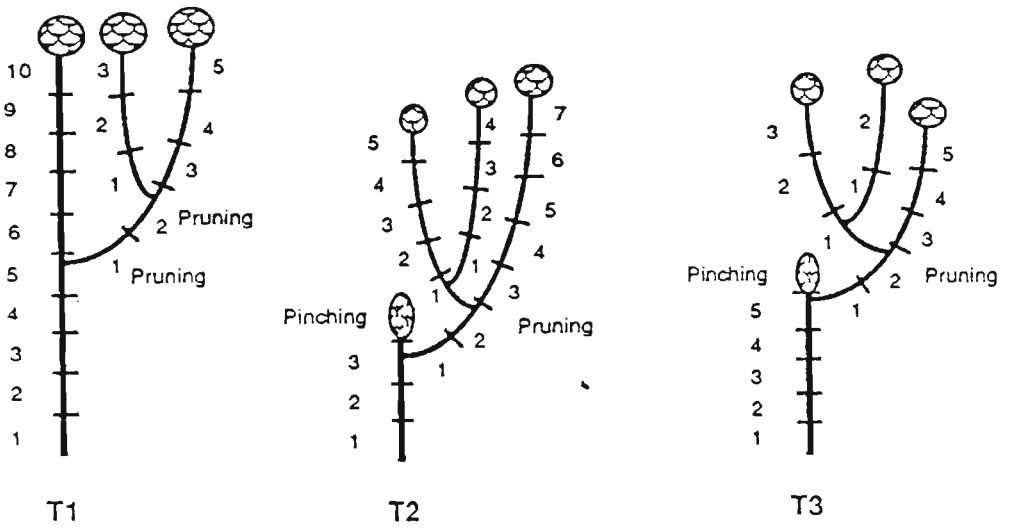



Figure 1 - Pinching and pruning according to the treatments

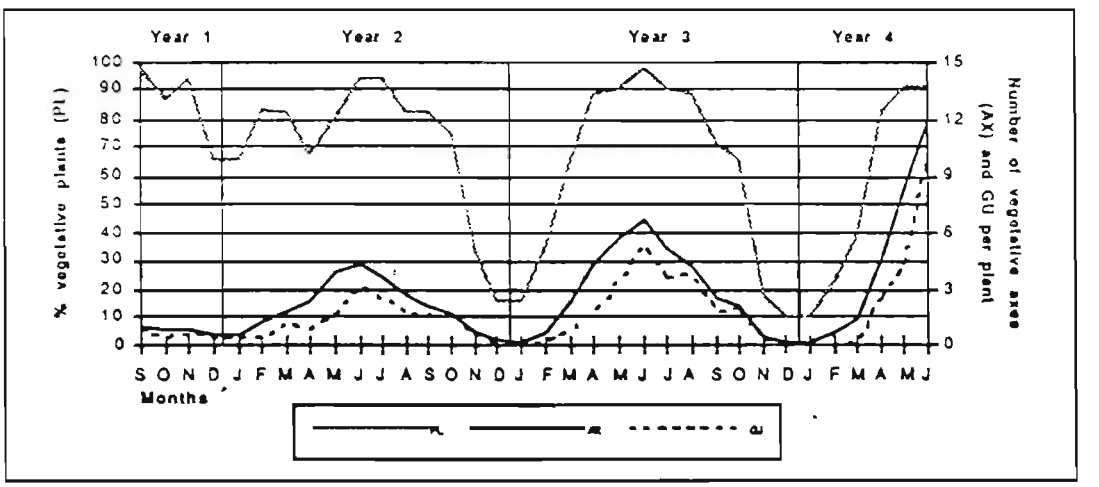



Figure 2 - Vegetative rhythms expressed in three different ways for treatment 3
AX = vegetative aves, GU = growth units, PL = vegetative plants

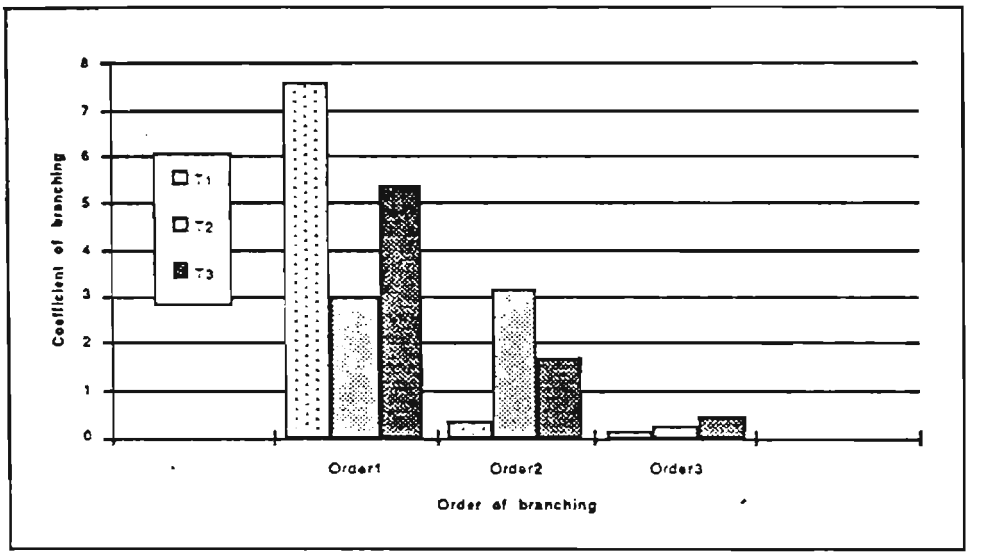
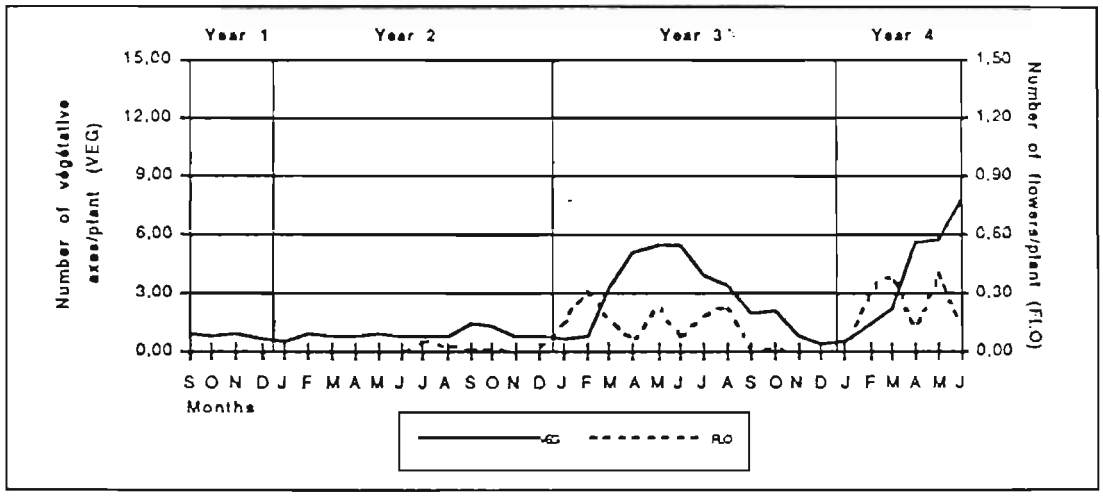
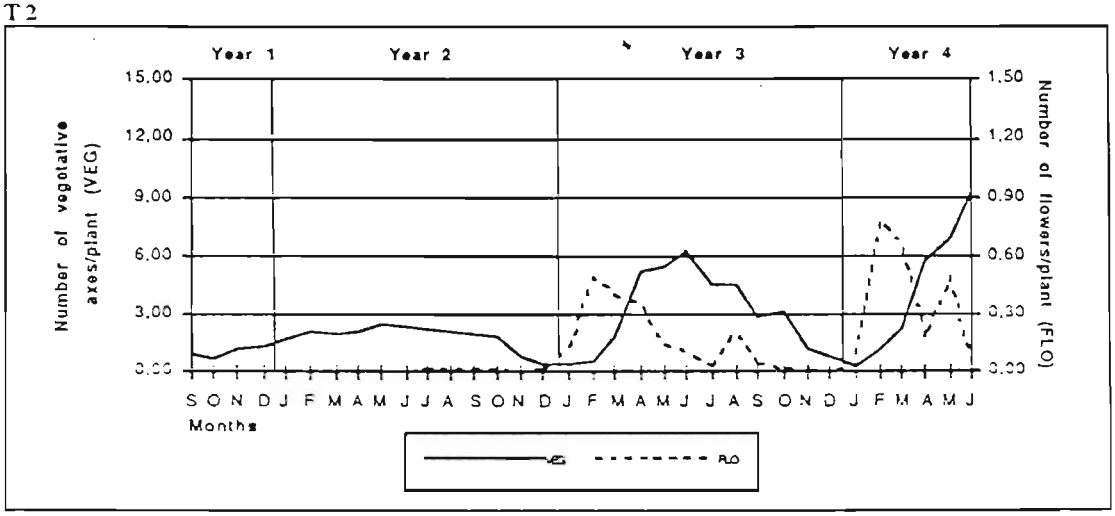



Figure 3 - Coefficient of branching of the different orders

T1




T2




T3

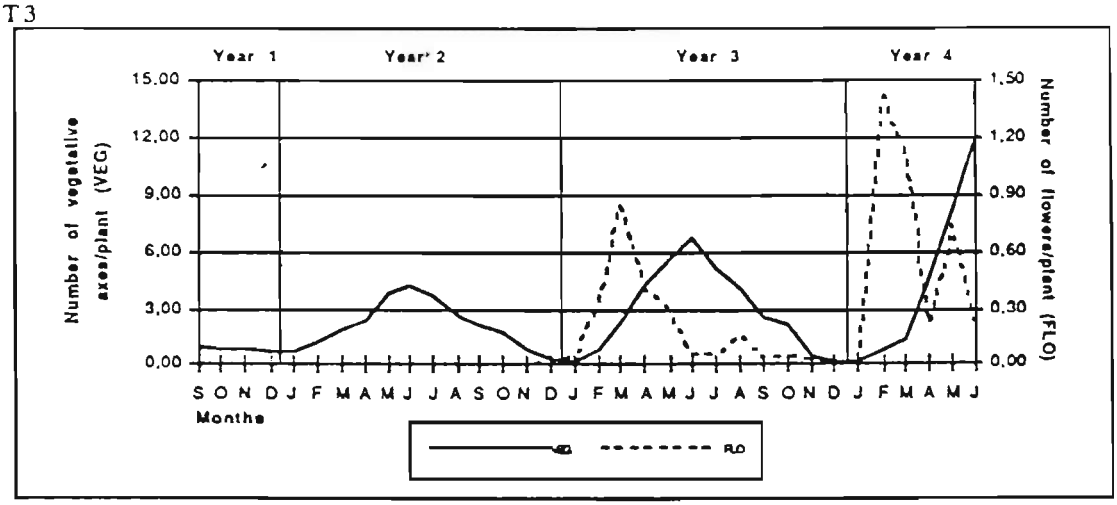



Figure 4 - Comparison of vegetative rhythms and floral production

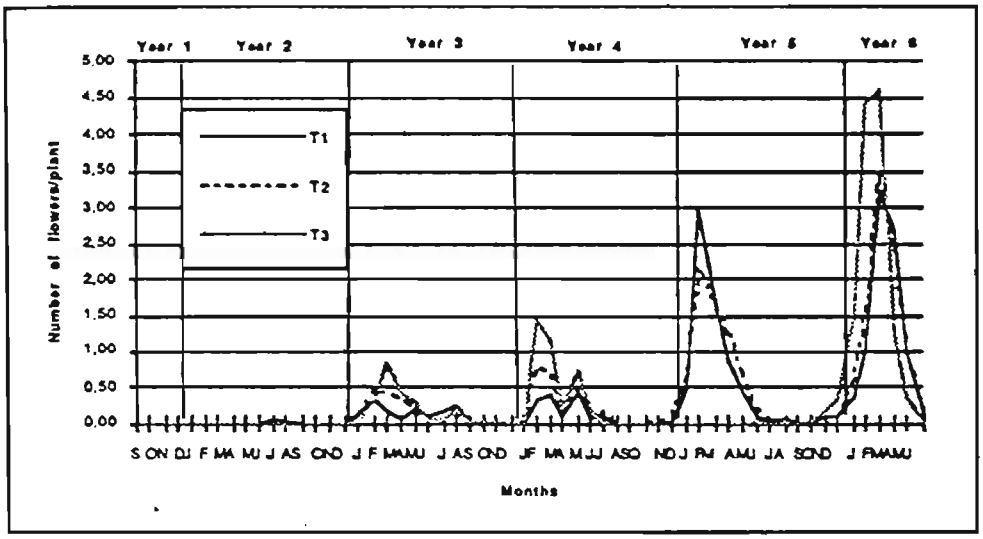



Figure 5.a - Variation of floral production per plant

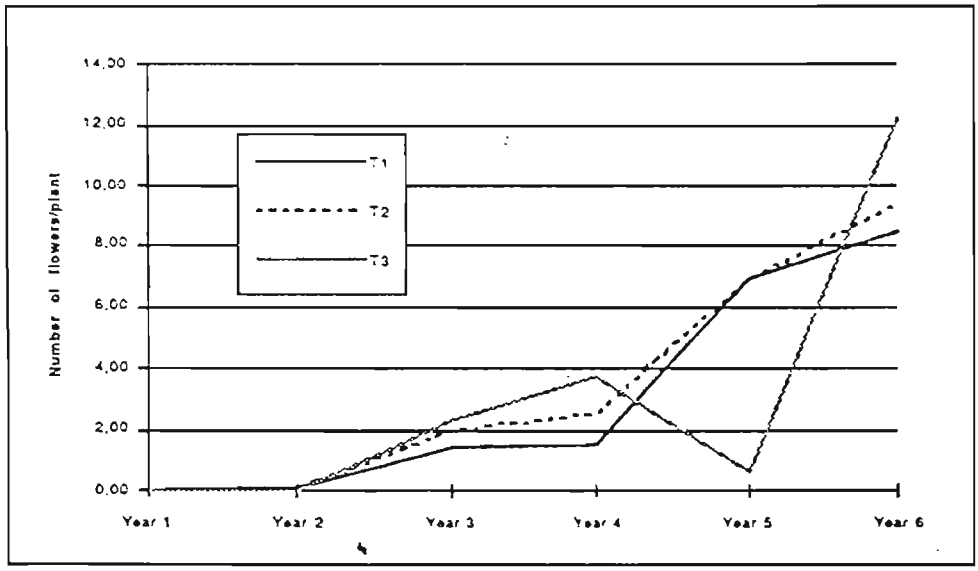



Figure 5.b - Annual floral production per plant

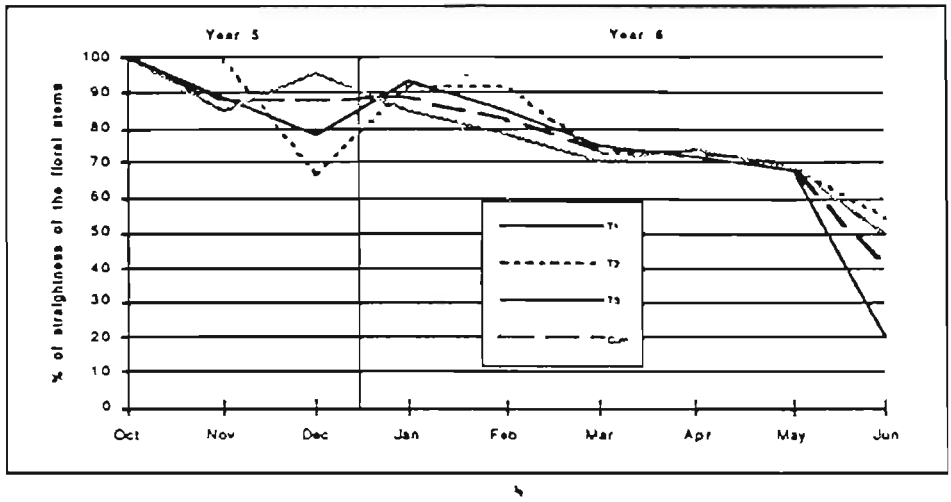



Figure 6 - Evolution of the straightness during the last period of flowering

# PRUNING PROTEA CULTIVAR CARNIVAL FOR BIENNIAL CROPS OF IMPROVED YIELD AND QUALITY

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Abstract

Plants of *Protea* cv. Carnival (a natural hybrid, possibly between *P. neriifolia* and *P. compacta*) were pruned at two different times of the year, over a five year period. Pruning in Spring induced a biennial bearing pattern, while pruning in Autumn, induced an annual bearing pattern. The biennial harvest of 1993 averaged 54.7 salable blooms per bush, 82% more than the cumulative annual harvests of 1992 and 1993. The stem length of 89% of the flowers from the biennial harvest was longer than 50 cm, while only 6% of the flowers from the annual harvests had stems longer than 50 cm. The biennial harvests reached picking maturity predominantly in February (southern hemisphere), two months earlier than the annual harvests. Mature bushes harvested and pruned for the annual cycle, can be induced into the biennial cycle of bearing by specific pruning techniques. A model for pruning new plantings into the biennial cycle of production, for improved yield and quality, is also proposed.

## 1. Introduction

In cutflower production, not only is the number of flowers produced per hectare or per square meter important, but also the quality of the flowers and the time of harvest. Stem length is an important quality criterion in cutflowers, with higher prices being paid for flowers with longer stems. Time of harvest is important, as there are certain times when specific products are in low supply while the demand is high, and times when the supply of the product is high or competition from other products makes that product less attractive to the buyer. In the case of proteas produced for the European market, competition from European summer flower production is high during May to August and thus proteas command lower prices. During the European winter months proteas are in high demand. Supply is generally low in January and February.

*Protea* cv. Carnival (a natural hybrid, possibly between *P. neriifolia* and *P. compacta*) initiates flowers on the spring flush or the first summer flush, but not on the second summer flush or the autumn flush (Greenfield *et al.*, 1994). Flower initiation takes place when terminal shoot growth ceases and the apical bud becomes reproductive. The period during which this transition can take place is the flower initiation window. *Protea* cv. Carnival thus has a flower initiation window between late spring and early summer. Greenfield *et al.* (1994) also report that a minimum requirement of at least two flushes is needed before the shoot can initiate a flower. De Swardt (1989) found that the length and thickness of stems of *Protea* cv. Carnival contribute significantly to the ability of the stem to produce a flower. Gerber *et. al* (1995), showed that with specific pruning practices, plants of *Protea* cv. Carnival produced shoots in one year and flowers in the following year, resulting in greater reproductive biomass production. In this paper we show how the knowledge of a specific flower initiation window can be used commercially with certain pruning practices to attain higher yields and better quality in both existing plantations and new establishments.

Proc. Fourth Int. Protea Symp.
Eds. G.M. Littlejohn, H. Hettasch
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## 2. Material and methods

Mature plants and young plants of *Protea* cv. Carnival grown in a commercial plantation under dry-land conditions near Stellenbosch, Cape Province, South Africa (33°54'S, altitude 250m) were used. The area has a Mediterranean climate with a mean annual rainfall of 600-700 mm.

### 2.1. Annual bearing cycle

In 1992 and 1993 plants were pruned in Autumn, after harvest, leaving 10-15 cm bearers from flowering and thick non-flowering shoots, and removing all other shoots with thinning cuts. In 1994 flowers were harvested with thinning cuts and all other shoots were left on the plant.

### 2.2. Biennial bearing cycle

In 1991 shoots were cut to 15 cm bearers in spring. No flowers were produced in 1992 and plants were not pruned. Flowers were harvested in January and February of 1993 and pruned in early March. Flowers were harvested leaving 15 cm bearers, and pruning entailed cutting back thick non-flowering shoots and removing thin shoots with thinning cuts.

In 1994 flowers were harvested with thinning cuts and all non-flowering shoots were retained.

### 2.3. Young plants

The number of shoots on two and four year old unmanipulated plants were counted and categorized as flowering shoots and non-flowering shoots. Theoretical models were proposed to predict the potential crop over time using combinations of pruning cycles at different degrees of complexity.

## 3. Results

### 3.1. Yield and quality improvement

Plants in the annual bearing cycle were pruned in Autumn each year and produced 13 and 17 marketable flowers per plant in 1992 and 1993 respectively. Plants in the biennial bearing cycle were pruned in the Spring of 1991 only and produced no flowers in 1992 and 54.7 marketable flowers per plant in 1993. The yield of the biennially bearing plants in one year, 1993, was thus 82% higher than the cumulative yield of the annual bearing plants over two years, 1992 and 1993.

Plants in the annual bearing cycle, produced 13, 17 and 11 flowers per plant in the years 1992, 1993 and 1994 respectively. The 1994 harvest from these plants was cropped using thinning cuts and all non-flowering shoots were retained. The 1995 harvest from these plants produced an average of 54 flowers per plant.

In the annual harvests of 1992 and 1993 the stem length of 46% and 6% of the flowers respectively was longer than 50 cm. In the biennial harvest of 1993, 89% of the flowers had stems longer than 50 cm. Figure 1 shows the stem length distribution of the 1993 harvests from the plants in the annual bearing cycle compared to the plants in the biennial bearing cycle.

When plants in the annual bearing cycle were pruned to induce the biennial cycle of bearing, the stem length distribution shifted towards longer stems. Of the 1995 harvest from plants previously in the annual bearing cycle, 94.5% of blooms were longer than 50 cm. The stem length distribution of the plants previously in the annual bearing cycle, induced into the biennial bearing cycle and the plants originally in the biennial bearing cycle was very similar in the 1995 harvest (figure 2).

3.2. Harvest time

The distribution of harvesting time in 1993 (figure 3) shows that the harvest from the plants in the annual bearing cycle is predominantly in March and April, with 58% of flowers being harvested in April. The harvest from the plants in the biennial bearing cycle peaked in February with 61% of the crop being produced in this month.

When plants in the annual cycle of bearing are pruned to change to the biennial bearing cycle, the harvest is earlier. In the 1995 harvest from plants previously in the annual cycle of bearing, 96% of the crop was harvested by the end of February. In the case of the plants in the biennial cycle of bearing, 92% of the crop had been harvested by the end of February in the 1995 harvest (figure 4).

3.3. Young plants

Unmanipulated plants in the annual bearing cycle reached full production of 18 flowers per plant in year five after planting. According to the model, the same plants induced into the biennial cycle of bearing in their fourth year, will produce 18 flowers per plant two years later, but continue to increase to full production of 43 flowers in year nine. Plants with a higher degree of complexity early pruned in the biennial cycle, produce 8 flowers per plant in year 3 and reach 55 flowers per plant in year 5. (Table 1).

4. Discussion

Presently *Protea* cv. Carnival flowers are harvested leaving bearers, and all non-flowering shoots are cut back after harvest, also leaving bearers. Every year, many shoots are produced, but only a few initiate flowers. At harvest all shoots are cut back. Young plants must be pinched to increase complexity early, or harvested with the annual pruning cycle until complex, before inducing the biennial pruning cycle.

4.1. Pruning of mature plants

To prevent flower initiation in the first year of shoot growth, plants must be pruned in spring. The shoots do not meet the requirements for flower initiation during the flower initiation window between late spring to early summer. Shoots grow only vegetatively and no crop is produced. By the second spring, most shoots can initiate flowers early in the flower initiation window, many flowers are produced and the harvest is early. In this scenario, plants will produce no crop in the one year and a large crop in the following year, thus a biennial crop.

To achieve the above, plants must be re-pruned in spring. The crop of the preceding autumn must be harvested leaving long bearers, about 20cm in length. In spring, these bearers are cut back to 15 cm, thereby removing any new growth. Shoots from these bearers start growing in spring and only initiate flowers in the following spring. The biennial crop is harvested leaving long bearers, which are then re-cut in spring.

The disadvantages of this system are that bearers have to be re-cut, increasing labor input and depleting the plants of energy. The alternative system described below, does not require recutting and in addition to the large biennial harvest also produces a small harvest in the in-between years. This model also provides a smooth transition from the annual cycle without any loss in production. This method is referred to as biennial pruning.

Flowers from plants in the annual cycle of bearing are harvested with thinning cuts and all non-flowering shoots are retained on the plant. During the subsequent spring, flowers are initiated on these shoots and a large crop can be harvested early in the second year. This crop is harvested leaving 15 cm bearers and non-flowering shoots are removed. Of the shoots that grow from these bearers, a few will flower in the following year and be harvested with thinning cuts. The majority will flower in the year after that.

Harvesting the small harvest in the first year of the biennial pruning cycle with thinning cuts, allows maximizing of the stem length. The flowers in the second year of the biennial pruning cycle, have longer stems and these flowers can be harvested leaving a 15cm bearer, without compromising marketability. At the end of the cycle, plants consist of bearers only, fully exposing the lateral buds to sunlight for development.

Harvesting using thinning cuts takes place in one year and harvesting leaving bearers, and pruning, in the following year, thus the biennial pruning cycle.

### 4.2. Pruning of new establishments

The more complex the plant is in its structure, the higher the potential crop, increases to a certain point. In the biennial pruning cycle, the complexity of the plants can only be increased every second year, when flowers are harvested leaving bearers. The slow increase in complexity leads to a slow increase in a potential crop, and a long time before plants reach full production. High complexity in new establishments is thus a prerequisite before plants are induced into the biennial pruning cycle. A combination of high complexity early in the plant's life and the application of the biennial pruning cycle, lead to a favorable potential crop.

If young plants are not manipulated after planting, complexity increases slowly, initially by natural branching, and later through harvesting. If young plants are pinched after each flush of growth, by removing the shoot tip, complexity can be increased rapidly. The optimum degree of complexity for plants at different stages of maturity has not yet been established.

### 4.3. Other cultivars

*Protea* cultivars with *Protea compacta* parentage can possibly be manipulated in similar ways. It is not known, however, whether flower initiation of hybrids such as *Protea* cv. Pink Ice (*P. compacta* x *P. susannae)* and *Protea* cv. Brenda (*P. compacta* x *P. burchellii)*, as influenced by the other parent, *P. susannae* and *P. burchellii* respectively. Observations of growth vigor and time of flower initiation of hybrids under local conditions will indicate the applicability of the pruning methods described.

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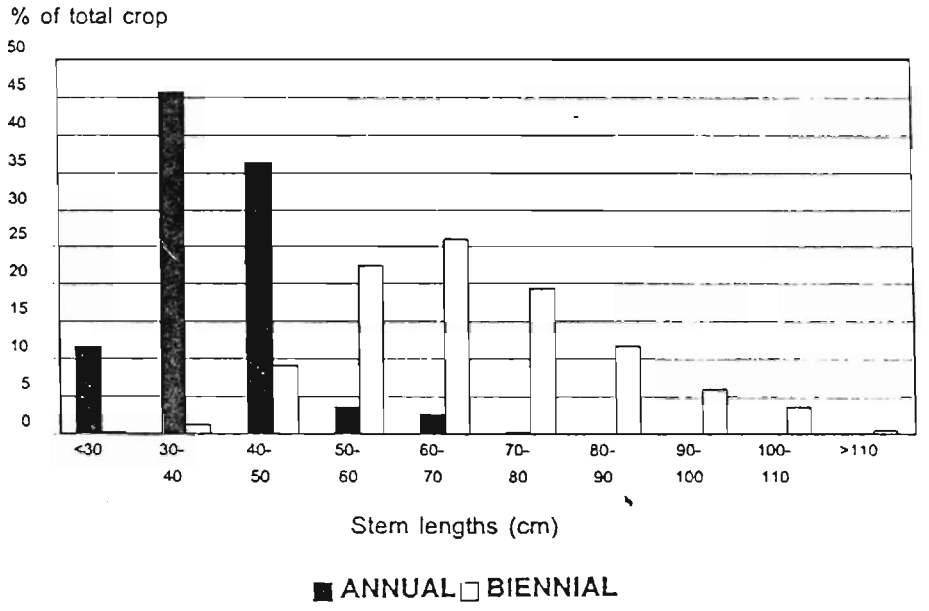


Figure 1. Stem length distribution of the 1993 crops.

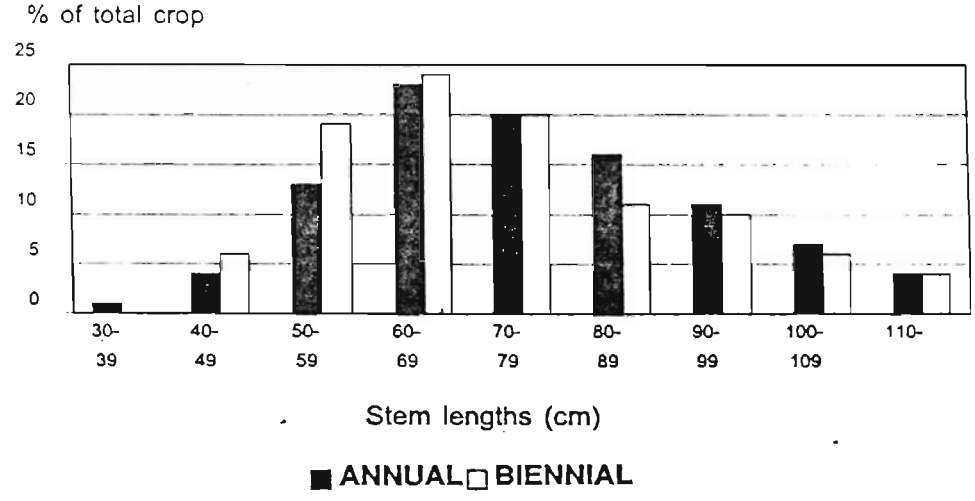


Figure 2. Stem length distribution of the 1995 crops. Plants previously in the annual bearing cycle are induced into the biennial bearing cycle.

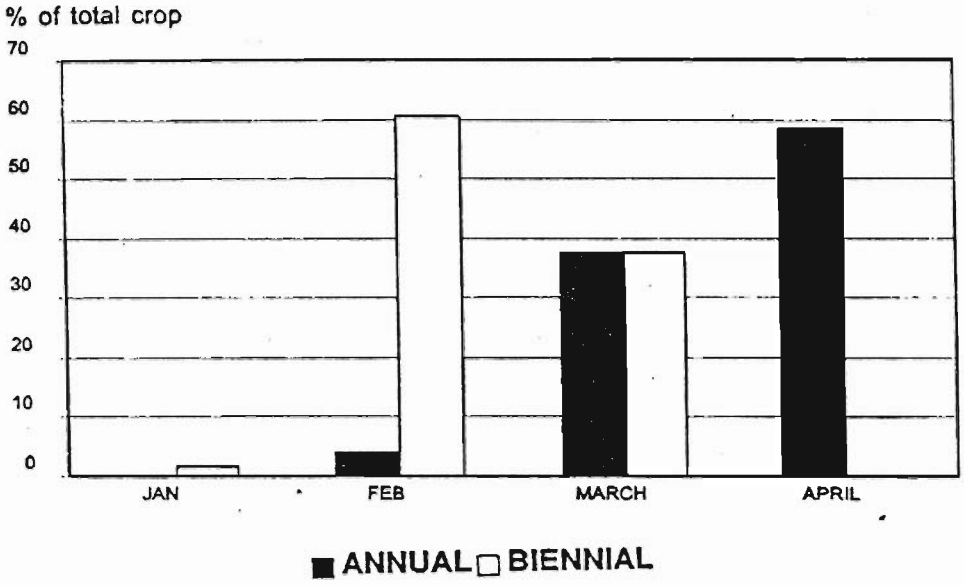


Figure 3. Distribution of harvesting time of the 1993 crops.

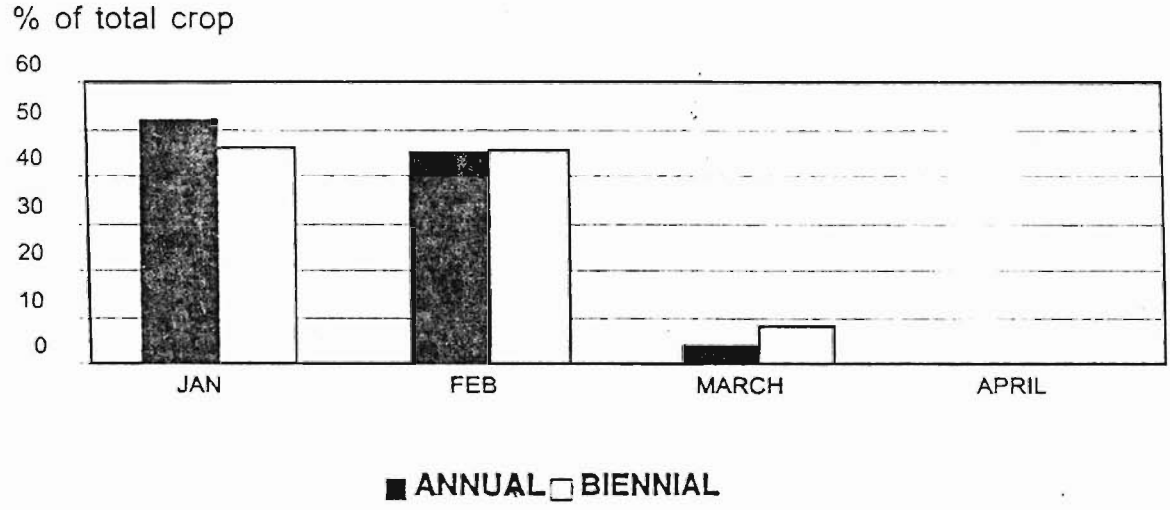


Figure 4. Distribution of the harvesting time of the 1995 crops. Plants previously in the annual bearing cycle are induced into the biennial bearing cycle.

Table 1. Predicted potential crop over time, using combinations of bearing cycles at different degrees of complexity.

| Year | Month | Shoots / Flowers | Shoots / Flowers | Shoots / Flowers |
|---|---|---|---|---|
| 3 | Feb | | | |
| | April | 6 / 4 | 6 / 4 | 3 / 8 |
| 4 | Feb | | | |
| | April | 18 / 6 | 18 / 6* | 96 / 18* |
| 5 | Feb | | 12 / 10 | 78 / 55 |
| | April | 54 / 18 | | |
| 6 | Feb | | | |
| | April | 18 | 36 / 12* | 18* |
| 7 | Feb | | 24 / 20 | 55 |
| | April | 18 | | |
| 8 | Feb | | | |
| | April | 18 | 72 / 18* | 18* |
| 9 | Feb | | 54 / 43 | 55 |
| | April | 18 | | |

* Harvest with thinning cut, retain non-flowering shoots.

# WATER AND MINERAL ABSORPTION FOR TWO PROTEA SPECIES (*P. eximia* and *P. cynaroides*) ACCORDING TO THEIR DEVELOPMENT STAGE

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Abstract

Basic soilless nutritional needs of most species of the *Protea* genus have been shown to be much lower than those of common ornamental plants from the northern hemisphere. The present work investigates in more details the variability of mineral intakes of two species, *P eximia* and *P. cynaroides*, having very different growth kinetics. The results globally show that growth rates mainly affect the volume of intakes and not its relative composition. However, there is a difference in Mg requirements of the two species, and a specific drop of P and K requirements in the second part of the vegetative cycle of *P. cynaroides*. Keeping soilless nutrition at the optimum therefore requires a careful monitoring of drainage rates and mineral drifts in the leachates of each species.

## 1. Introduction

Cultivation of Proteaceae in the South of France was chosen, because the climatic conditions are similar to those prevailing where they grow naturally. Studying their nutritional and climatic requirements entail growing them in a greenhouse and under soilless conditions.

A nutrient solution was established by Montarone (1993). This solution enabled us to grow many species and varieties without being sure that this solution was entirely adapted to specific requirements. According to Lemaire, *et al.* (1989) there are a certain number of constraints involved in cultivation using containers as there is only a limited volume available for the root system to grow in. Soilless conditions are generally favorable to production potential (Montarone 1989, 1991). It is necessary to provide the roots with water and minerals so as to balance supply and demand. The quantities of elements absorbed by a plant increase during its vegetative cycle, and vary not only according to the plants development stage, but also depending on the species and the required growth form (cut flowers, mother plants or pot plants).

Furthermore it is well known that there is a close link between the amount of water and minerals absorbed by a plant. The dry-matter produced has a relatively constant mineral concentration. Numerous authors have underlined the difficulties encountered in Proteaceae cultivation as far as minerals are concerned, Classens (1980), Tibbits, *et al.* (1981), Brits (1984) and Voster (1984), pointed out that the needs are not well established, but that most of these authors draw attention to the fact that these plants are sensitive to high levels of phosphorus, nitrogen and potassium.

The cultivation of Proteaceae in Sophia Antipolis (South France) has already demonstrated the influence of chemical content of the substrate and the importance of irrigation frequency in some growing conditions. However the aim of this study is to establish clearly the water and mineral requirements of these plants experimentally by analyzing nutrient samples regularly so as to establish absorption kinetics.

Proc. Fourth Int. Protea Symp.
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## 2. Material and methods

### 2.1. Plant material

The study was carried out on two morphologically different species of *Protea* : *P. eximia* and *P. cynaroides*. The plants used were nine month old seedlings. The plants were pinched above the second flush so as to obtain more rapid branching.

### 2.2. Experimental design

The trial was carried out in a closed cycle watering system in which the nutrient solution was recycled (Fig. 1). The set-up consisted of five units of four two-liter pots for each species. Each unit was linked to a container of nutrient solution. The nutrient solution was pumped into the pots at regular intervals. A timing system was used to ensure a regular ebb and flow of nutrient solution. The concentration of minerals per liter were as follows : 1.7 me of nitrogen ($NO_3$ + $NH_4$), 0.1 me of phosphorus, 1.0 me of potassium, 1.6 me of calcium and 1.3 me of magnesium. The growing substrate was siliceous sand of a diameter between 2 and 3 mm.

The minimum temperature maintained in the greenhouse was 8 °C.

### 2.3. Measurements taken

#### 2.3.1. Plants

The dry weight of stems, leaves and roots, as well as the mineral content of the plants was determined for each unit, using a complete plant. Measurements were taken after six and 12 months and will be taken again after 18 and 24 months, thereby measuring the absorption of minerals by the plant during its development.

The following measurements were taken for each plant : number of leaves, number of branches and dry weight of stems, leaves, roots and flowers (when present).

#### 2.3.2. Nutrient solution

Monthly measuring of water and mineral absorption was done by precise weighing of volumes and by mineral analysis of nutrient solution remaining in the container.

## 3. Results

### 3.1. Nutrient solution

The absorption of water and minerals was calculated as follows :

- *Water*

**Initial volume - Final volume = Water absorbed**

This is established by weighing

- *Minerals*

At the start (T0) :

Initial volume x Initial concentration = Quantity of minerals available Q1

Second measuring :

T1 : Final volume x Final concentration = Quantity of minerals remaining **Q2**

**Quantity absorbed = Q1 - Q2**

For both species, the results were obtained for the following minerals: N, P, K, Ca, Mg and expressed in milligrams absorbed, and the volume of water in liters. The absorption kinetics for minerals concerned are given in Fig. 2, 3, 5, 4.

3.1.1. Curve analysis

For both species, all the curves obtained showed a period of low absorption corresponding partly to the settling down of the plant as well as to a period of low seasonal activity (little light and heat). From the beginning of April, the curves for *P. cynaroides* showed much higher mineral requirements than *P. eximia* except for magnesium. The requirements for *P. cynaroides* were four times higher for phosphorus five times higher for nitrogen, three times higher for potassium and 2.5 times higher for calcium.

3.1.2. Analysis of absorption periods

In the case of *P. eximia* absorption of potassium was low until May, where after it increased steadily and began to level out in September in spite of the presence of flower buds.

In the case of *P. cynaroides*, K absorption was higher than for *P. eximia* from April on. It leveled out only in December perhaps as a result of a cold, rainy period. Nitrogen requirements did not seem to be very high for *P. eximia*. The absorption was low until August and increased when axillary budding appeared ; for *P. cynaroides* absorption was moderate until July, the second part of the curve seems to correspond with the formation of the lignotuber. The amount of phosphorus in the nutrient solution was very low and hence its absorption was more difficult to evaluate.

The amount of calcium absorbed by *P. cynaroides* increased rapidly from April and only leveled out in December. During its settling down phase, this species developed a number of lateral branches before producing buds at its base at the end of Spring. In the case of *P. eximia* after the settling down phase there was a sharp increase in calcium absorption followed by a leveling out and a new increase in September when lateral buds appeared on the floral stems. Absorption of magnesium was seen to be regular for both species after the settling down phase.

3.1.3. Water absorption

After the settling down period, the curve of water absorption was regular. The *P. cynaroides* water requirement was 2.5 times greater than that of *P. eximia*.

3.2. Vegetal

Table 1 shows the development results obtained in the first year. The results are expressed in terms of the number of leaves and the total dry matter which was produced. For both species the number of leaves was about the same, 227 for *P. eximia* and 218 for *P. cynaroides*, but there is a big difference between the two species in terms of the dry leaf weight : 160 mg for *P. eximia* with an area of 16,5 $cm^2$ and 605 mg for *P. cynaroides* with an area of 35 $cm^2$. For the two species the stem dry weight is almost the same, but the roots and trunk were respectively 2,5 and 3 times heavier in *P. cynaroides*.

## 4. Discussion

Taking into account all the results obtained on nutrient solution as well as those linked to the development of the two species, we were able to evaluate the minerals used by the plant to produce one gram of dry matter. This calculation was established for the following growth periods : Period A from 15 December 1994 to 1 June 1995 and Period B from 1 June 1995 to 1 December 1995.

For both species phase A includes the settling down and vegetative development period ; phase B corresponds to the end of the vegetative period and the beginning of floral initiation. The results are shown in Fig. 7. During phase A the mineral quantities used to produce one gram of dry matter were similar for both species in the case of N, K, Ca. However *P. eximia* during this period requires quantities of phosphorus and magnesium two or three times greater than *P. cynaroides*. In the second period, the mineral requirements are greater for *P. eximia* except phosphorus. *P. cynaroides* seemed to require more nitrogen. These results showed a great difference in needs between the two species.

The results can be also expressed in terms of absorption concentration of each element and are shown in Fig. 8. The curves obtained confirm the existence of two distinct periods, the first corresponding to a growing period with relatively high absorption concentration and the second being a pre-flowering period during which absorption concentration are lower. These results enabled us to established the N, P, K fertilization balance as well as the K, Ca, Mg proportions for each species and each period.

| | N | P | K |
|---|---|---|---|
| Period A : *P. eximia* | 1 | 0.36 | 2.25 |
| Period A : *P. cynaroides* | 1 | 0.17 | 1.74 |
| Period B : *P. eximia* | 1 | 0.25 | 2.58 |
| Period B : *P. cynaroides* | 1 | 0.15 | 1.24 |
| **Nutrient solution** | 1 | 0.10 | 2.18 |

These results clearly show a great difference in the fertilization balance requirements of the two species. Their potassium requirements are similar but *P. eximia* requires twice as much phosphorus. In fact to be really precise, the amounts of these minerals supplied would have to be modulated. The results also indicated that our nutrient solution does not really correspond to the requirements of the plants.

For the proportions of K, Ca, Mg, the results were as follows :

| | K% | Ca% | Mg% |
|---|---|---|---|
| Period A : *P. eximia* | 40 | 31 | 29 |
| Period A : *P. cynaroides* | 52 | 36 | 12 |
| Period B : *P. eximia* | 36 | 32 | 32 |
| Period B : *P. cynaroides* | 46 | 35 | 19 |
| **Nutrient solution** | 37 | 32 | 31 |

These results confirmed those obtained previously for the species requirements, especially for magnesium ; the nutrient solution used would be satisfactory for *P. eximia* but not suitable for the low magnesium requirements of *P. cynaroides*.

In view of the number of species and varieties a single solution cannot be attributed to a single species. Care must be taken to avoid the limiting factors which are very often linked to fertirrigation frequencies in soilless cultivation.

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Table 1 : Development of *P. eximia and P. cynaroides* (Leaf number and Dry Matter)

| | Leaves n° | Leaves : DM g | Stems : DM g | Trunk :DM g | Flowers : DM g | Roots : DM g |
|---|---|---|---|---|---|---|
| Eximia-0 | 42,2 | 0,75 | 0,32 | | | 0,28 |
| Eximia-6 | 78,8 | 10,72 | 4,27 | | | 2,27 |
| Eximia-12 | 227 | 36,38 | 20,68 | 4,84 | 4,85 | 9,62 |
| Cynaroides-0 | 31,4 | 4,82 | 1,51 | | | 1,61 |
| Cynaroides-6 | 62,4 | 28,84 | 11,05 | 12,2 | | 8,24 |
| Cynaroides-12 | 218.0 | 132.06 | 27.20 | 10.84 | 1.98 | 31.56 |

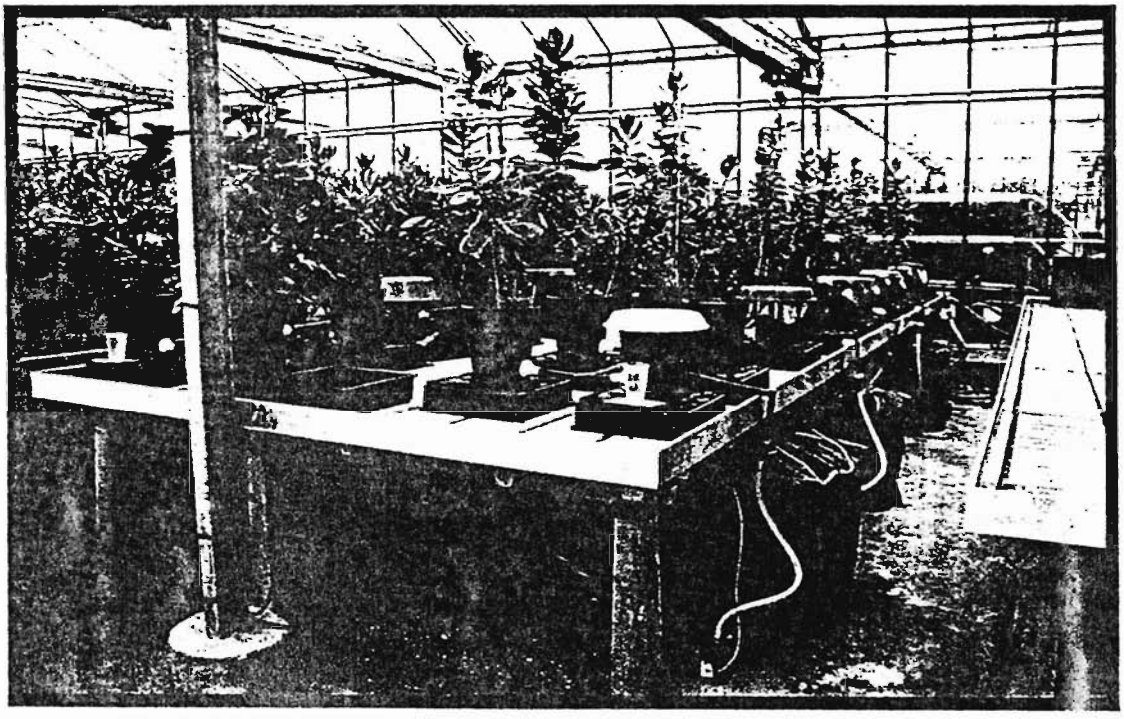


Figure 1. Experimental set up

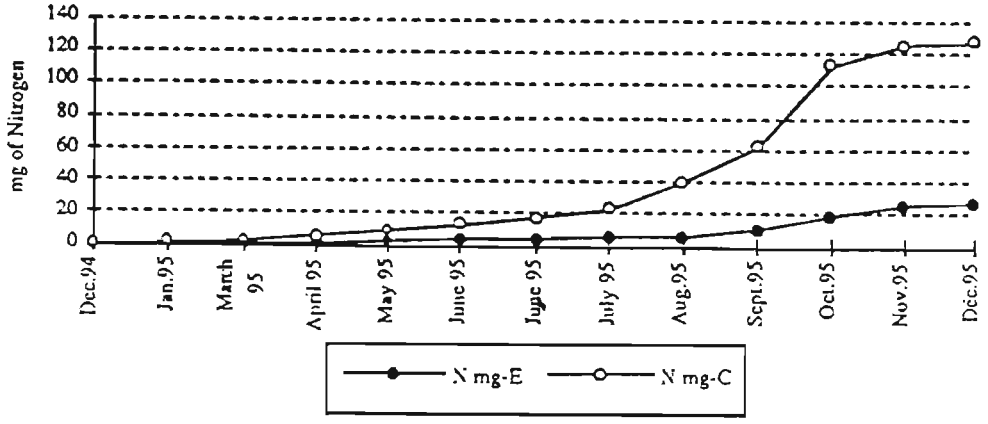



Figure 2 : Cumulative absorption of Nitrogen according to species (E = *P. eximia* C = *P. cynaroides*

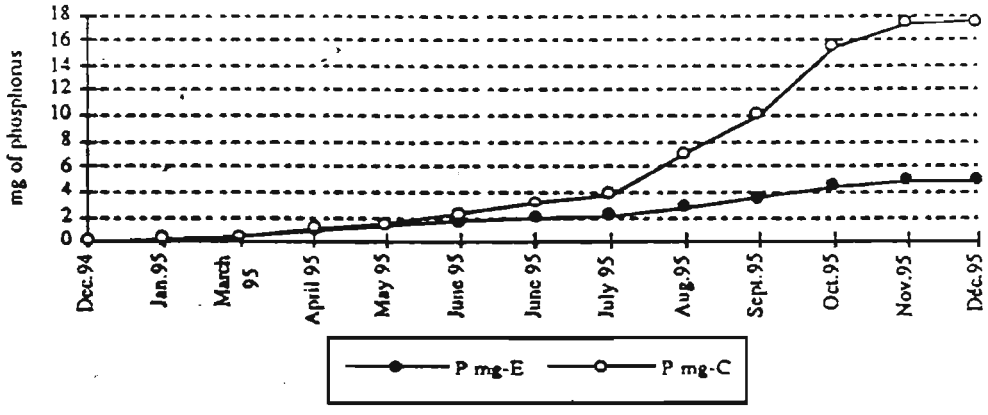



Figure 3 : Cumulative absorption of Phosphorus according to species (E = *P. eximia* C = *P. cynaroides*

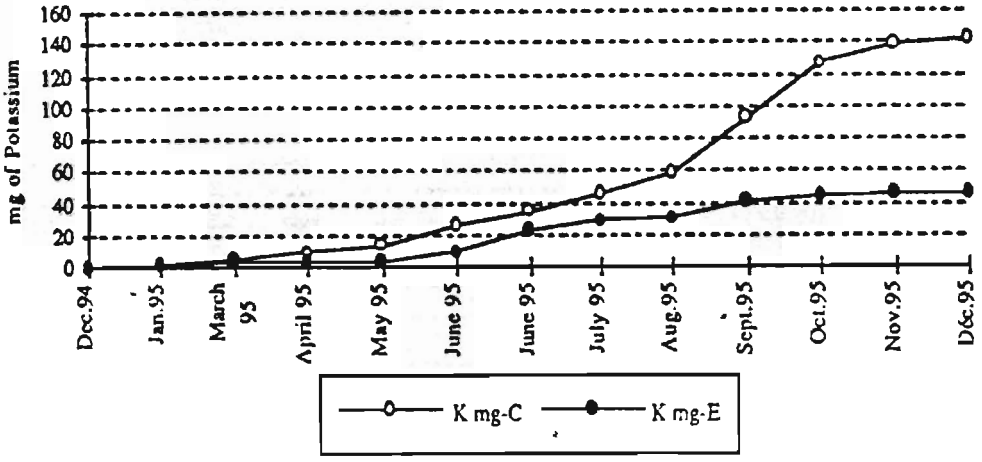



Figure 4 : Cumulative absorption of Potassium according to species (E = *P. eximia* C = *P. cynaroides*

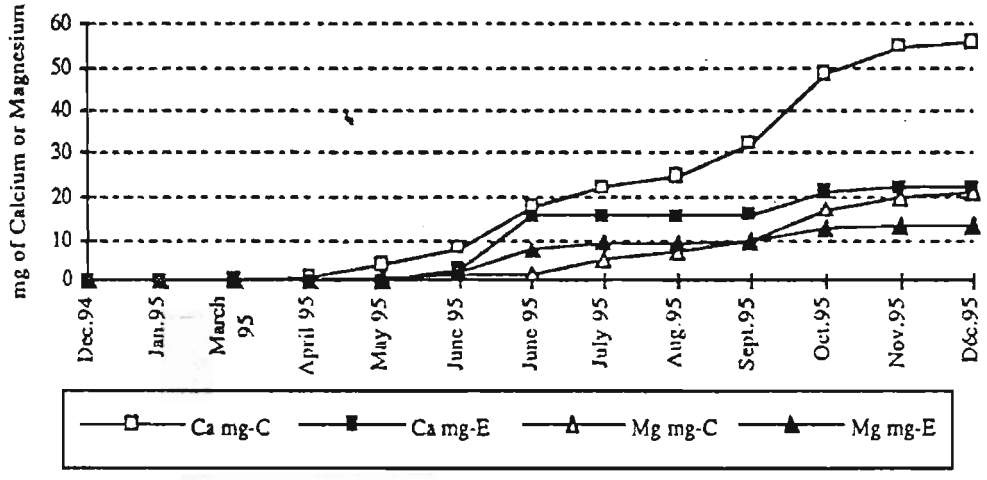



Figure 5 : Cumulative absorption of Calcium and Magnesium according to species (E = *P. eximia* C = *P. cynaroides*

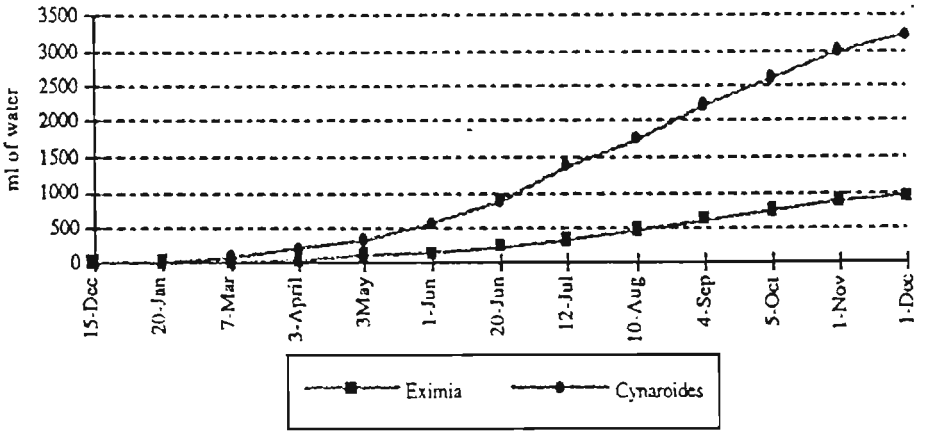
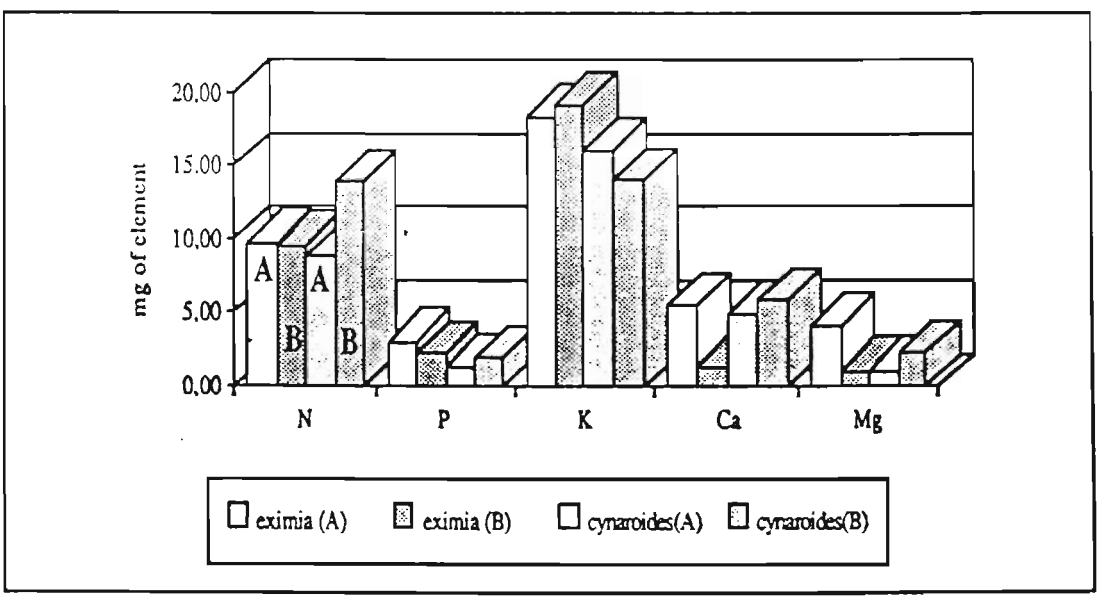



Figure 6 : Cumulative absorption of Water according to species (E = *P. eximia* C = *P. cynaroides*)




**A = Vegetative phase**
**B = Pre- floral phase**

Figure 7 : Mineral requirements for 1 gram of dry matter.

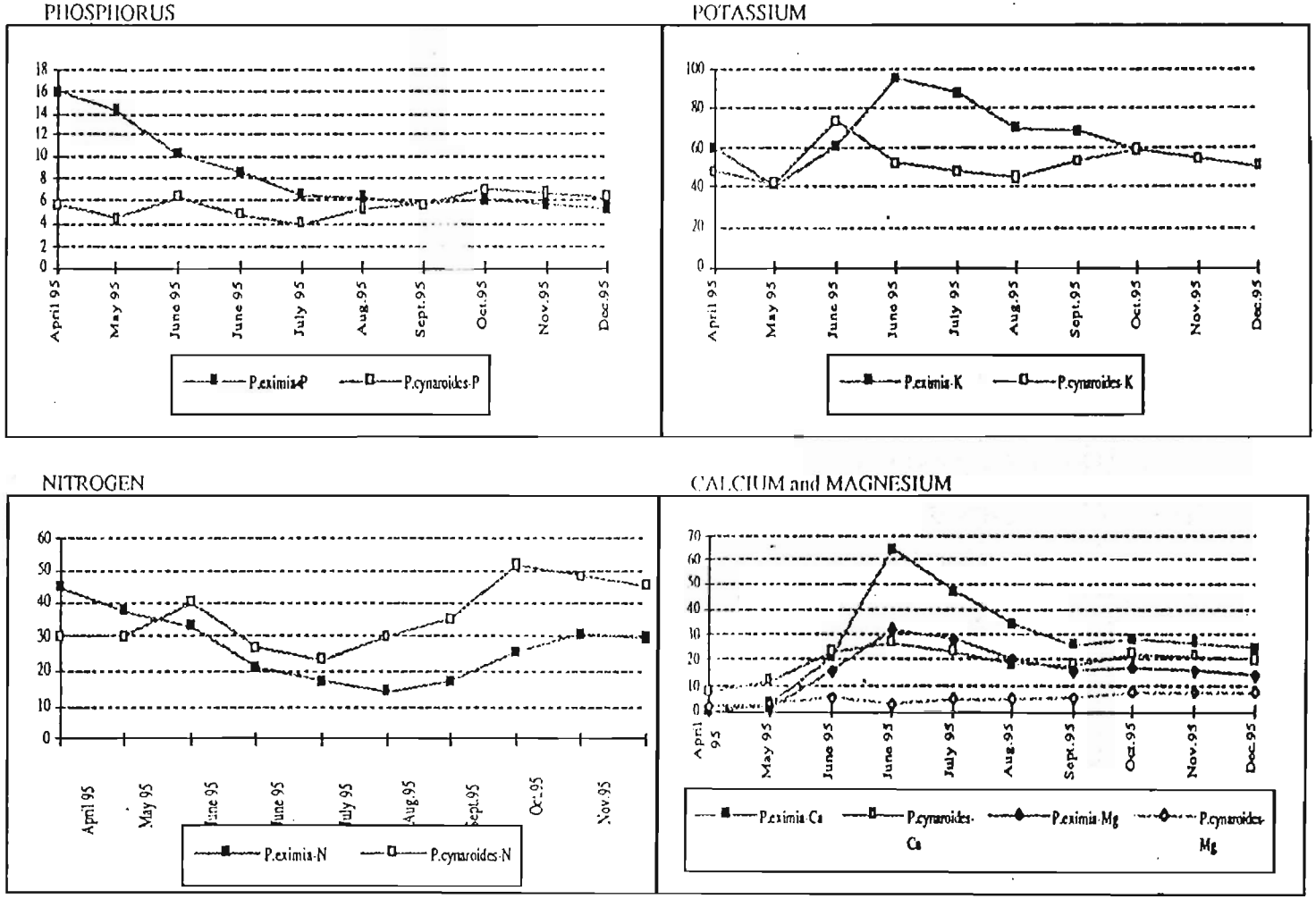



Figure 8. Absorption concentration in mg.dm$^{-3}$ for nitrogen, phosphate, potassium, calcium and magnesium

# SWOT ANALYSIS OF THE FYNBOS INDUSTRY IN SOUTH AFRICA WITH SPECIAL REFERENCE TO RESEARCH

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Keywords: floriculture; indigenous flowers; Proteaceae; rural agriculture

Abstract

The indigenous flower industry is a small, but integral, part of agriculture in the Western Cape region of South Africa. The flower industry uses a natural resource and turns it into valuable foreign currency as well as directly employing more than 4 000 people. The monetary value of the industry is approximately R81.7 million, of which the dried flower component is approximately R37.22 million. During 1995, 2 861 212 kg of fresh flowers were exported, a 15.5% increase on the previous year. The industry shows promising signs of growth potential, but certain aspects need considerable attention for this growth to be realized. The practice of harvesting in the wild, for the fresh flower trade, will have to be phased out and replaced with cultivated plantations. While the range of products currently marketed from South Africa is large, the quality of the products will have to be upgraded through greater use of cultivars. The use of economically viable cultivation practices, such as pruning, manipulation of flowering time and the use of fertilization will keep South African producers competitive with other protea growing countries. Phytosanitary problems with exported Proteaceae, Ericaceae and other indigenous fresh flowers exported need addressing. These problems are being addressed by the Agricultural Research Council Fynbos Unit research projects. Successful implementation of the research results will ensure the continued growth of the fynbos cut flower industry, both for established and new fynbos farmers.

## 1. Introduction

The indigenous floricultural industry in South Africa's Western Cape province had its origin in the wild harvesting and marketing of floral material of the plant kingdom "Flora Capensis". The initial success of the industry was based mainly on the unique novelty value of the products. Proteas and other fynbos products infiltrated the "niche market" of the exotic floral products. In the sixties and seventies, flowers were marketed mainly on their exotic character. The flower industry developed into an important employment provider, in especially the rural areas (Coetzee and Littlejohn, 1995).

The indigenous flower industry in South Africa maintained its market segment during the years of political and economic isolation. Export figures indicate no or limited growth during this period of isolation.

During these years, however the opportunity arose for countries such as Australia, New Zealand and Zimbabwe to initiate the cultivation of indigenous flora of South Africa and annex a part of the international protea flower market. In the nineties, with a changed political climate in South Africa, the indigenous floral industry finds itself in a position where the demand for high quality flowers exceeds the supply. The danger for South African producers is that the local producers will lose their market share permanently to their competitors, if the international market demand can not be successfully maintained. As the flower industry, in mainly the Western Cape Province of South Africa, is a small but

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integral part of the agricultural sector, the loss of markets will negatively influence the economy of the area.

If the indigenous flower industry in South Africa follows the correct strategy with regard to development and marketing, the industry will maintain and even increase it's market segment.

## 2. Floral products of the indigenous flower industry in South Africa

The indigenous floral products marketed by South Africa, originate from the "Flora Capensis", a unique plant kingdom found in a small area on the southern tip of Africa. It is also in this area where more than 90% of the floral products are cultivated or harvested from their natural habitat. The industry comprises two components, namely the dry floral industry and the fresh flower industry. The dry flower industry markets about 64 products - the most important products are indicated in Table 1. These products are harvested mainly in their natural habitat (veld). The turnover of this industry is calculated to be in the order of R37.2 million (US $9.67 million).

The fresh flower industry markets 137 species or cultivars divided into the following main groups: *Protea*, *Leucospermum*, *Leucadendron*, *Erica*, "Cape greens", ferns, reeds and grasses. A list of the most important products is given in Table 2. The fresh flower industry still uses some products that are harvested from the wild, but the cultivation of flowers in plantations is rapidly increasing. The fresh flower exports concentrate mainly on the European market, although American and Far East markets are also looked at. The foreign currency earned by the fresh flower industry is estimated at R64.5 million (US $6.75 million).

Table 1 - Dried floral products harvested from natural stands in South Africa

| Botanical name | Trade name |
|---|---|
| *Aristea macrocarpa* | Aristea |
| *Cannomois virgata* | Assegaai |
| *C. virgata* | Bellreed |
| *Protea compacta* | Compacta flower |
| *P. compacta* | Compacta rosette |
| *P. magnifica* | Barbigera flower |
| *P. neriifolia* | Neriifolia bud |
| *P. neriifolia* | Neriifolia rosette "Curly Top" |
| *P. obtusifolia* | Obtusifolia flower |
| *P. repens* | Repens flower cream |
| *P. repens* | Repens flower red |
| *P. repens* | Repens rosette small |
| *P. repens* | Repens rosette medium |
| *P. repens* | Repens rosette "super cut" |
| *P. susannae* | Susannae |
| *Leucadendron coniferum* | Sabulosum |
| *L. muirii* | Muirii |
| *L. nervosum* | Nervosum |
| *L. platyspermum* | Platyspermum |
| *L. rubrum* | Plumosum |
| *L. xanthocomus* | Salignum branch with foliage |
| *L. xanthocomus* | Salignum branch |
| *Syncarpha vestita* | Capblumen |
| *Thamnochortus insignis* | Thatchreed |

Table 2 - A botanical list of the most important indigenous fresh-flower products cultivated or harvested from natural stands in South Africa

| Botanical name | Trade or cultivar name |
|---|---|
| ***Protea*** | |
| *P. compacta* | Compacta |
| *P. compacta* x *P. eximia* | Pink Duke |
| *P. compacta* x *P. magnifica* | Lady Di |
| *P. compacta* x *P. susannae* | Pink Ice |
| *P. cynaroides* | King Protea |
| *P. eximia* | Eximia |
| *P. eximia* x *P. susannae* | Cardinal |
| *P. eximia* x *P. susannae* | Sylvia |
| *P. grandiceps* | Grandiceps |
| *P. lacticolor* | Ivy |
| *P. magnifica* | Sederberg Barbigera |
| *P. magnifica* | Botrivier Barbigera |
| *P. magnifica* x *P. burchellii* | Sheila |
| *P. magnifica* x *P. susannae* | Susara |
| *P. mundii* | Mundii |
| *P. neriifolia* | Neriifolia |
| *P. obtusifolia* | Obtusifolia |
| *P. pityphylla* | Pityphylla |
| *P. repens* | Red Repens |
| *P. repens* | White Repens |
| *P. scolymocephala* | Scoly |
| ***Leucadendron*** | |
| *L. argenteum* | Silver tree |
| *L. coniferum* | Sabulosum |
| *L. coniferum* x *L. floridum* | Pisa |
| *L. discolor* | Green Discolor |
| *L. discolor* | Red Discolor |
| *L. discolor* | Yellow Discolor |
| *L. floridum* | Florida |
| *L. galpinii* | |
| *L. laureolum* | Decorum Star |
| *L. laureolum* | Leureolum male |
| *L. laureolum* x *L. salignum* | Safari Sunset |
| *L. linifolium* | Tortum female |
| *L. linifolium* | Tortum male |
| *L. laxum* | Smartrose |
| *L. meridianum* | |
| *L. muirii* | |
| *L. nervosum* | Nervosum female |
| *L. nervosum* | Nervosum male |
| *L. platyspermum* | Platy male |
| *L. platyspermum* | Platystar |
| *L. salignum* | Blush/Candles/Long Tom |
| *L. salignum* | Red Adscendens |
| *L. salignum* | Winter Red |
| *L. rubrum* | Rubrum female |

| | |
|---|---|
| *L. rubrum* | Rubrum male |
| *L. salicifolium* | Strictum |
| *L. tinctum* | Lollipop |
| *L. xanthoconus* | Salignum |
| | |
| ***Leucospermum*** | |
| L. conocarpodendron | |
| L. cordifolium | Vlam |
| L. cordifolium | Flamespike |
| L. cordifolium | Yellow Bird |
| L. cordifolium | Scarlet Ribbon |
| L. tottum x *L. glabrum* | Red Sunset |
| *L. cordifolium* x *L. lineare* | Sue Ellen |
| *L. cordifolium* x *L. lineare* | Succession I |
| *L. cordifolium* x *L. lineare* | Succession II |
| *L. cordifolium* x *L. patersonii* | High Gold |
| *L. cordifolium* x *L. patersonii* | Sunrise |
| *L. cuneiforme* | |
| *L. erubescens* | Veldfire |
| *L. glabrum* | |
| *L. glabrum* x *L. conocarpodendron* | Luteum |
| *L. patersonii* | Orange Reflexum |
| *L. reflexum* | Buxifolia |
| *L. reflexum* | |
| *L. truncatulum* | |
| | |
| Cape greens | |
| *Agathosma* spp. | Buchu |
| *Anthospermum aethiopicum* | New look |
| *Aspalathus* spp. | |
| *Aulax umbellata* | |
| *Berzelia abrotanoides* | Abrotan |
| *B. alopecuroides* | Strawberry Berzelia |
| *B. alopecuroides* | White Berzelia |
| *B. galpinii* | Baubles |
| *B. lanuginosa* | |
| *B. squarrosa* | Paleacea |
| *Blaeria ericoides* | |
| *Brunia albiflora* | Albiflora |
| *B. laevis* | Silver Brunia |
| *B. nodiflora* | Spray Brunia |
| *Diosma* | Buchu |
| *Eriocephalus racemosus* | White cotton |
| *Lanaria lanata* | Lambtails |
| *Metalasia* | |
| *Mimetes hirtus* | |
| *Nebelia paleacea* | |
| *Phaenocoma prolifera* | Red everlasting |
| *Phylica ericoides* | White Phylica |
| *P. lasiocarpa* | Snowtops |
| *P. pinea* | Pinea |
| *P. pubescens* | Green Phylica |
| *Rhetzia capensis* | |
| *Serruria* spp. | |
| *S. florida* | Blusing Bride |

| | |
|---|---|
| *Staavia radiata* | Glass-eyes |
| *Stoebe plumosa* | |
| **Ferns** | |
| *Blechnum punctulatum* | Sword fern |
| *Gleichenia polypodioides* | Coral fern |
| *Rumohra adiantiformis* | Knysna fern |
| *Todea barbara* | Fern |
| **Reeds and grasses** | |
| *Aristea confusa* | Seed Koala |
| *Calopsis paniculata* | Rekoala |
| *Cannomois virgata* | Elephant Quills |
| *Ceratocaryum argenteum* | Braids |
| *Ficinea* | Virginia reeds |
| *Ischyrolepsis hystrix* | Koala fern |
| *Rhodocoma gigantea* | Mikado stems |
| *R. gigantea* | Mikado tufts |
| *R. gigantea* | Steppen grass |
| *Tetraria secans* | Dekreed female |
| *Thamnochortus insignis* | Dekreed male |
| *T. spicigerus* | Mountain heather |
| *Erica* | |
| *E. baccans* | |
| *E. bicolor* | |
| *E. borboniifolia* | Mountain heather |
| *E. campanularis* | |
| *E. coccinea* | |
| *E. corifolia* | |
| *E. cubica* | |
| *E. cyathiformis* | |
| *E. crenata* | |
| *E. daphniflora* | |
| *E. deliciosa* | |
| *E. fastigiata* | Four sisters |
| *E. filipendula* | Elim heather |
| *E. imbricata* | Salt and pepper |
| *E. irregularis* | |
| *E. leucanthera* | |
| *E. patersonia* | |
| *E. perspicua* | Prince of Wales |
| *E. plukenetii* | |
| *E. ovina* | Lemon Plukenetii |
| *E. sessiliflora* | |

## 3. SWOT analysis of the Fynbos industry

### 3.1. Strengths

A demand for high quality indigenous South African flowers exists on the international markets. In contrast with the general decline of flower prices on the international markets over the last few years, the price for South African indigenous floral products remained constant and in some cases even indicated an increase. This economic tendency indicates a growth potential for the indigenous flower industry of South Africa.

The biodiversity of the floral material available in South Africa forms a base from which to market a large variety of flower products.

There are certain fynbos species that need specific climatic and soil conditions, requiring cultivation of these floral products in their natural habitat. The environmental requirements are adhered to when cultivating in the Western Cape.

The Western Cape's infrastructure supporting the export of agricultural products, is good. This infrastructure benefits producers giving them an advantage above producers in the rest of Africa.

The Fynbos Industry in South Africa is supported by a non-government industry organization; namely the South African Protea Producers and Exporters Association (SAPPEX). Research is conducted by the Agricultural Research Council (ARC: Fynbos). These organizations address the need of the industry.

Work opportunities, especially suitable for women are available in the indigenous floricultural industry, and will increase if the industry grows.

### 3.2. Weaknesses

Floral products picked in the wild do not always adhere to international standards. The marketing of low quality products has a negative effect on the price structure and results in a buyer reluctance against the product.

As flower products are cultivated in their natural habitat, the flowers are exposed to their natural enemies such as insects and fungal diseases. This forces producers to follow expensive control programs with a steep increase in production costs. The insect and disease symptoms make it difficult for flower products to satisfy international phytosanitary requirements.

Proteas and other fynbos products are often produced by rural farmers (small-scale producers), who do not always have the necessary infrastructure such as packaging and cooling units. This limitation may lead to lower quality flowers reaching the market.

### 3.3. Opportunities

By means of cultivation of fynbos and applying appropriate cultivation practices, South African producers can improve the quality to successfully serve existing markets and develop new markets.

New products, improved cultivars and plants flowering in the appropriate season can be produced by using the available, large and diverse genetic resources.

The Fynbos Industry in South Africa is one of the agricultural businesses that is suitable for new farmers. The industry makes it possible for rural communities, that at present pick flowers in the wild to be introduced to the formal agricultural sector by establishing cultivation in plantations.

### 3.4. Threats

The indigenous flower industry is gradually losing its diverse genetic source, including the natural habitat where certain products are harvested as a result of:

- Agricultural and industrial development
- Invasive alien plants
- Uncontrolled fires

Suitable agricultural land to cultivate fynbos is limited, especially in the Western Cape. High-quality agricultural land with irrigation is a relatively expensive component for fynbos production.

Competition from countries, classified as developing countries and therefore not paying import taxes in Europe, negatively influences the profitability of South African producers.

Due to the scaling down of government support for research, South Africa could lose its leading position in this research field, which in the long term will influence the industry in a negative way.

Uncontrolled expansion of the industry in South Africa can place pressure on the existing infrastructure, for instance air space. This will threaten marketing with serious consequences.

As Proteas and other fynbos products lose their exotic value, they will compete directly with the traditional cut flowers on the market. To maintain the exotic market segment, well planned promotion strategies are needed.

## 4. Research on indigenous flowers

The indigenous flower industry in South Africa is supported by various research organizations such as universities and governmental instances. The research goal of the Fynbos Unit of the parastatal Agricultural Research Council is to convert the indigenous fresh-flower industry from a wild-based industry to an industry where flowers are commercially cultivated.

The fynbos research programme of the ARC is compiled in cooperation with the industry and focuses on the following:

- Preserving genetic material with floricultural value;
- Breeding and selection of new cultivars and products;
- Crop science aspects such as propagation, pruning, manipulation of flowering time and irrigation,
- Plant protection concentrating on the pest and disease spectrum.

The genebank collection contains plant species with floricultural potential. This collection is used as a base for the breeding, selection and evaluation project. Producers also provide natural hybrids for evaluation to the genebank. Thirty five cultivars have already been released from research work undertaken in this project (Coetzee and Brits, 1991). In 1995 the following cultiyars were released:

- Sheila* (*P magnifica* x *P burchelli*)
  - showing good yield and vigor, flowering May to July. Registered by Mr. Klaasie Strauss.
- Lady Di (*P magnifica* x *P compacta*)
  - vigorous with long stems, little secondary growth, flowering May, June. Developed by Protea Heights.
- Sue Ellen (*Leucospermum lineare* hybrid)
  - good yield of long straight stems, flowering September. Developed by Protea Heights.
- Memory (*Leucospermum cordifolium* selection)
  - more adaptable to heavy soils, flowering September to October. Developed by ARC: Fynbos Unit.

- Magenta Sunset (*Leucadendron salignum* x *L. laureolum*)
  - excellent vigor and yield, harvestable from February to August. Developed by ARC: Fynbos Unit.
- Rosette I and II* (*Leucadendron laureolum* x *L. elimense*)
  - vigorous, erect producing long straight stems, green - February to May; yellow - June to August, green with red cone - September. Developed by ARC: Fynbos Unit.

(* Indicates plant breeders rights).

The potential and cultivation protocol of products such as *Brunia*, *Erica*, and *Phylica* are investigated and released to the industry (Rugge, personal comm.).

Basic research is undertaken on seed germination (Brits, 1995) and flower initiation (Malan, 1994). Interspecific incompatibility studies are undertaken (Van der Walt, 1995) to solve problems in developing new cultivars.

Plant protection is seen as an important problem in the industry. To determine the insect and disease component is important to develop an integrated pest management strategy (Wright and Saunderson, 1995). If the protection programme is successful it will allow farmers in the position to deliver environmentally friendly products to the market.

## 5. Conclusion

If the indigenous flower industry uses its opportunities and addresses its threats, the industry has the potential to keep and increase its market share. This industry growth will expand the essential job opportunities needed for women in South Africa. The export product that can be produced won't compete with producers in Europe, as Europe cannot cultivate fynbos on a large scale. With the correct strategic approach, the fynbos industry can accommodate new farmers in floriculture and informal pickers from the wild can become part of the formal agricultural sector.

## Acknowledgments

The authors wish to thank Dr. G. Littlejohn and Dr. E. Reinten for their input in this paper.

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# IMPROVED METHODS FOR ROOTING CUTTINGS OF *PROTEA OBTUSIFOLIA*

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Abstract

Methods for improved vegetative propagation of *Protea obtusifolia* were examined. Different hormone treatments, seasons, mother plant treatments, and cuttings in different physiological age were tested. The results showed that the use of semi hardwood cuttings and treating them with IBA 2000 ppm gave the highest rooting percentage. Growing mother plants under 30-50% shading net improved rooting percentage. Rooting of cuttings was improved greatly by repeated rooting for 3 generations. Cuttings taken from the last generation of plants rooted at 75% compared to 37% when cuttings were taken from matured field grown plants.
Using these methods, we got high rooting percentage of 75% in a period of 10 weeks.

## 1. Introduction

It is difficult to grow Proteas in Israel. The climate, the soil and the water are not ideal for successful commercial production of Proteas as cut flowers. *Protea obtusifolia* is one of the species which is very tolerant to alkaline soil and grows in limestone soils in nature. This fact makes it so important for the introduction of Proteas as cut flowers in Israel (Ben-Jaacov 1986). *Protea obtusifolia* is compatible graft on many other Protea species, thus, it can be used as a rootstock for those species (Brits 1990a, Brits 1990b, Maffott and Turnbull 1994). In the last 20 years there have been several attempts to grow *Protea obtusifolia* in Israel, but most of the plants were raised from seeds, showed high genetic variability and therefore were of low commercial value. The highest rooting percentage of *P. obtusifolia* obtained by Perez (1992) was 10% after 40 weeks. In order to propagate *P. obtusifolia* as cut flowers or as rootstocks it is important to improve vegetative propagation.

In this study we tested several methods, the most successful are presented in this paper.

## 2. Material and methods

### 2.1. Plant material

The first generation of cuttings were collected from 8 years old clonal mother plants grown at the Volcani Center at Bet Dagan. All plants were grown under the same environmental conditions unless it was the factor investigated.

### 2.2. Growth regulators

Cuttings were treated with IBA as powder or liquid, and with an experimental auxin conjugate.

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2.3. Rooting conditions

Cuttings were placed in rooting tables heated in winter to 28°C in medium of coconut fibers; polystyrene 1:1 (V:V), in a greenhouse equipped with evaporative cooling system.

Rooting was done under mist conditions of 10-20 seconds every 10-15 minutes. The mist conditions were changed according to the climatic conditions.

## 3. Results

3.1. Growth regulators

After few experiments with different concentrations of growth regulators we found that IBA as powder in concentration of 0.4%, and as liquid at 2000 ppm gave the highest rooting percentage (Table 1). IBA at 300 ppm (data not shown) and the auxin conjugate produced poor results.

3.2. Cutting's age and physiological condition.

3.2.1. Cuttings in 3 growth stages were tested:

Herbaceous, semi hardwood and hardwood. The semi hardwood cuttings rooted at the highest percentage (Table 2).

3.2.2. Cuttings were taken from mother plants in two physiological ages:

Juvenile (one year old) and mature (8 years old). Cuttings that were taken from the juvenile plants rooted at higher percentage (Table 3).

3.2.3. Cuttings were taken from 3 generations of *P. obtusifolia* plants.

Generation II was raised vegetatively from cuttings taken from generation I, and generation III plants were raised from cuttings taken from generation II. Cuttings from generations II and III (Table 4) rooted at higher percentage than those taken from generation I. The difference between generation II and I was greater than the difference between generation II and III.

3.3. Mother plants treatment

Mother plants with actively growing shoots were covered with shading nets of 30% or 50% shade.

The cuttings from shaded plants rooted at a higher percentage than sun grown plants (Table 5). Cuttings grown under 50% shade showed higher percentage of rooting than cuttings produced under 30% shade, but both rooted better than the control unshaded cuttings.

3.4. Rooting season

Cuttings from 2 clones of *P. obutsifolia* were taken during the year, on the 15th of every month. The results (Table 6) show that in the hot season (in Israel), June-October, the rooting percentage was low. Rooting was improved in the fall and winter and the best rooting was achieved in the spring (April).

## 4. Discussion

This study demonstrated that several factors influence rooting: proper treatments of the stock plants and the cuttings lead to rapid rooting with high percentage of success.

1. Mother plants: First generation of cuttings taken from matured (8 years old) plants rooted poorly (40%). Cuttings taken from the second generation of mother plants, grown under partial shade (best at 50% shade) rooted better and faster. Cuttings taken from the third generation rooted best and fastest (80% in 10 weeks).
2. Best time for sticking the cuttings was in the spring and the best hormonal treatment was a ten second dip of the bases of the cuttings in 2000 ppm IBA.

Table 1. Influence of growth regulators as powder or as liquid in various concentrations, on rooting of *P. obtusifolia* cuttings.

| Treatment | Control | IBA (Powder) | | IBA (Liquid) | | Auxin Conjugate |
|---|---|---|---|---|---|---|
| | | 0.8% | 0.4% | 4000ppm | 2000ppm | (Powder) 0.2% |
| Rooting % | 30 c* | 43 b | 66 a | 48 b | 72 a | 8 d |

* Different letters represent significant difference between treatments.

Table 2. Influence of growth stage of the plant material on the rooting of *P. obtusifolia* cuttings. The cuttings were treated with IBA 4000 ppm.

| Cuttings = growth stage | Rooting % |
|---|---|
| Herbaceous | 5 c* |
| Semi-hardwood | 78 a |
| Hardwood | 43 b |

* Different letters represent significant difference between treatments.

Table 3. Influence of the physiological age on rooting of *P. obtusifolia* cuttings. The cuttings were treated with IBA 2000 ppm.

| Physiological age | Rooting % |
|---|---|
| Juvenile (1 year old) | 60 a* |
| Mature (8 years old) | |
| "Red" | 13 b |
| "Pink" | 10 b |

* Different letters represent significant difference between treatments.

Table 4: Rooting of cuttings from 2 clones of *P. obtusifolia* and Pink Ice taken from 3 consecutive generations. The cuttings were treated with IBA 2000 ppm. Data collected 10 weeks after the cuttings were stuck.

| Plant | Rooting % | | |
|---|---|---|---|
| | Generation I | Generation II | Generation III |
| Pink Ice | 43.2 b* | 75.0 ab | 87.5 a |
| Clone C-82 | 37.5 b | 68.7 ab | 81.2 a |
| Clone LK-1 | 37.5 b | 62.5 ab | 75.0 a |

* Different letters represent significant difference between treatments.

Table 5: Rooting of *P. obtusifolia* cuttings taken from mother plants grown under 30% or 50% shading nets, after 6 and 10 weeks. all cuttings were treated with IBA 2000 ppm.

| Treatment of mother plants | Rooting % after | |
|---|---|---|
| | 6 weeks | 10 weeks |
| 30% shading | 40 | 70 |
| 50% shading | 55 | 80 |
| Control non-shaded | 10 | 30 |

Table 6: Influence of the season on rooting of *P. obtusifolia* cuttings. Cuttings were treated with IBA 2000 ppm. Cuttings were taken on 15th of every month.

| | Rooting % Clone | |
|---|---|---|
| Month | LK-1 | C-82 |
| Jan | 60 | 58 |
| Feb | 70 | 70 |
| Mar | 68 | 78 |
| Apr | 78 | 80 |
| May | 58 | 63 |
| Jun | 40 | 49 |
| Jul | 28 | 25 |
| Aug | 23 | 20 |
| Sep | 25 | 28 |
| Oct | 38 | 40 |
| Nov | 55 | 55 |
| Dec | 60 | 63 |

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## Acta Horticulturae

Acta Horticulturae is used for publishing research and review articles.
Research reports of an oral or poster presentation should contain a commentary on a finished research project. A review article deals with knowledge obtained about a certain subject. Abstracts of copies of posters are not published.

As decided by the Council of ISHS, the proceedings of ISHS-symposia are published in a volume of Acta Horticulturae. The regulations for the publication of the proceedings are mentioned in a special agreement, to be signed by the organizer of a symposium, by the institution involved and the Executive Director of ISHS. The ISHS secretariat takes care of printing and publication.

## Reprints

An orderform for reprints is enclosed with the authors' instructions. The order of a minimum of 100 reprints can be forwarded to the ISHS secretariat. An invoice for the reprints will be sent to the author.

## Other ISHS publications

- **Chronica Horticulturae**, the magazine of the Society which keeps members of ISHS informed of its activities and about other matters related to the objective of the Society.
- **Horticultural Research International**, the fifth edition which appeared in 1993, contains information on horticultural research in 74 countries, research institutes (some 2500), research workers (about 18.000), main fields of interest, and an alphabetical list of research workers and places.
- **Proceedings of the International Horticultural Congress**, published by ISHS in Acta Horticulturae and obtained from the ISHS Secretariat.
- **Scientia Horticulturae**, published by Elsevier Science and sponsored by ISHS which has a co-responsability for the appointment of the editorial board.
- **Elseviers Horticultural Dictionary**, a directory in 10 languages compiled by ISHS and published in close cooperation with Elsevier Science.

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The objective of the Society is the advancement of horticulture through improvement of international cooperation in science and technology. Besides through its members other means available to the Society for the achievement of the objective are :

* the holding of **International Horticultural Congresses** at least every 4 years.
* the setting up of :
  - **Sections** dealing with groups of horticultural plants
  - **Commissions** engaged in various scientific and technical aspects of horticulture
  - **Working Groups** having interest in special horticultural science areas or activities within the the Sections and Commissions
* the organizing of symposia on specific topics for scientists and other specialists
* the publishing of the proceedings of such symposia and other relevant publications

**The ISHS distinguishes three kinds of members :**

- **Individual members** being individual persons engaged or interested in horticultural science or technology
- **Member organizations** being societies, associations, ministries, institutes, agencies, firms or sections of any of these concerned with the advancement of horticulture
- **Country members** being countries from where the annual dues for the country membership are paid and who nominate up to 2 individual members as members of the Council, representing the scientific horticulture in the country concerned.

**Advantages for members are:**

- a reduced fee at each symposium organized by ISHS for each individual member and for two representatives of a member organization
- the privilege to organize ISHS symposia or other scientific meetings (for organization members only)
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- a special subscription price on Scientia Horticulturae (for individual members only)
- a free copy of the list of members and of the directory of members of Sections, Commissions and Working Groups
- a reduced subscription fee for other ISHS publications.

The Society has 6 Sections, 12 Commissions and 89 Working Groups.
Members of Sections and Commissions are nominated by the national Council members.
Members of Working Groups are nominated by the members of Sections and Commissions.

| Section | Commission | |
|---|---|---|
| Fruit | Engineering | Education and Training |
| Vegetables | Plant Protection | Economics and Management |
| Ornamental Plants | Plant Substrates | Nomenclature and Registration |
| Medicinal and Aromatic Plants | Urban Horticulture | Tropical and Subtropical |
| Root and Tubercrops | Protected Cultivation | Horticulture |
| Viticulture | Post Harvest | Biotechnology |
| | | Plant Genetic Resources |