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International Society for Horticultural Sci

First International Protea Research Symposium

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J. Ben Jaacov
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Cape Town, South Africa

FIRST INTERNATIONAL PROTEA RESEARCH SYMPOSIUM

Cape Town

South Africa

28 and 29 August 1985

Convener

Dr. J.T. Meynhardt

Protea Working Group
Section Ornamentals

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CONTENTS PAGE

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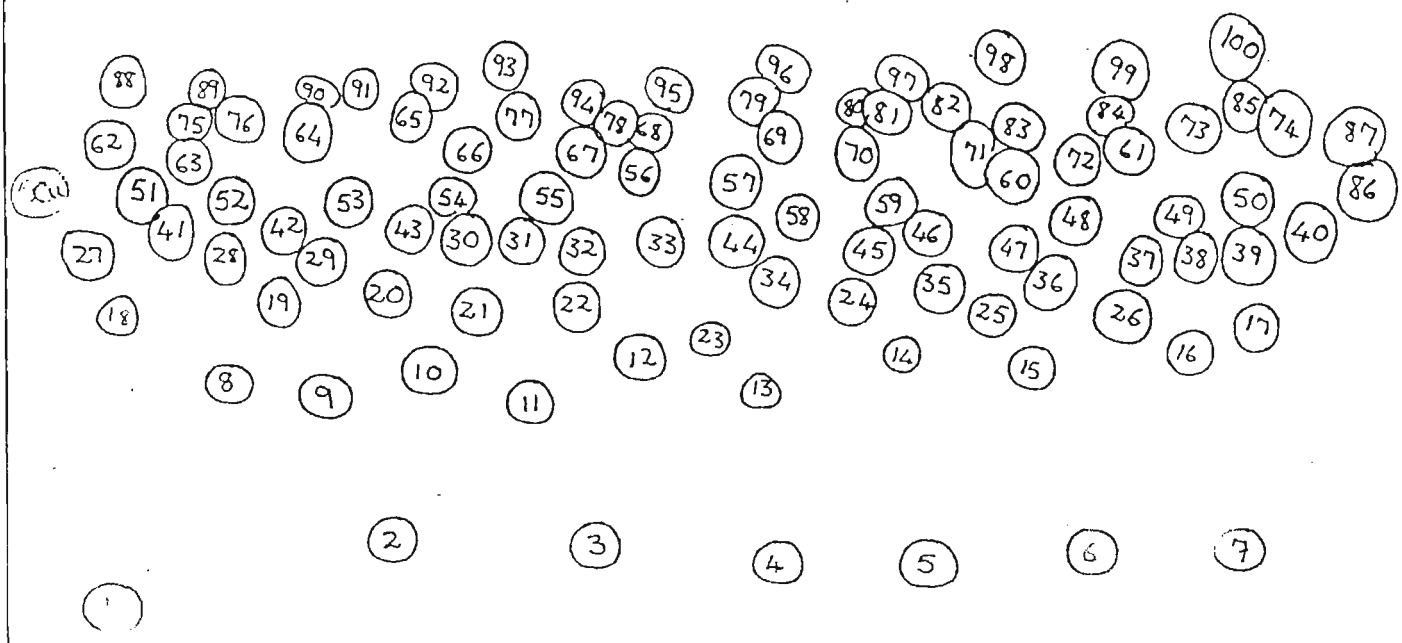

International Protea Conference (IPA) and Symposium (ISHS)

Key to group photo taken at Kirstenbosch Botanic Garden
Cape Town - 1 September 1985

1 Rourke J P
2 Mathews, P
3 Parvin, P E
4 Sayers, M F
5 Paulin, G N
6 Gibson, H B
7 McNamara, M J-R
8 Woodward, N E
9 Sayers, T
10 Morgan, R A
11 Anthoine, J B P
12 Anthoine, T D
13 Morris, C
14 Perry, G
15 Paulin, B F.
16 Middelmann, W J
17 Gray, A D
18 Middelmann, R
19 Redgate, G G
20 Ferreira, S
21 Seeley, C
22 Seeley, J G
23 Grose, M J
24 Perry, D
25 Stead, C N
26 Brits, C
27 Albert, D R
28 Ferreira, D I
29 McEwan, L E
30 Richards, B A
31 Daws J
32 Nutting, G R
33 Middelmann R H
34 Middelmann, M C
35 Mathews, R
36 Larsen, U H
37 Larsen, D V
38 Huston, J
39 Brits, G J
40 Eloff, J
41 Paull, A G
42 Benic, L M
43 Mathews, D
44 Arnott, M
45 Arnott, K
46 Flannery,P
47 Sack, J M
48 Paull, R C
50 O'Brien, A B
50a Dupee, S
51 Coetzee, J H
52 Rodrigues, J A
53 Sayers, M E
54 Salinger
55 Ewing, S
56 Ewing, B V
57 La Rue, B H
59 Flanders, B
60 Heemskerk, A
61 O'Brien, P T
62 Vardy, J J L
63 Ben-Jaacov, J
64 Dennis, D
65 Harris, B C
66 Mason, G W
67 Rudd, W B
68 Dietrich, M J
69 La Rue, R L
71 Heinsohn, R D
72 Salomon, L
73 Salomon, D
74 Niemand, J F
75 Nicklin, L
76 Ben-Jaacov, H
77 Paton, J
78 Rudd, J D
79 Green, S
80 Erasmus, K
81 West, K
82 Hunter, R Q
83 West, V
84 Miller, M P
85 Miller, V S
86 Huston H
87 Peters, J
88 Hardesty, L
89 Davies, W
90 Davies
91 Lamont, B
92 Robb, M
93 Tricks, D V C
94 Van Zyl, I
95 Walker, C
96 Le Roux, D
97 Eybers, E R
98 Bonner, R L
99 Paull, G A
100 Alberts, J

PREFACE

The family Proteaceae comprises of 62 genera and approximately 1 400 species. The largest variety of Proteaceae occur in Australia where approximately 20 genera and 760 species are indigenous. However, the 400 South African members of the Proteaceae family are as a group the most attractive with an outstanding potential as cut flowers.

It is therefore appropriate that the first International Protea Research Symposium was held in South Africa. This meeting was combined with the 3rd International Protea Conference. The Symposium was organised under the auspices of the International Society for Horticultural Science and the Conference under the auspices of the International Protea Association.

This first Protea Research Symposium was the outcome of the work of the Protea Research Working Group which was formed under the Ornamentals Section of the ISHS in March 1984. The main emphasis of the Symposium was placed on formal sientific meetings at which papers were presented on a variety of the most recent research aspects of protea growing, from breeding and propagation to post-harvest handling. These papers are compiled in this volume of Acta Horticulturae. Several technical excursions were offered to allow participants to acquaint themselves with protea growing in South Africa.

The combination of growers and scientists at the same meeting led to very fruitful discussions and excellent co-operation in future is envisaged.

I have to thank all the people, scientific, technical, administrative and growers who have devoted time and energy to this Symposium and Conference and thus contributed to an even greater success than was expected. The 150 participants from nine countries around the world made full use of the opportunity to communicate and I truly believe that the foundation was laid for increased activity in protea growing and research.

The generous financial support of the Department of Agriculture and Water Supply is recognised with thanks.

Dr D I FERREIRA
Co-chairman, Organising Committee

RESEARCH PLANNING AND INTERPRETATION

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Abstract

Research may be defined as a critical and exhaustive investigation or experimentation having as its aim the revision of accepted conclusions in light of newly discovered facts.

Or we may shorten it to say that research is the acquiring of facts based on carefully conducted experiments and proper interpretation of research data. University, college, experiment station, and industry researchers may conduct studies at various levels of sophistication with a proper balance between the so-called "applied" and "basic" research.

An experimental outline, and some examples of interpretation are presented.

* * * * *

1. Experimental outline

Before one starts an experiment, a detailed research outline must be developed, as suggested in the following:

1.1. Title

The title should be a concise heading but include information so the reader can tell what the research is to be.

1.2. Research objectives and justification

This describes why the research is to be conducted. If the research relates to specific horticultural crops, one may wish to give information about the monetary value of the crop, and potential financial benefit of the research.

1.3. Review of literature

Before preparing one's own outline of research methods and techniques, it is essential to review previous literature on the particular subject in order to benefit from observations in previous research as well as to prevent costly duplication of research efforts.

1.4. Methods and materials

Outline the methods and techniques to be employed in conducting the research. Include materials, equipment, and labor that will be required. If conducted in a glasshouse, or controlled environment

chambers, these facilities must be included.

1.5. Probable duration and cost

An estimate of the duration of the experiment along with the previous listing of materials, equipment, labor, glasshouse or controlled environment space and other costs such as computer time, etc. provides the basis for determining the potential cost of the research project. These data help in determining the source of supporting funds such as university, college, government, and outside grants.

2. Interpretation of research results, and conclusions

The conclusions must be based on specific research data. In interpretation of data, one must be aware of potential limitations of the experiment. Seldom is it possible to study a single factor in an experiment so one must be aware of potential interactions as one develops the experiment and interprets the results.

3. Some examples of research planning and interpretation

3.1 Randomization of plants and plots.

Some researchers assume that the environment and growing conditions are uniform throughout a glasshouse but this is not so. Because of variations of light and temperature in various locations of the glasshouse, plants and plots must be randomly located according to good statistical design. Even in the controlled environment room, only a relatively small area in the central part has uniform environment.

In field research, experiment design and plot layout are very critical because of potential variations in soil structure and drainage, natural fertility, and soil moisture. This is very important if one is studying the growth and flowering of various cultivars under field conditions.

If the research is a nutrition study, it is desirable to supplement the field research with allied experiments having plants in containers of a standard substrate with controlled nutrient and moisture supplies.

3.2. Effect of cultivar

Results obtained with 1 cultivar or species cannot be assumed to apply to all other species or cultivars of a particular species. Consider conducting the research on more than one species or cultivar.

An extremely important factor is the test plant. Cathey and Stuart (1961) found marked differences among 55 genera and species in response to the growth retardants Amo-1618, phosfon, and CCC.

A marked effect of cultivar on results of research on the

phytotoxicity of some paint volatiles to C h r y s a n t h e m u m m o r i f o l i u m was reported by Seeley (1979), who observed severe axillary bud abortion of 'Wild Honey' while 'Yellow Paragon' had none. 'Bright Golden Anne' and 'Yellow Mandalay' were intermediate in response. If the research had been conducted with only 'Wild Honey', conclusions would have been opposite to those with 'Yellow Paragon' as the test plant.

3.3. Growth studies with natural photoperiods

Many experiments on plant response to photoperiod and temperature have been conducted with natural photoperiods, but there must be an awareness of the effect of weather, especially close to the period of critical photoperiod.

For instance, flowers of E u p h o r b i a p u l c h e r r i m a initiate when the dark period is greater than 12½ hours at temperatures from 15 to 21°C, with some variation due to cultivar. At a latitude of 35°N, the critical photoperiod for poinsettia occurred in late September (Larson et al, 1978). Patronella (1976) observed that flower bud initiation of 'Annette Hegg Dark Red', 'Annette Hegg Diva', 'Annette Hegg Supreme', and 'Mikkel Super Rochford' grown with air temperatures of 15 to 17°C in glasshouses in Columbus, Ohio (latitude of 40°N) occurred between September 26 and 30 in 1975. Starting September 18, plants of each cultivar had been placed in long photoperiods and at 3 to 4 day intervals, some plants were moved to natural photoperiods until flowering.

There is a hazard to many experiments conducted with natural photoperiods. It must be recognized that rainy and cloudy weather naturally reduces the photoperiod and, if this occurs near the time of critical photoperiod, flower bud initiation occurs earlier than if the days were clear.

In Ithaca, New York, in 1977, there were 17 rainy and cloudy days and only 4 clear days between September 16 and October 6. Thus many of these days were short photoperiods for the poinsettia, and flowering occurred earlier than in other years.

In addition, in research on flowering of photoperiodically-sensitive plants, the effects on flower bud initiation must be differentiated from those on flower bud development. Often experiments have been conducted without definition of the effect of factors on these two stages of plant growth.

3.4. Effect of temperature on plant growth

Temperature is another factor that must be well controlled in experiments. It may be satisfactory in controlled environment rooms, but there the light intensity usually is not equivalent to that of a glasshouse.

In the glasshouse, temperatures fluctuate quite a bit even with

the most sophisticated controls. Temperature must be measured in close proximity to the plants, not at a sensing element a meter or so above the plants, and not shielded from the sun. Results of some research make it appear that plant tissue temperature may be more important than the ambient air temperature.

The interrelationship between the effect of temperatures in the dark period and the light period must be considered in relation to results obtained with constant temperatures during the 24-hour day.

3.5. Interaction of temperature and photoperiod

In studies with *Euphorbia pulcherrima*, Langhans and Miller (1960) found that as constant day and night glasshouse air temperatures increased from 10 to 27°C, shorter photoperiods were required for flowering. Also, the required number of short photoperiods increased.

Subsequently, with 'Barbara Ecke Supreme' poinsettia, Langhans and Larson (1960) observed similar interactions of photoperiod and temperature, as well as interactions between day and night temperature. With 4 temperatures (10,16,21, and 27°C) and 2 daylengths (natural and 9-hour), the warmer the day temperature with any 1 night temperature, the sooner the plants flowered in the glasshouse. With increasing night temperatures up to 21°C, the faster the crop matured. With 27°C, however, plants did not flower when grown with the natural daylength of Ithaca, New York, but did flower with a 9-hour photoperiod.

Larson and Langhans (1963) determined that for the poinsettia cultivar, Barbara Ecke Supreme, the critical photoperiod for flower bud initiation varied with temperature in the glasshouse. At 18 and 21°C, the critical photoperiod was 12 1/2 to 12 3/4 hours, whereas at 16°C, the critical was 13 hours, which is approximately September 23 in Ithaca, New York (latitude 42°N).

These research reports emphasize the importance of recognizing the interaction of temperature and photoperiod as one conducts and interprets research on the growth and flowering of photoperiodically-responsive plants.

3.6. Antagonism of elements in plant nutrition

Often it is not easy to study a single element in plant nutrition research because of the potential effect of one element on another. In research on magnesium nutrition of poinsettia, Cox and Seeley (1980) found that the amount of potassium (K) in a nutrient solution had a very important effect on the expression of magnesium (Mg) deficiency symptoms when the supply of magnesium was low.

With 235 parts per million (ppm) of K and 5 ppm of Mg, no deficiency symptoms appeared. But with 420 ppm of K and 5 ppm of Mg, deficiency symptoms appeared on lower leaves, indicating a decrease of Mg in the plant by the higher level of K. This was confirmed by

tissue analyses. Thus in conducting and interpreting nutrition research, it is essential that the influence of concentration of one element upon the activity of another element be recognized.

3.7. Factors causing foliage injury

Often research is conducted to determine the specific cause of a problem so proper alternate cultural practices can be developed.

Stuart (1949) and Seeley (1949) described a leaf burn or leaf scorch of *Lilium longiflorum* 'Croft', which was a physiological disorder causing death of cells at the apex of a leaf resulting in a dark brown necrotic tip, or in some cases, semi-circular areas along the margin of the leaf.

It was found that, in commercial production of Easter lilies, the leaf burn problem could be prevented by using a root medium with a relatively low level of phosphorus (very little superphosphate), high pH and adequate calcium from ground limestone, and a steady supply of nitrogen by fertilization with calcium nitrate and potassium nitrate. However, the basic cause of the trouble was unknown.

About 20 years later, Conover and Poole (1971) reported the induction of foliar necrosis of several foliage plants by fluoride from several sources such as single superphosphate and German peat moss, both of which contained fluoride, as well as irrigation water which sometimes contained fluoride. Shortly thereafter, Marousky and Woltz (1975) showed that the leaf scorch of Easter lily was the result of too high a concentration of fluoride in the plant. With this research information, it was possible to develop recommendations to prevent leaf scorch in commercial production.

A similar scenario occurred in the case of chlorosis, leaf cupping, leaf burn, and loss of lower leaves of poinsettia. The basic cause was not known until the research report of Jungk et al (1970). The physiological disorder was due to molybdenum deficiency. With this knowledge, recommendations were developed easily to eliminate the problem in commercial poinsettia production.

4. Summary

Although there are many kinds of research including field, glasshouse, controlled environment chamber, and laboratory, these few examples emphasize the need for careful planning, and honest interpretation based on properly accumulated data.

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THE INFLUENCE OF GENOTYPE, TERMINALITY AND AUXIN FORMULATION ON THE ROOTING OF LEUCOSPERMUM CUTTINGS.

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Abstract

Terminal and subterminal semi-hardwood cuttings of six clones of Leucospermum cordifolium and some Leucospermum hybrids were rooted in Autumn, with and without bottom heat and mist irrigation, at 23,0 ± 0,8 °C and 12,7 ± 2,0 °C respectively. IBA in four formulations was applied as a basal dip at concentrations of 5 g ℓ^{-1} solution or 10 g kg^{-1} powder. Genotype and temperature influenced rooting percentage the strongest and interacted strongly with each other as well. Rooting temperature also interacted with the other two factors. Terminal cuttings rooted consistently better at the higher but not at the lower temperature. Auxins had little effect on rooting percentages at the higher, but influenced rooting strongly at the lower temperature. At the lower temperature 10 g kg^{-1} IBA powder increased mean rooting percentage significantly above 5 g ℓ^{-1} IBA in 50% ethanol alone or combined with NAA and ethephon. It was concluded that a knowledge of the temperature requirements of individual Leucospermum cultivars is required when using unheated rooting frames. Economizing applications are discussed.

1. Introduction

The develpoment of commercial cultivars of Proteaceae of South African origin is a relatively new, but vigorously growing international industry (Brits, 1985). Many of the new cultivars originate from Leucospermum (pincushion) species and their hybrids (Matthews & Carter, 1983). These cultivars are propagated almost exclusively from stem cuttings. A number of factors influencing the rooting of Leucospermum cuttings have been investigated, including cutting maturity and length, collection time, composition of rooting medium and auxin concentration (Rousseau, 1967; Vogts & Rosseau, 1976; Jacobs and Steenkamp, 1976a,b). NAA and ethephon promoted the rooting of Protea cuttings (Rousseau 1967; Criley & Parvin, 1978). IBA in combination with NAA led to higher rooting percentages in Persoonia (Proteaceae) cuttings than IBA alone (Ellyard, 1982). The use of terminal Leucospermum cuttings is recommended by Jacobs & Steenkamp (1976b).

Although the optimum temperature for the rooting of cuttings is generally accepted to be in the range of 20 to 25 °C (Ellyard, 1982), little quantitative evidence is available to substantiate this in the case of Leucospermum. Published information

[illegible] the interaction of factors, is lacking. Two present problems of commercial *Leucospermum* cutting propagation are a) the poor rooting of certain species and clones, and b) the comparatively poor economics of rooting cuttings in heated mist beds. The present work was undertaken to study some of these aspects.

2. Materials and methods

Six *Leucospermum* clones cultivated at Tygerhoek Experimental Farm near Riviersonderend, Cape Province, were used in this experiment:
(i) *L. cordifolium* "Vlam"; (ii) *L. linearе* X *L. tottum* "Totsiens"; (iii) *L. cordifolium* X *L. tottum* "Caroline"; (iv) *L. cordifolium* X *L. tottum* "T 74 10 11"; (v) *L. conocarpodendron* X *L. cuneiforme* "T 75 11 24"; and (vi) *L. cordifolium* "Gold Dust". Vlam, Caroline and Gold Dust are commercially grown cultivars. Terminal shoot sections, 300 mm long, of the current season's growth were cut and divided into halves on April 15, 1977. The resulting terminal and subterminal cuttings were stripped of leaves on their basal half, taking care not to damage the phloem excessively. A fresh cut was made at the base of each cutting before dipping the basal 2 mm for three seconds in one of the following preparations: (i) control, 50% ethanol; (ii) 50% ethanol followed by a dip in "benkap 10% fungicidal powder mixed with IBA at 10 g kg^{-1} (1%); (iii) 5 g ℓ^{-1} IBA in 50% ethanol; (iv) 5 g ℓ^{-1} IBA plus 0,5 g ℓ^{-1} NAA plus 0,5 g ℓ^{-1} ethephon in 50% ethanol (cocktail). All cuttings dipped in liquid were subsequently dipped in "benkap 10%", consisting of talc with benomyl at 5% a.i. and kaptab at 5% a.i. concentration.

Cuttings were planted in a mixture of 50% (on volume basis) of pelletised polystyrene foam and peat moss ($pH_{(H_2O)}$ of 5,2) in plastic propagating trays. These were placed on a sand bed in well ventilated but wind-protected lath house structures under 50% shade. In one lath house bottom heat was provided at 23,0 ± 0,8 °C, by an electric cable buried in the sand bed; mist irrigation was supplied by misting nozzles, at 30 ℓ/h for 20 s of every 10 minutes between 08 h00 and 16 h00. In another lath house an unheated sand bed was used; the average rooting temperature was measured at 12,7 ± 2,0 °C. Cuttings in the latter bed received irrigation via microjets, at 30 ℓ/h for four minutes every 2 h during the same daily period as applied in the mist bed, thus equalling the amount of irrigation.

Treatments (clones, cutting terminality, auxin formulation) were completely randomised within the two rooting beds (two temperatures). Two replications of six cuttings per treatment were used. Propagating trays were rerandomised on a daily basis. Cuttings were scored for adventitious root development at 6 and 12 weeks. Scores were based on an ordered rooting scale (Snedecor & Cochran, 1967) of 2 = transplantable (Jacobs & Steenkamp, 1976a); 1 = roots present but not transplantable; 0 = no roots. The total

of 6 week and 12 week scores were expressed as a percentage of the potential maximum score and transformed to arcsin percentage values (Snedecor & Cochran, 1967). The results were subjected to analysis of variance and to statistical analysis by the LSD method.

3. Results and discussion

The difference of 10,3 °C between ambient and artificial temperature treatment resulted in a large average difference of 31,1% in rooting response (Table 1). Root formation was observed to be very slow at low temperature.

Clonal differences had an extreme effect on rooting percentage and interacted strongly with temperature (Table 1). The latitude in rooting response was 45% at 23,0 °C and 38,4% at 12,7 °C.
Cv. Gold Dust rooted well at both high and low temperature but cv. Caroline only at high temperature.

Table 1 – Effect of two temperatures on mean percentage rooting (arcsin) of six *Leucospermum* clones

	% Rooting							
Temperature	Vlam	Tot-siens	Carol-ine	T 74 10 11	T 75 11 24	Gold Dust	LSD P<,05	Mean
23,0 °C	46,9	71,9	74,8	65,8	29,8	60,7	9,2	58,4
12,7 °C	21,5	36,4	29,6	13,2	12,3	50,7	4,7	27,3

Terminal cuttings rooted moderately and consistently better at 23,0 °C, by 16,9% on average, than subterminal cuttings (Figure 1). At the lower temperature, however, subterminal cuttings rooted better in cvs. Totsiens, Caroline and T 74 10 11, realizing a slightly higher mean rooting percentage (3,4%) in subterminal than in terminal cuttings. The results suggest that subterminal cuttings root reasonably well. However, in large-scale commercial operations the significant interactions of genotype and terminality should be taken into account. Genotype also interacted with cutting terminality in commercially propagated *Grevillea* (Groesbeck & Rauch, 1985).

At 23 °C the applications of auxins had very little effect (3,5% average improvement) on rooting percentage (Figure 2). At 12,7 °C, however, auxin treated cuttings rooted much better than controls.

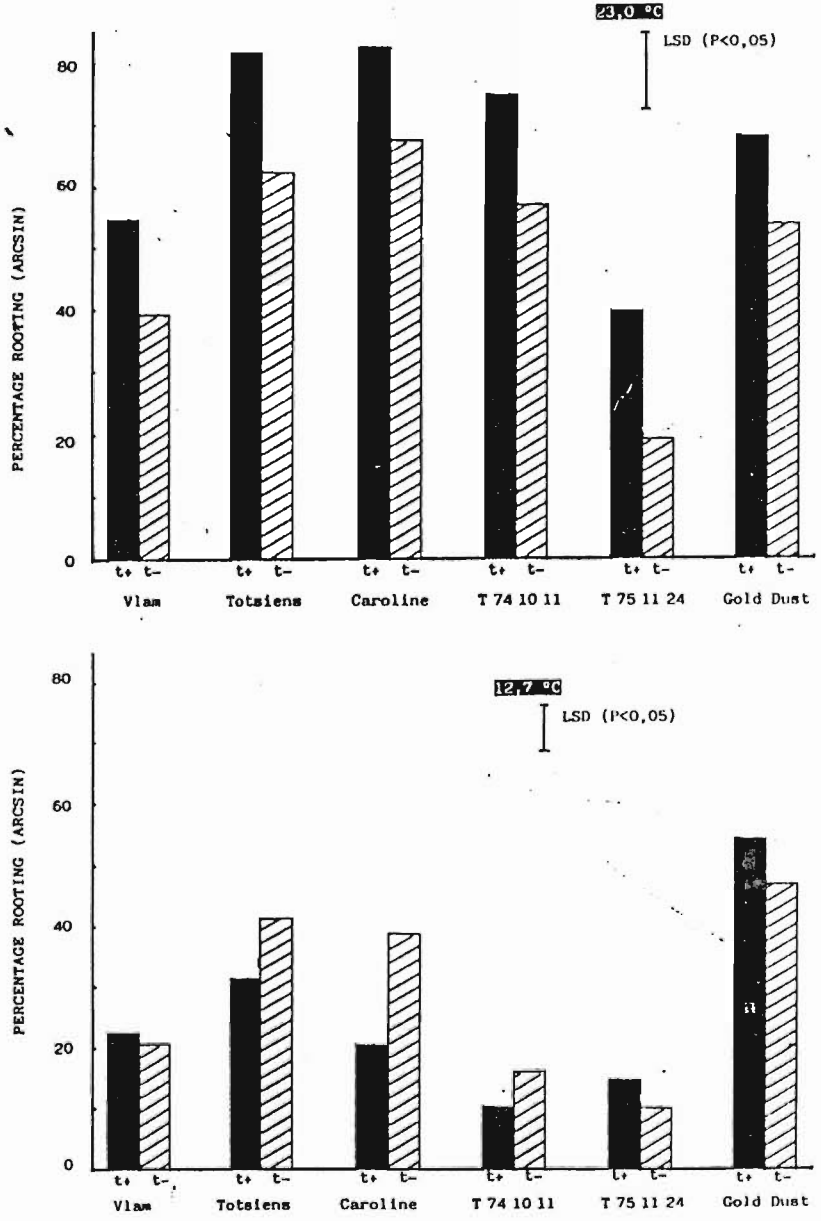

Figure 1 - Interactions of genotype (clones) X cutting type (t+ = terminal, t- = subterminal) at two temperatures.

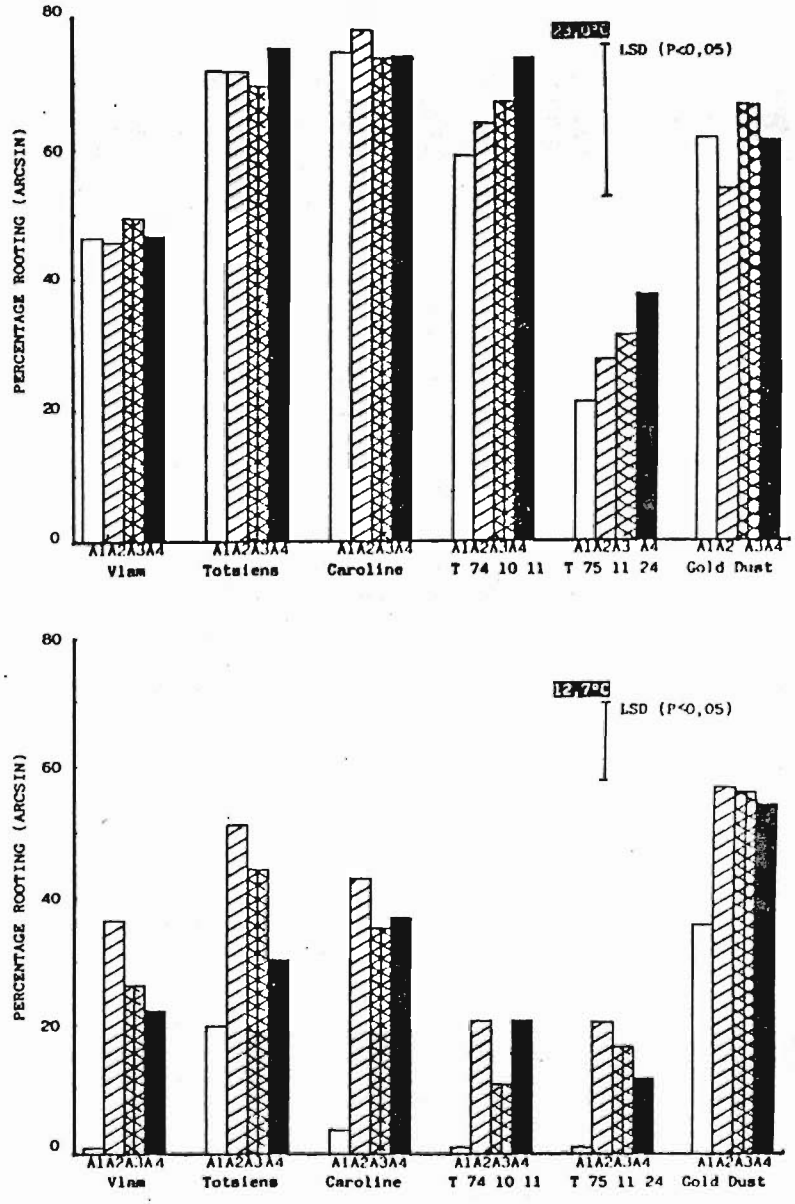

Figure 2 - Interactions of genotype (clones) X auxin formulation at two temperatures. A1 = control, A2 = 1% IBA powder, A3 = 0,5% IBA solution, A4 = 0,5% IBA + 0,05% NAA + 0,05% ethephon solution.

Table 2 - **Percentage germination of *Protea compacta* achenes which were imbibed for 24 h in 200 mg ℓ^{-1} gibberellic acid, benzyladenine, promalin (GA_4/GA_7 plus benzyladenine), or a combination of gibberellic acid and benzyladenine, respectively, before being incubated at 10° or 20°C.**

Treatment	Incubation temperature	
	10°C	20°C
Control	28±10	2±2
Promalin (GA_4/GA_7+benzyladenine)	70±3	40±6
Benzyladenine	8±5	0
Gibberellic acid	22±6	0
Benzyladenine+gibberellic acid	14±9	4±2

The results presented in Table 2 clearly shows that an incubation temperature above 10°C is detrimental to the germination of *Protea compacta* achenes. Promalin which contains a mixture of GA_4/GA_7 and benzyladenine increased germination significantly. Even at 20°C which is detrimental to germination promalin was still effective. Neither benzyladenine, gibberellic acid nor a combination of these two hormones could substitute for promalin. From the available evidence it would appear as if the cytokinin alone could not stimulate germination. This can apparently only be done by GA_4 and GA_7 as gibberellic acid was also ineffective. From these results it would seem as if the endogenous cytokinin changes which occurred in the achenes during incubation were related to the resumption of growth and not to the breaking of dormancy. GA_4 and GA_7 are apparently concerned with the breaking of dormancy in pepper seeds and not with an increase in cell division responsible for radicle elongation (Watkins and Cantliffe, 1983). This role is probably the most likely one to be attributed to the endogenous cytokinins in achenes of *Protea compacta*. The 60 day stratification treatment and the promalin treatment both improved germination to the same extent, whereas benzyladenine alone was ineffective. This suggests that it is the gibberellin levels that are enhanced as a result of stratification and indicates that the endogenous levels of these hormones require investigation.

Acknowledgements

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ESTABLISHING PROTEA LEUCOSPERMUM AND SERRURIA IN VITRO*

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Abstract

Shoot parts of *Protea cynaroides*, *Leucospermum cordifolium* x *L. lineare* hybrid and *Serruria florida* were successfully established *in vitro*. Selection of explant material is very important to the successful establishment of Proteaceous plants *in vitro*. *P. cynaroides* shoots sprouting from the lignotuber were the best source for explants for this species. Shoots of *Leucospermum* and *P. compacta* x *P. neriifolia* which were too soft and hairy failed to grow.

Serruria grew well on AND, MS and WPM media. *Leucospermum* and *Protea cynaroides* were tried only on AND medium and grew well. Growth was best on paper bridges in Liquid media or on agar containing charcoal.

Buds of *Serruria* and *Leucospermum* resumed growth shortly after explanting. Buds of *Protea cynaroides* sprouted *in vitro* only if treated with GA.

Auxin was not needed and inhibited the successful establishment of cultures. BA was not shown to be essential for the establishment of the cultures but when used at 5 ppm caused proliferation of *Serruria* shoots.

1. Introduction

There are 3 main reasons for growing Proteaceous plants *in vitro*: rapid vegetative propagation, preventing spread of disease and insects by shipping clean plants, and the study of the unique nutritional requirements and growth physiology of these plants.

Complete methods for *in vitro* propagation have been worked out only for *Grevillea* (Gorst et al. 1978 and Ben-Jaacov and Dax 1981) and indeed these are the only Proteaceous plants at present being propagated commercially by tissue culture (George and Sherrington, 1984). Other research on tissue culture of Proteas has been carried out mainly by Van Staden, studying callus formation in seedlings of *Leucospermum* (Van Staden and Bornman, 1976) and callus and proteoid roots on seedlings of *Protea*

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neriifolia (Van Staden et al., 1981). Recently Seelye et al (1985) were successful in propagating *Telopea speciosissima* in vitro.

Rapid, in vitro vegetative propagation may be useful for the initial increase of newly developed clones of *Leucospermum*, *Serruria* and some other easy to root proteaceous plants. But, in some proteas, especially the difficult to root cultivars such as some *P. neriifolia* hybrids, this method seems to be indispensible.

Propagating and selling protea plants in the test tube may prevent the danger of spreading serious diseases and insects. New cultivars are being developed around the world and vegetatively propagated plants are shipped from one place to another. It seems that many of the protea diseases and certainly the insects are still restricted in their spread (Ben-Jaacov, 1985 and Knox-Davies et al., 1985). For these reasons limiting shipping of vegetatively propagated plants to those in the test tube would prevent spread of diseases and insects.

The use of tissue culture would help in better understanding the unique nutritional requirements of Proteas as well as the physiology of their growth pattern. The effect of different nutrient media, and the level of phosphorus required can be studied. The mechanism and growth substances responsible for dormancy and sprouting of buds in various species of Proteaceous plants can be evaluated.

2. Material and methods

2.1 Plant material

Explants were collected from plants commercially grown at Protea Heights in the Stellenbosch district, Rep. of South Africa. The climate is Mediterranean with cool wet winters and hot dry summers. The annual rainfall is 700 mm. The plants were neither irrigated nor fertilized. Insects and diseases were controlled by regular spraying program. Leaves were cut off leaving 1-2 mm petioles. The stems were cut into 6-7 cm long pieces and surface sterilized by constantly stirring them in 2% NaOCl solution containing a few drops of Agral (a commercial surfactant) for 20 minutes. After 3 successive rinses in sterile distilled water the stems were cut into segments with 1-2 buds each and placed on the media.

2.2 Media

Nutrient media used, Anderson (AND), Murashige and Skoog (MS) and Woody Plant Medium (WPM), were prepared according to Hartmann and Kester (1983) with the following changes in AND stock solutions to be: .0025 g/l $CuSO_4 .5H_2O$, .03 g/l KI and .0025g/l $CoCl_2 .6H_2O$. Vitamins levels used as in MS and WPM. The stock solutions were frozen in batches of 10 ml and used when needed. Three percent sucrose was added to the media. Growth regulators used were of analytical quality except "Promalin" which contains 19g/l of each 6-benzyladenine and GA_{4+7} and "ABG-3034 liquid concentrate" which contains 21 g/l 6-benzyladenine, both materials manufacured by Abbott Laboratories.

ing environment

[illegible] were incubated in a growth chamber lit for 12 hours photoperiod with cool white fluorescent tubes providing 60 u mol $S^{-1}m^{-2}$ [illegible] 400-700 nm) at plant height. The temperature was kept at 25 a[illegible]°C respectively for the dark and light hours.

3. Results and Discussion

3.1 *Serruria florida*

In a factorial experiment, the effect of explant support (agar solidified medium and filter paper bridges in liquid medium), three different nutrient media (AND, MS and WPM) and three levels of NAA and BA on the growth of Serruria stem explants were evaluated, using 10 test tubes with a 2-bud stem segment in each as an explant.

The stem segments used were 1.5 - 4 mm in diameter of partially lignified wood taken 10 - 15 cm below the shoot apex. Results were taken after 37 days in culture. Contamination ranged from 0-7 reps per treatment. The proportion of successfully established cultures is presented in Table 1. An evaluation of the growth of the best 3 reps are presented in Fig. 1 and 2 and in Table 2).

Growth appeared better on the liquid media. An interaction between the supporting systems and the nutrient media was observed. With the low nutrient media, AND and WPM, growth was moderate, both when agar or liquid media were used. But, when the high nutrient, MS medium was used growth was superior on the liquid media (Fig. 1 & 2, Table 1).

Growth regulators were used at the rate of 0, 0.1 and 0.2 ppm NAA and 0, 1 and 2 ppm BA. The addition of NAA even at low concentration or in combination with BA, suppressed bud break and shoot growth (Table 1 & 2). The addition of BA had no effect on the growth of the explants. When cultures started on 0, 1 or 2 ppm BA (Fig. 3) were transfered to MS liquid medium containing 5 ppm BA terminal growth ceased or died and side shoots started to grow (Fig. 4).

It may be concluded that buds on shoot segments placed on AND, MS or WPM liquid media sprouted. When transferred to MS medium with 5 ppm BA the sprouting shoots proliferated to form many side shoots.

3.2 *Leucospermum*

Only limited observations were made using "Red Sunset" (a natural hybrid between *L. cordifolium* and *L. linearе*) and on *L. cuneiforme*. "Red Sunset" is one of the main commercial cultivars grown at Protea Heights and *L. cuneiforme* represents a species with persistent rootstock (lignotuber).

With "Red Sunset", soft and semi-hard wood shoot segments were used. With *L. cuneiforme* only soft wood stems sprouting from the lignotuber were used. Softwood explants failed to grow. Semi-hard wood "Red Sunset" explants were established successfully and buds sprouted in a number of cases (Fig. 5).

The use of wood which was too soft, especially in very hairy

species of the Proteaceae (tried with P. compacta x P. neriifolia hybrids, Mimetes arboreus and Leucospermum) seems to be unsuccessful. Surface sterilization is difficult in addition to which it appears that the matted indumentum of crisped hairs (Rourke, 1972) caused explants to be covered by a layer of liquid. Reducing hairiness may improve the success of culturing.

The limited work done with this genus indicates that buds of semi-hard wood shoot segments of "Red Sunset" sprouted best when placed on liquid AND medium with 2 ppm BA (Fig. 5).

3.3 Protea cynaroides

Cultures of Protea cynaroides were started from seeds, shoot segments and tips of one-year old seedlings and from ten-year old matured plants growing at Protea Heights.

The fine hairs present on the seeds were removed by rubbing them off (Van Staden et al., 1981) then the seeds were rinsed for 10 seconds in 75% ethanol and stirred for 20 min. in 3.5% NaOCl solution, with a few drops of Agral, followed by 3 successive rinses in sterile distilled water. The seeds were placed on AND liquid medium supported by paper bridges and incubated in growth chamber at light and dark temperatures of 25° and 10° respectively for 12/12 hrs.

Only 5% of the seeds sterilized germinated successfully. The fact that Benic et al. (1983) were able to improve germination of P. compacta by hot water treatment and that NaOCl did not prevent latent contamination suggest that the seeds were internally contaminated.

The media were supplemented by 0, 1, 5 and 10 ppm BA. In the absence of BA normal seedlings did develop, although growth was very slow. With 1 and 5 ppm BA normal shoots developed but without roots. When the medium was supplemented with 10 ppm BA the roots did not grow as with the 1 & 5 ppm BA. The shoots, however, developed into a unique structure. The area where the coltyledones were attached to the stem was much enlarged and many side shoots proliferated at the axis of the cotyledones (Fig. 12).

One-year old P. cynaroides seedlings grown in the growth chamber were used for a preliminary factorial experiment, examining the effect of Promalin spray on the mother plant and the subsequent growth of terminal shoot harvested from these plants, on different media in culture. The 10 - 15 cm tall plants were cut back to a height of 5 cm and sprayed once a week, for 6 weeks with 0.1% promalin to which a few drops of Agral were added. Two months after the last spraying, when the shoots were harvested the sprayed plants had many more sprouting shoots than the control plants.

The terminal shoots harvested were placed on AND medium; liquid supported by paper bridges, 0.6% agar and 0.6% agar with 2.5% activated wood charcoal. The factorial experiment included 3 levels of BA; 1, 10 and 100 ppm and 3 levels of NAA 0.3, 3 and 30 ppm. All explants placed on highest levels of BA and NAA died. Plants survived better at the lowest level of NAA, (0.3 ppm) than at the intermediate level (3ppm). There was no difference between 1 and 10 ppm of BA.

Considering the 3 support media, plants looked best on agar medium containing activated charcoal, second on the liquid medium, and poorest on the agar medium (Fig. 6). No difference was noted between terminal shoots taken from promalin treated plants and the control. All the explants, even those on the agar with the activated charcoal, ceased to grow despite an increase in leaf size and healthy appearance.

Experiments with plant material harvested from 10-year old, matured plants growing at Protea Heights fall into two categories: experiments started in August and November 1984 using the current year's growth of unpruned plants, and experiments started from January to April 1985 using shoots sprouted from lignotuber of plants pruned to ground level in November 1984.

Two experiments were done with plant material harvested from the unpruned plants. The first experiment started in August 1984 using one bud, one cm long shoot segments. The medium used was ½ MS with 0.6% agar with a factorial combination of 0, 1 and 1 ppm NAA and Benzyladenosine- riboside. A callus was produced by many of the explants, especially in the high NAA treatments, but none of the 90 buds cultured sprouted up to the termination of the experiment six months later.

The second experiment started in November 1984 using resting terminal buds which were either placed directly, unexposed on the media or after most of the protecting bud scales were removed. The medium used was AND in factorial combination of normal and $^1/_{10}$ level of phosphorus in liquid and semisolid forms, and with 0 and 0.2 ppm NAA in combination with 0 and 2 ppm 2 ip, .1 ml/l and 1 ml/l promalin. The general observations in these experiments are as follows: a. Lowering the level of phosphorus usually reduced growth rate and in any event did not improve growth. b. Exposed buds, especially when placed on agar containing media, turned brown, and in particular the tissue immersed in the agar. Even when exposed buds stayed green and alive for long they ceased to grow. c. The only good growth achieved in this experiment was that of the bud surrounding the unexposed buds placed on liquid media containing 0.1 ml/l Promalin (approximately 2 ppm BA and 2 ppm GA_{4+7}), with 0 or 0.2 ppm NAA (Fig. 7). We failed to subculture the side shoots developed.

Experiments with shoots sprouted from lignotubers. Previous experiments indicated that with P. cynaroides unlike Serruria florida and Leucospermum it is very difficult to force the buds on the the explant to sprout. Pinching the 10 cm sprout 2 weeks before explanting enhanced sprouting of buds in the culture but still the newly formed growth was temporary and ceased after the expansion of the first few leaves. The possibility of forcing buds to grow by GA treatment was tested.

Treating the explant with gibberellic acid is possible in several ways. There are conflicting reports regarding the destruction of GA by high temperature. Abdel-Rahman et al. (1981) indicated that GA_3 is decomposed at temperature above 50°C. Still Goussard (1984) obtained significant effect of GA_3 on Vitis even though the GA he used was autoclaved with the media. There are three ways of

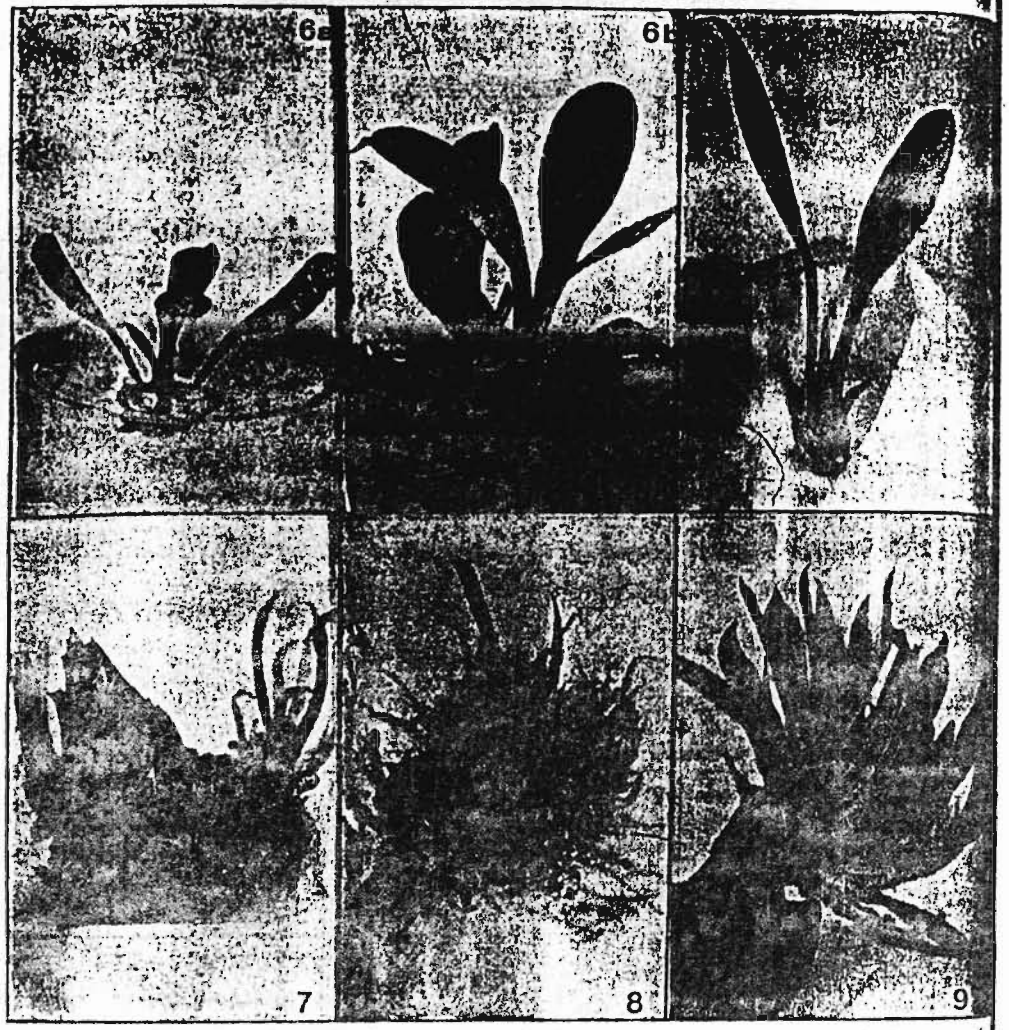

Figure 6 - Shoot terminal segments of P r o t e a c y n a r o i d e s grown for 60 days on AND media as affected by different supporting systems; a. agar, b. agar and activated charcoal, and c. liquid with paper bridges.

Figure 7 - Unexposed resting terminal bud cultured for 60 days on liquid AND medium containing 0.1 ml/l Promalin. Note the growth of the substanding buds.

Figure 8 - Sprouting bud of P r o t e a c y n a r o i d e s 90 days after placed on an AND liquid medium containing 0.05 ml/l filter sterlised promalin.

Figure 9 - Sprouting bud of P r o t e a c y n a r o i d e s 90 days after being dipped for 5 minutes in 5 ml/l filter sterlised promalin and cultured on AND liquid medium.

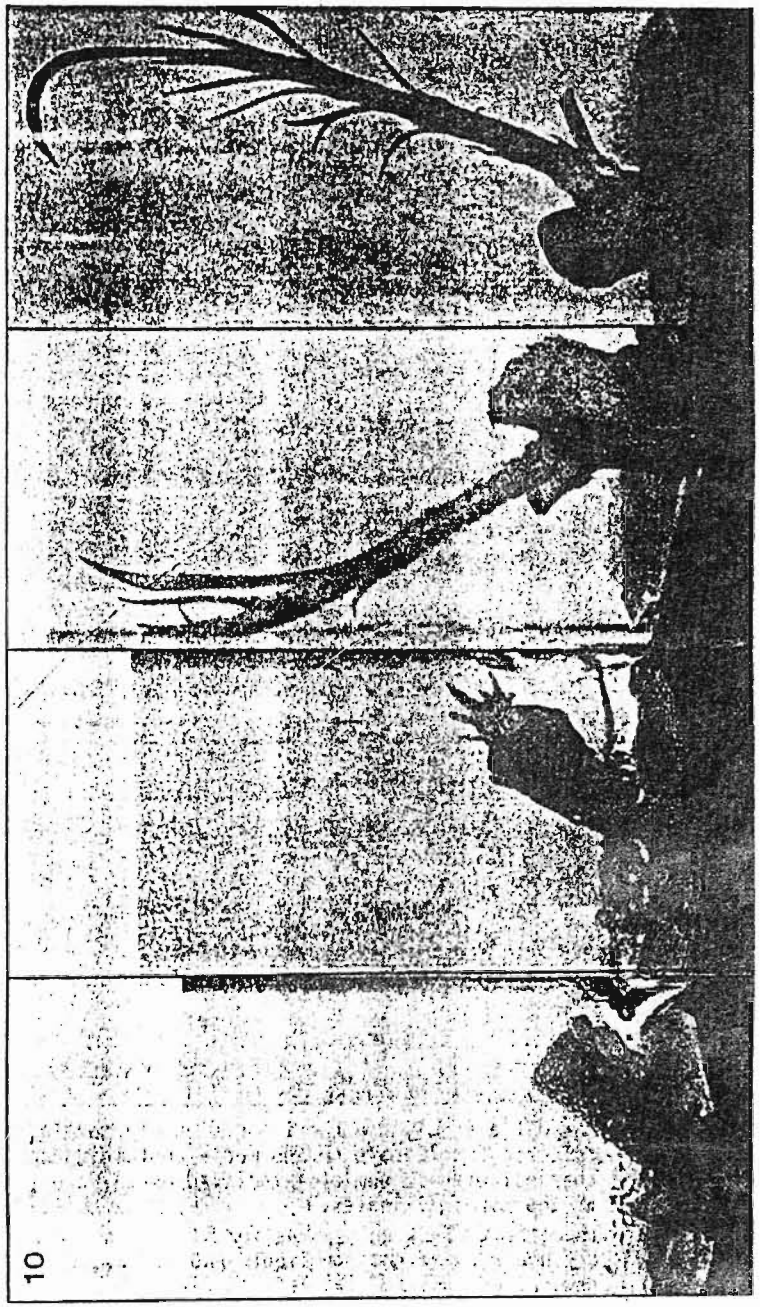

Figure 10.- The effect of autoclaved GA_3 on sprouting of P r o t e a c y n a r o i d e s cultured for 30 days on AND media containing left to right; 0, 1, 10, 50 ppm GA_3.

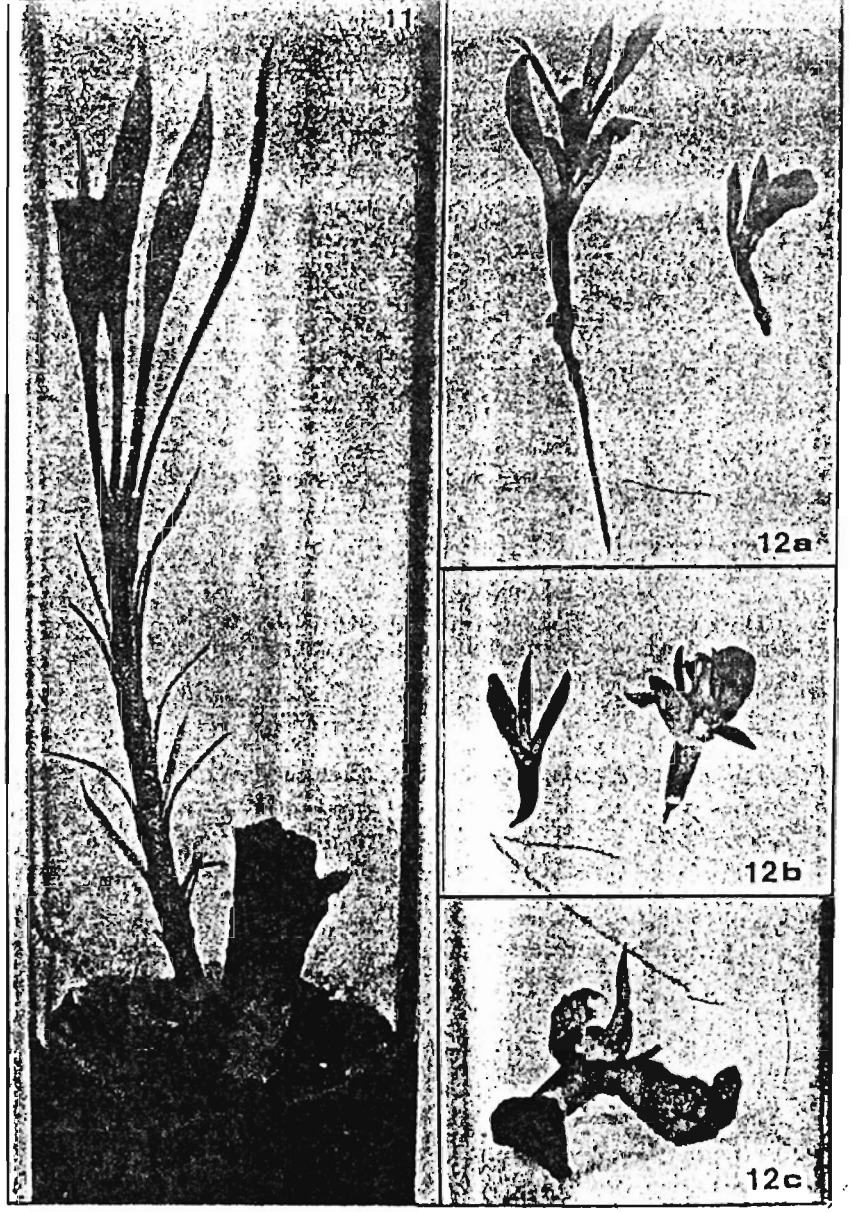

Figure 11 - *Protea cynaroides* newly developed shoot cultured for 70 days on AND media containing agar and charcoal with 10 ppm of autoclaved GA_3. Note the broadening of the terminal leaves.

Figure 12 - The effect of BA on germination of *Protea cynaroides* on liquid AND media. Photographed 100 days after sowing. (a) left to right 0 and 1 ppm BA (b) left to right 5 and 10 ppm BA (c) a close-up of germinating seed in medium containing 10 ppm BA.

Table 1 - The effect of supporting and nutrient media and levels of NAA and BA on proportion of successfully established *Serruria florida* explant (+ indicates $^2/_{10}$ or more success and - indicates $^2/_{10}$ or 0 successes).

		AND				MS				WPM			
	NAA (ppm)	BA (ppm) 0	1	2		BA (ppm) 0	1	2		BA (ppm) 0	1	2	
Liquid	0	-	+	-		+	+	+		+	+	-	
	.1	-	-	-		-	+	-		-	-	-	
	.2	-	-	-		-	-	-		-	-	-	
Agar	0	-	+	-		-	-	+		+	+	+	
	.1	-	-	-		-	-	-		-	-	-	
	.2	-	-	-		-	-	-		-	-	-	

Table 2 - The effect of NAA and BA on side shoot growth (1-5 scale, where 1 = bud is inactive, 2, 3, 4 & 5 are increasing shoot growth rates) of *Serruria florida* stem segments cultivated 5 weeks on liquid MS media (mean of 3 best reps).

	BA (ppm)		
NAA (ppm)	0	1	2
0	3.3	3.6	3.0
.1	2.3	2.6	2.0
.2	2.0	1.6	2.0

GERMINATION OF ACHENES OF *LEUCOSPERMUM CORDIFOLIUM*

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Abstract

Treatments for overcoming poor germination in *Leucospermum* were investigated. Studies on the imbibition of water by the fruits showed that water uptake is relatively rapid during the first 48 h of imbibition and seeds were fully imbibed within 72 h. Alternating temperatures of 10°C and 20°C and a constant temperature of 15°C gave the best germination results. Samples of "medium" weight (91-110 mg) achenes generally gave a higher percentage germination than samples of lighter or heavier achenes. Treatments which gave the most improved germination were soaking in GA_3 or "Promalin" (containing GA_4, GA_7 and benzyladenine). Ethrel and ethylene gas also improved germination in some seed samples. Preconditioning achenes in polyethylene glycol (PEG) solutions generally improved germination, but responses were not always consistent.

1. Introduction

Of all the South African species of Proteaceae those belonging to the genus *Leucospermum* confront both the researcher and horticulturist with the most serious problems with respect to germination. While most of these species are currently propagated vegetatively, breeding programmes require high rates of germination if they are to be successful. For these reasons methods of overcoming poor germination have been investigated and an understanding of the underlying reasons for low seed viability and seed dormancy in the genus is being sought.

Some preliminary studies done by Van Staden and Brown (1973) suggested that the outer and inner pericarp played a role in imposing dormancy as their removal increased germination. High oxygen tensions significantly increased germination of intact seed, suggesting that the covering structures exert their influence by acting as a barrier to oxygen diffusion to the embryos. Brits and Van Niekerk (1976) used hydrogen peroxide to improve the germination of seed of *Leucospermum cordifolium* and suggested that the increase in germination was related to the improved oxygen supply to the embryo.

As successful as these treatments are on many seed samples, other samples are frequently encountered which do not respond or respond only poorly, suggesting that other factors may be contributing to poor germination. The aim of this project therefore was to attempt to improve germination by investigating the effect of a range of seed treatments, most of which had not previously been applied to *Leucospermum*.

2. Materials and methods

The fruits of *Leucospermum cordifolium* (Salisb. ex Knight) Fourcade used in this study were collected from Protea Heights experimental farm, Stellenbosch, Cape. The fruits are one-seeded and termed achenes.

The embryos are enclosed by a pericarp consisting of two layers. The outer layer is thin and brittle and can easily be removed. The inner pericarp layer is hard and woody and is approximately 0.5 mm thick. While the inner pericarp shows no visible change upon imbibition, the outer layer becomes soft and gelatinous and apparently interferes with gaseous exchange to the embryo. Removal of the outer coat results in improved germination (Van Staden and Brown, 1973). In this study the outer coat was removed routinely once achenes had become imbibed. Achenes were germinated in petri dishes on Whatman No. 1 filter paper moistened with distilled water. Unless otherwise stated, achenes were incubated under alternating temperatures of 10°C for 8 h and 20°C for 16 h. Light (11 Wm^{-2}) was provided, using cool white fluorescent tubes, to correspond with the period of higher temperature. The splitting of the inner pericarp and the protrusion of the radicle was used as the criterion of germination. Unless otherwise stated, there were five replicates of ten achenes (i.e. 50 achenes) for each treatment and each trial was carried out three times. The results are given as mean percentages of these three trials.

3. Results and Discussion

In a preliminary experiment to investigate the effect of temperature on germination, samples of achenes were incubated at 10°C, 15°C, 20°C and alternating temperatures of 10°C for 8 h and 20°C for 16 h. The results in Table 1 show that the 15°C and 10°/20°C treatments gave the highest percentage germination. The latter temperature regime was therefore used in all subsequent experiments.

Table 1 - The effect of temperature on the germination of unsorted achenes of *Leucospermum cordifolium*. Figures represent means (± SE) of three trials of 50 achenes each.

Temperature (°C)	10	15	20	Alternating 10/20
Germination %	4±2	9±1	1±1	10±2

In a preliminary characterization of the achene sample in terms of individual achene mass, the mass of each of 100 achenes was determined. The results in Table 2 shows that 54% of the achenes fell into the category 91-100 mg; 20% in the category <91 mg; and 26% in the category >110 mg. Achenes in these categories were designated as "medium" weight, "light" or "heavy", respectively.

Table 2 - Characterization of achenes of *Leucospermum cordifolium* in terms of achene mass. Mean mass per achene = 91.6 mg.

Mass category (mg)	Number of achenes	Percentage per category
41 - 50	2	20% light
51 - 60	0	
61 - 70	2	
71 - 80	6	
81 - 90	10	
91 - 100	26	54% medium
101 - 110	28	
111 - 120	18	26% heavy
121 - 130	6	
131 - 140	2	
Total	100	

Achenes of each mass category were imbibed in distilled water and the change in mass monitored at regular intervals for 148 h. In all three mass categories water uptake was relatively rapid during the first 48 h with no further increase in mass after 72 h. The rate of water uptake and the final percentage increase in mass was significantly greater in the light achenes, when compared to medium and heavy achenes. This is possibly due to the fact that many of the light achenes contained immature and shrivelled embryos. Results for all achenes also suggest that the pericarp does not hinder water uptake by the achene.

In an investigation of the relationships between achene mass and germination, samples of achenes of each category were germinated under standard conditions. The results in Table 3 show that "medium" and "light" achenes gave the highest pericarp germination. This indicates that seed sorting treatments involving flotation (Van Staden and Brown 1973) are not necessarily a satisfactory means of eliminating non-germinable seeds.

Table 3 - The germination of samples of "light", "medium" and "heavy" achenes of *Leucospermum cordifolium* under alternating temperatures of 10°C for 8 h and 20°C for 16 h. Figures represent means (± SE) of three trials of 50 achenes each.

Mass Category	Light 41-90 mg	Medium 91-110 mg	Heavy 111-140 mg	Unsorted 91.6 mg
Germination (%)	8±1	9±2	4±1	10±2

PROSPECTS OF DELAYING FLOWERING TIME OF L E U C O S P E R M U M

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Summary

L e u c o s p e r m u m plants grow vegetatively during spring and summer. Reproductive development commences in autumn after shoot extension growth has terminated and the inflorescences develop during winter. The inflorescences open in spring. Secondary flower buds develop below the primary inflorescence. Floret differentiation in these buds has progressed to the stage where the perianth initials are visible. Further development of the secondary flower buds are inhibited by the primary inflorescence. Removal of the primary inflorescence causes secondary flower buds to develop thus delaying the flowering time.

Axillary buds below the secondary flower buds are completely inhibited. These buds can develop into inflorescences if they are released from correlative inhibition between April and the end of June. Factors related to the induced state for flower formation are discussed.

Introduction

Marketing prospects of non-European cut flowers to Europe lie essentially in the European winter months from November to March (Hörmann, 1978). The flowering time of L e u c o s p e r m u m c o r d i f o l i u m and hybrid clones of L e u c o s p e r m u m grown commercially is restricted to a short period during spring. In the southern hemisphere (South Africa) the L e u c o s p e r m u m cutflower crop thus comes too early (September/October) while in the northern hemisphere the crop comes too late (March/April) for the period of peak demand in Europe. In South Africa the overproduction of L e u c o s p e r m u m during September and October results in low prices on the Euopean market. Between November and March the supply of L e u c o s p e r m u m does not meet the demand.

This paper reviews the present knowledge of flower initiation and development in L e u c o s p e r m u m and the progress made in delaying flowering time. The first part of this paper reviews the growth and development of the inflorescence. Subsequent sections deal with the secondary flower buds and flower initiation.

1. Flower development

The genus L e u c o s p e r m u m (Proteaceae) with its 47 species is confined to Southern Africa (Rourke, 1972). They are

evergreen woody perennial plants and most species are erect shrubs or small trees (Rourke, 1972). Cut flowers are harvested mainly from L. cordifolium, L. patersonii L. lineare, L. conocarpodendron and L. vestitum growing under cultivation or in the wild. An increasing number of interspecies hybrids are grown commercially (such as hybrids between L. cordifolium, x L. lineare and L. cordifolium, L. conocarpodendron) as clonal selections propagated from cuttings (Jacobs, 1985).

The vegetative and reproductive growth of Leucospermum follow in sequence. The plants grow vegetatively during spring and summer. Individual shoots have strong apical dominance. Reproductive development commences in autumn after shoot extension growth has terminated and the flower heads develop during winter. The flowers open in spring (Jacobs 1980, 1983, Jacobs et al. 1979).

The growth and development of "Red Sunset" inflorescences can be divided into four stages viz. the pre-floret, floret initiation, floret differentiation and enlargement stages. The pre-floret phase is the initial growth of the bud and lasts until the first week in May. Growth is slow, the first bracts are formed without floret initials in the axils. These bracts finally make up the involucre covering the peduncle. The floret initiation phase is characterized by the appearance of the first floret initials in the bract axils of later bracts and lasts until the cessation of floret initiation during the third week of June. The drymass increase during this phase is slow. The floret differentiation phase is from the completion of the floret initiation to the near completion of organ differentiation of the basal florets by mid-August. The growth rate is slow at first but increases rapidly as organ differentiation advances. The enlargement phase is from near completion of organ differentiation in the basal florets to anthesis in early October. The growth rate is rapid during this phase (Napier, 1985).

The inflorescence is a capitulum arising from axillary buds situated distally on a shoot. They are borne solitary in spp. having large inflorescences (L. cordifolium, L. lineare, L. conocarpodendron) or in groups of up to 10 in spp. having small inflorescences (L. oleifolium, L. parile) (Rourke, 1972).

2. Secondary flower buds

The developing inflorescence correlatively inhibits other axillary buds from developing (Jacobs 1983, 1985). The degree of inhibition of the axillary buds depends on its position on the shoot. The first 6 to 10 axillary buds immediately below the developing inflorescence are only partially inhibited since they develop to ca. 5 mm in diameter. Floret differentiation in these buds has progressed to the stage where the perianth initials are visible. They are buds referred to as secondary flower buds. Buds lower down on the flowering shoot show no signs of development and are

apparently completely inhibited. When the primary inflorescence is removed one or more of the uppermost secondary flower buds resume development (Brits, 1977, Brits et al., 1983).

Removal of the primary inflorescence thus causes a secondary flower bud to develop which flowers later. Flowering time of cv. Golden Star can effectively be delayed until December by removal of the primary inflorescence during the first week of October (Jacobs et al., 1978). The developmental period of the secondary flower buds becomes shorter the later the primary inflorescence is removed due to the rising temperatures of spring and summer (Jacobs et al., 1979). The cv. Golden Star required ca. 920°C heat units above 5,8 base temperature to mature 90% of the secondary flower buds. These heat units accumulated over a period of 107 and 83 days respectively for disbudding dates of 5 August and 7 October respectively (Jacobs et al., 1979). Disbudding primary inflorescences too late (November) resulted in resumption of shoot growth since the secondary flower buds have aborted (Jacobs, 1980). The secondary flower buds subsequently abscised. Delaying the flowering time of Leucospermum by releasing the correlative inhibition of the secondary flower bud is therefore limited up to ca. mid October in cv. Golden Star. Secondary flower buds which reach anthesis during December are of a poorer quality (Jacobs, 1983). The dry weight is less and there are fewer styles than in primary inflorescences flowering in September/October. In addition the colour is paler. High temperature during flower development is possibly the cause. Shading during this period was not effective in restoring the quality of the flowers (Jacobs, 1983).

3. Flower initiation

3.1 Acquisition of the induced state

In Leucospermum cv. Red Sunset the induced state for flower initiation has been attained by the first half of April (Jacobs, 1983; Napier, 1985). This is indicated by the development of an inflorence when shoots are cut back to a completely inhibited axillary bud. Shoot growth occurred when shoots were cut back prior to this date. Flower initiation can only occur after cessation of shoot growth. Applying growth regulators (Indole acetic acid, Gibberellic acid, Ethephon; Benzyladenine, Abscisic acid and the growth retardant C C C) as a single spray did not advance or delay the onset of the induced state (Napier, 1985). Shading during the high light intensity period of summer reduced the percentage shoots forming an inflorescence. Long shoots are less responsive to inhibition at low light intensities than short shoots (Jacobs, 1983). Long days delay the onset of the induced state. Apparently flower initiation in Leucospermum takes place in response to high light intensities during the vegetative phase and in conjunction with short days.

3.2 Loss of the induced state

Leucospermum cv. Red Sunset remained induced for 2 to

3 months after which there was a gradual loss of the induced state. Gibberellic acid, ethephon and shade hastened the loss of the induced state while the growth regulators (Benzyladenine, Indole acetic acid, Abscisic acid and the growth retardant CCC) tested had no effect on the time of loss of the induced state (Napier, 1985).

Apparently shade and ethephon acted synergistically since the induced state can be overcome almost immediately by a combination of low light intensity and ethephon. It is therefore possible that the loss of the induced state is related to the low light intensity of winter (Napier, 1985).

Napier (1985) studied changes in carbohydrate levels in leaves and shoot of cv. Red Sunset plants in full sun and 80% shade during winter. Shading plants at the onset of the induced state caused a rapid decrease in leaf starch and to a lesser extent leaf and shoot sugar. Concurrently shoot starch increased to double that of the control plants grown in full sunlight. It therefore appears that the initial reaction of the plants to shade is to mobilize large amounts of carbohydrate reserve in the form of shoot starch. Whether the associated changes in leaf and shoot carbohydrates are the reason for the loss of the induced state is uncertain. It appears that the capacity to form flowers is lost when leaf carbohydrate levels are low in "Red Sunset" plants.

Flowering time in L e u c o s p e r m u m can also be delayed by cutting back shoots to an inhibited bud. This effect can be obtained until the end of June. Inflorescences developing from these inhibited buds will flower later than control shoots. A procedure worth testing is to cut back shoots and subsequently remove the developing inflorescence.

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IMPROVING STEM LENGTH AND FLOWER QUALITY OF *LEUCOSPERMUM* WITH GROWTH REGULATORS

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Abstract

Hybrids of *Leucospermum conocarpodendron* x *L. cordifolium* produce flowering stems which are too short to market. Treating plants with gibberellic acid stimulates shoot growth. Both internode length and number of internodes are increased.

Flower quality of *Leucospermum cordifolium* x *L. lineare* cv. Red Sunset was improved by benzyladenine treatment. Spraying plants during the latter half of March caused an increase in the number of florets per inflorescence and the dry weight of the inflorescence.

1. Introduction

Short flowering stems of *Leucospermum conocarpodendron* and clonal selections of *L. cordifolium* limit their value as commercial cut flowers. Promotion of shoot elongation with gibberellic acid (GA_3) has been well documented (Marth, Audia and Mitchell, 1956; Sachs, 1956; Gray, 1957). Part of this paper reports on extending of the shoots of a *L. conocarpodendron* x *L. cordifolium* hybrid with a spray application of GA_3.

Leucospermum flowers borne on long thick stems are of better quality than those on short thin stems (Jacobs and Minnaar, 1980; Jacobs, 1983). Benzyladenine (BA) increased the mass of carnation flowers and chrysanthemum inflorescences (Jeffcoat, 1977). We report on the improvement of inflorescence quality of *Leucospermum* cv. Red Sunset (a natural hybrid between *L. cordifolium* x *L. lineare*) by spray application of 6-benzylaminopurine (BAP).

2. Materials and Methods

The experiments were carried out in a commercial *Leucospermum* plantation propagated by cuttings and grown under dry land conditions on the farm Protea Heights in the Stellenbosch district, Republic of South Africa. The climate is Mediterranean with cool, wet winters and hot, dry summers. The annual rainfall is between 650 and 750 mm. The plants were spaced at 0.75 m in the row and 1.75 m between rows, clean cultivated and not fertilized.

Shoot elongation

Number of GA sprays - Experiment 1

Three-year old plants of *L. conocarpodendron* x *L. cordifolium* were pruned on 14/5. Pruning consisted of removal of all but 4-5 shoots, which were cut back to 20 cm. Plants were sprayed with a 1 000 mg/ℓ GA_3 solution prepared by dissolving Berelex tablets (active ingredients GA_3 1 g/10 g) in water and adding 1 drop/ℓ Agral as sticker. Plants were sprayed to drip-off with a hand-spray. Untreated plants were left as controls. All new shoots were allowed to develop. Since the plants were still in the induced state for flower formation on the date of pruning, inflorescences formed instead of shoots. These were removed by hand. Treatments were replicated 5 times with a single plant/replicate in a randomised block design.

Plants were sprayed on 15/5, 15/6, 15/7, 15/8, 15/9, 15/10, 15/11, 15/12 and 15/1. Treatment 1 received only one application on 15/5 and 15/6 and so on, up to treatment 9, which received nine applications on 15/5, 15/6, 15/7, 15/8, 15/9, 15/10, 15/11, 15/12 and 15/1. Untreated plants were left as controls. Shoot elongation was completed by die middle of March. All shoots were measured on 30 March. At the end of April representative shoots were selected from each plant and the following variables measured: internode length, length of the basal part of the shoot covered with scale leaves, shoot diameter at the third fully developed leaf from the distal end, the number of nodes/shoot, leaf area (10 representative leaves randomly selected/shoot), dry weight of the leaves and dry weight of the shoot (dried for 7 days at 90°C). Leaf damage caused by the GA_3 sprays was rated from 0 to 3, i.e. 0 for no damage and 3 for severe leaf discolouration and necroses.

Concentration GA_3 - Experiment 2

Similar plants to those used in Experiment 1 were pruned in mid-August as described in Experiment 1. Plants were sprayed at 3-weekly intervals on 12/9, 3/10, 24/10, 15/11 and 5/12. The GA_3 concentrations used were 250, 500, 750, 1 000, 1 250 and 1 500 mg/ℓ. Data collection was as in Experiment 1.

Flower quality

Improvement of flower quality - Experiment 3

Current season's shoots (35-45 cm long) of seven-year old Red Sunset plants were selected in Autumn after elongation growth had stopped. BAP solutions, prepared by autoclaving commercial promalin for 20 minutes at 1 atm, were applied to individual shoots with a paint brush. BAP (200 mg/ℓ) was applied once on 29/3, twice on 29/3 and 30/4, three times on 29/3, 30/4 and 30/5 or four times on 29/3, 30/4, 3/,5 and 30/6. Untreated shoots were left as control. Only the primary inflorescence was allowed to develop on each shoot.

Inflorescence dry weight (dried at 110°C for 3 days), shoot diameter and peduncle length (from the point of shoot attachment to the point where the flowerhead broadens out) were measured and the number of florets/inflorescence counted.

3. Results and Discussion

Shoot elongation

The effects of sequential GA_3 applications on stem quality are presented in Table 1. No increase in shoot length was obtained with up to 4 sprays due to the plants still being in the reproductive phase at the time when the chemical was applied. Shoot length of plants receiving 5 or more spray applications increased rapidly with increasing number of sprays. The GA_3 is thus effective only when the plants are in the vegetative phase and when conditions for shoot growth are favourable. The first application should thus be made not earlier than 15/9. The only noticeable effect of the GA_3 application before 15/9 was the stimulation of internode lengthening between the bracts at the base of the stem. Continuation of GA_3 application after 15/9 increased the internode length, the number of nodes produced and the dry weight of the shoot, but caused a reduction in the dry weight/cm of the shoot and the dry weight and area of individual leaves. Shoot diameter appeared to the unaffected by GA_3 applications. Similar and conflicting results have been found in other plants (Marth, Audia and Mitchell, 1956; De Hertogh and Blakely, 1972; Greene, 1983; Abdul and Said, 1984; Arteca, 1984). GA_3 at 1 000 mg/ℓ resulted in leaf damage during the vegetative phase.

The effects of different GA_3 concentrations are presented in Table 2. GA_3 at 750 mg/ℓ applied 5 times at three-weekly intervals appears to be the optimum for shoot elongation. GA_3 concentrations higher than 750 mg/ℓ did not result in increased shoot length due to the higher concentrations destroying the shoot tip. In addition, the node number decreased as a result of shoot tip abortion and the severity of leaf damage appeared to increase at concentrations higher than 750 mg/ℓ. Internode length, however, increased throughout the concentration range.

GA_3 application resulted in an increase in shoot dry weight and a decrease in shoot diameter, dry weight/cm shoot and individual leaf dry weight and area, whereas different GA_3 concentrations appear to have no effect on these parameters, the length of the basal shoot section covered with bracts was not affected by GA_3 as the basal section was already formed at the time of the first spray.

Flower Quality

Shoot diameter, dry weight of the inflorescence and length of the peduncle increased linearly with increased number of BAP applications (Table 3, Fig. 1). A single application of BAP on 29/3 greatly increased the number of florets. A second and third application caused a further but slight increase in the floret number, while a fourth application had no effect (Fig. 1). The increase in inflorescence dry weight by BAP agrees with work done on chrysanthemums (Jeffcoat, 1977). However, Jeffcoat (1977) recorded no increase in floret number of chrysanthemums after BAP application. BAP is thus effective in improving the

quality of *Leucospermum* flowers by increasing the inflorescence dry weight and the number of florets per inflorescence but also causes excessive and unwanted peduncle growth. For this reason, BAP should be applied as a single spray at the end of March.

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Table 1 - The effect of sequential applications of GA3 on shoot characteristics of a *L. conocarpodendron* x *L. cordifolium* hybrid

No. of applications	Shoot length (cm)	Length of shoot base covered with bracts (cm)	Stem dry weight (g)	Dry weight/ cm stem (g)	No of nodes
Control	23:47 ab	3.58 a	2.67 ab	0.43 a	33.30 a
1	18.79 a	4.61 a	1.56 a	0.35 b	21.24 b
2	21.94 ab	5.46 ab	2.34 ab	0.31 b	28.84 ab
3	22.04 ab	5.18 ab	2.81 ab	0.47 a	28.50 ab
4	26.21 bc	7.18 bd	3.05 ab	0.40 ab	32.50 a
5	32.40 c	10.74 c	4.13 abc	0.31 b	41.32 c
6	46.08 d	9.30 cd	5.98 bc	0.31 b	50.05 d
7	47.70 d	10.40 c	5.45 bc	0.21 c	46.62 cd
8	57.62 c	9.56 c	5.73 bc	0.20 c	50.70 d
9	57.97 e	9.38 c	7.23 c	0.20 c	53.44 d

Table 1/Cont.

No of applications	Node length (cm)	Avg. leaf area (cm^2)	Avg. leaf dry weight (g)	Leaf damage	Shoot diameter (cm)
Control	0.61 ac	12.45 a	0.23 a	0.00	6.54 ab
1	0.76 ab	11.84 a	0.25 ab	0.00	5.95 ac
2	0.87 bde	12.60 a	0.23 a	0.00	6.42 ab
3	0.65 ac	12.67 a	0.28 b	0.00	6.99 b
4	0.56 c	11.81 a	0.22 a	0.00	6.91 b
5	0.62 a	9.61 b	0.17 c	0.20	7.06 b
6	0.77 a	0.22 b	0.17 c	0.40	6.47 ab
7	0.83 bd	6.57 c	0.11 d	0.47	5.80 ac
8	0.97 de	7.40 bc	0.12 d	0.47	5.42 a
9	1.04 e	7.84 bc	0.11 d	0.40	5.69 ac

Values within a column not followed by the same letter differ significantly at the 5% level, Tukeys D-test.

Table 2 - The effect of different concentrations of GA3 on shoot characteristics of a *L. conocarpodendron* x *L. cordifolium* hybrid

Concentration (ppm)	Shoot length	Length of shoot base covered with bracts (cm)	Stem dry weight (g)	Dry weight/ cm stem (g)	No of Node	Node length (cm)
Control	19.83 a	3.44 a	1.79 a	0.45 a	27.36 a	0.53 a
250	35.55 bd	4.56 a	3.07 b	0.22 b	39.16 b	0.89 bc
500	31.93 b	5.08 a	2.74 ab	0.21 bc	34.30 ab	0.77 b
750	46.18 c	5.58 a	3.61 b	0.18 bc	41.16 b	0.89 bc
1 000	42.54 cd	4.70 a	3.35 b	0.18 bc	36.22 b	1.02 cd
1 250	39.03 bc	5.82 a	3.18 b	0.16 bc	31.02 ab	1.08 cd
1 500	41.29 cd	5.64 a	3.11 b	0.16 c	32.02 ab	1.12 d

Table 2/Cont.

Concentration (ppm)	Avg. leaf dry weight (g)	Avg. leaf area (cm^2)	Shoot diameter (mm)	Leaf damage
Control	0.23 a	12.01 a	6.63 a	0.07 a
250	0.13 b	9.55 b	7.78 b	0.33 ab
500	0.10 b	6.16 c	5.45 c	0.33 ab
750	0.11 b	8.00 bc	4.78 c	0.17 a
1 000	0.11 b	8.19 bc	4.81 c	0.53 ab
1 250	0.10 b	7.55 bc	4.78 c	0.83 b
1 500	0.11 b	8.84 b	4.62 c	0.80 b

Values within a column not followed by the same letter differ significantly at the 5% level, Tukeys D-test.

Table 3 - Effect of repeated applications of BAP on shoot diameter, inflorescence dry weight, floret number and peduncle length in *Leucospermum* cv. Red Sunset. Analysis of variance.

Source	F. ratio	Significance level
Inflorescence dry weight		
Number of applications		
Linear	8.2	0.01
Floret number		
Number of applications		
Linear	7.2	0.02
Quadratic	7.5	0.02
Peduncle length		
Number of applications		
Linear	12.6	0.00

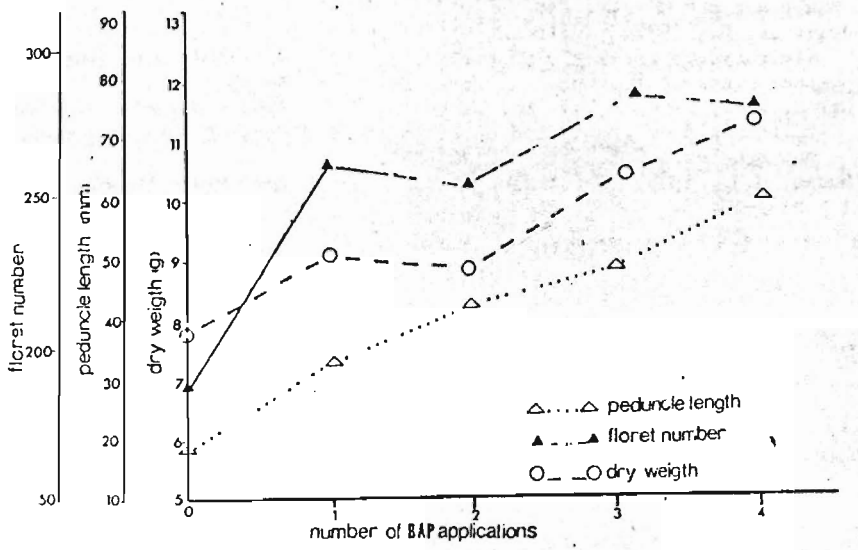

Fig. 1

Effect of repeated sprays with BAP on inflorescence dry weight, number of florets and peduncle length of *Leucospermum* cv. Red Sunset. Values are means of five replicates and five shoots per replicate.

SEED GERMINATION AND SEED SET IN SOUTHERN AFRICAN PROTEACEAE: ECOLOGICAL DETERMINANTS AND HORTICULTURAL PROBLEMS

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Summary

The domestication of the Proteaceae is a unique enterprise, in that large wild stocks still occur in the countries of origin. Many of the horticultural problems encountered in the domestication of the Proteaceae stem from ecological adaptations of the taxa to their natural environments. This allows a two tier approach to horticultural research: a predominantly physiological approach solving specific problems; and an ecological approach in which environmental and evolutionary constraints are studied. The combination of these two complementary approaches should reduce the research time needed to resolve specific horticultural problems. To this end an ecological data base for the southern African Proteaceae is being compiled. The application of the ecological approach is demonstrated with two examples: by reviewing the literature on seed germination in the southern African Proteaceae in an ecological context; and by comparing patterns of seed set in the different Proteaceous genera in an attempt to explain why such a low seed set is observed.

1. Introduction

The domestication of the major crop and animal species occurred in prehistoric times. By contrast, the domestication of the Proteaceae is still in its initial stages, having been begun this century (Parvin, 1984). Very large natural gene pools exist in both South Africa and Western Australia, from which selected species are being grown commercially. As a commercial industry, the Proteaceae only became important during the last 20 years (Davies, 1984). Proteas are currently being cultivated in Hawaii, California, Israel, New Zealand, Zimbabwe and the Transvaal (South Africa), in addition to those areas in which they originated (Australia and the Cape (South Africa))(Parvin, 1984).

Research into the horticultural problems encountered by the industry has to a considerable extent been purely physiological in approach. The dormancy of Proteaceae seeds (achenes botanically) was identified as a major problem

early in the development of the industry (Vogts, 1960), and has received much attention. It was only after 20 years of physiological research that ecologists discovered that many of the Proteaceae have seeds which are dispersed and stored by ants (Slingsby and Bond, 1981). Had the ecological and physiological research been undertaken in parallel, many apparent anomalies may have been resolved earlier. In this context the domestication of the Proteaceae offers an opportunity for physiologists, studying proximal influences (e.g. climatic factors influencing the physiology of flower bud initiation), and ecologists, studying ultimate influences (e.g. the pollinator phenology and long-term environmental factors which have influenced flowering times), to co-operate in their research approaches. Combined, more progress can be made than any research programme undertaken in isolation. This may become critical for an understanding of some of the industry's problems, such as the control of insects in the flower heads of P r o t e a or the manipulation of flowering time in L e u c o s p e r m u m.

In this paper we will first review the data on seed germination in the light of the ecological constraints which may have moulded the patterns evident. Secondly, utilizing ecological data currently being analysed (Rebelo and Rourke, unpublished data), we will review the observed patterns of seed set in the southern African Proteaceae, and highlight areas worthy of physiological study.

2. Germination

The major ecological dichotomy in Proteaceae seed biology is the storage strategy employed. The genera P r o t e a (most south-western Cape species), A u l a x and L e u c a d e n d r o n (in part) store their seeds in closed heads in the canopy (Kruger, 1983). The remaining genera, including some species in L e u c a d e n d r o n, have seeds with an elaiosome, which results in their being carried underground into ants' nests (Bond and Slingsby, 1983). Both strategies (serotiny and myrmecochory) not only protect the nutrient-rich seeds from fire, but also from avian and rodent predation in an otherwise nutrient-poor environment (Rebelo, unpublished data).

2.1. Serotiny

Among serotinous species, seeds are maintained in the infructescences on the plant until they are released by the death of the plant, usually as a result of fire (Brits 1980). Since seeds are released into a 'fire-sterilized', fertilized, unoccupied substratum, the only requirement theoretically missing for germination is water. Therefore inhibitors to germination are theoretically not required,

except to prevent germination in the unfavourable warm dry summer in the winter-rainfall region. This can theoretically be regulated by means of a low temperature requirement. Horn (1962) found no effect of low temperature on germination, but Brown and van Staden (1973a,b,c, 1975a) and Deall and Brown (1981) found that low temperature stratification enhanced germination of viable P. c o m p a c t a and P. m a g n i f i c a seeds. Seeds germinate rapidly and uniformly after rains (Brits, 1980), with about 80% of viable seeds germinating within eight weeks of the onset of suitable conditions (van Staden, 1966, Mitchell et al., 1985).

Seeds not germinating in the first rainy season subsequent to fire would probably be predated (Breytenbach, 1984). It is therefore unlikely that seeds should be long-lived once released. Membrane and chromatin damage has been observed in harvested seeds stored over relatively short periods of time (van Staden et al., 1975a,b, 1976), but published information on Proteaceae seed longevity is generally lacking.

Germination is infrequently observed in living infructescences, despite their filling up with water during the rainy season in many P r o t e a species (pers obs.). However, viable seeds germinate readily once released. While the lack of oxygen may inhibit germination in flooded infructescences, a possible factor inhibiting germination may be the inability of the seed to absorb water. Until the seed has become detached from the involucral receptacle it is apparently unable to absorb water through the radicle end. The trichomes on P r o t e a seed play an essential role in germination (Horn, 1962), possibly by orientating the radicle end to the soil surface for water uptake, in addition to protecting the seeds from heat damage on the soil surface, where temperatures may exceed 70'C in summer (Cowling, pers. comm.). Serotinous seeds germinate optimally when lying on the soil surface, and may fail to grow when sown at a depth of 20mm (Meynhardt, 1974). In serotinous seeds germination commences with the growth of the radicle, which anchors the seeds to the ground, in contrast to myrmecochorous seeds where germination commences with the seed coat splitting before radicle elongation occurs (Brits, 1980, Mitchell et al., 1985).

2.2. Myrmecochory

Factors influencing germination are more complex in the Proteaceae with nut-like seeds. Seeds ripen within two months of flowering (Vogts, 1982), and are immediately removed by ants to their nests, where parts of the outer pericarp are consumed (Bond and Slingsby, 1983, 1984a,b). The outer pericarp is not eaten outside the nest presumably

in order to prevent other ants from stealing the seed - implying that the time required to remove the elaiosome exceeds that of carrying the seed to the nest. The removal of the pale, fleshy outer pericarp (which, in stored seeds, becomes papery with age) significantly enhances germination possibly by allowing oxygen to reach the seed unimpeded (van Staden and Brown, 1973b).

Germination under mature vegetation in a nutrient-poor environment would not favour establishment of young plants, because the low dispersal distances inherent in myrmecochory would result in competition between seedlings and adults (Bond and Slingsby, 1983); and, because of the high risk of seedling predation (Breytenbach, 1984), all of which are considered as factors influencing the evolution of myrmecochory (Breytenbach, 1984, Milewski and Bond, 1982). Seedlings apparently only appear after fire (Bond and Slingsby, 1983), with seeds germinating under optimal growing conditions - in cleared, 'fertilized' soils after fire.

Factors synchronizing seed germination to the immediate post fire period have been elucidated by Brits (1980). These include temperature fluctuations in devegetated soil exposed to sunlight and, possibly, sterilization of the soil surface by fire. Two other factors possibly also play a role: the improvement of the availablity of oxygen and especially of the oxygen to carbon dioxide ratio in ants nests in the post fire environment, and the drop in pH with the likely leaching of formic acid from destroyed ants nests, which would be coupled with the first rains. Both increased oxygen concentration and acid treatment have been shown to increase seed germination in *Leucospermum* (van Staden and Brown, 1973a, Brits and van Niekerk, 1976). However, these experiments have used short term exposure to strong acids, and the effect of long-term exposure to weak acid is unkown. Brits (pers. comm.) has shown that *Leucospermum* seeds germinate in cycles parallelling cooler periods during which cold fronts brought rain. The search for an inhibitor which may be progressively leached out of seeds, which dominated the early Proteaceae seed research (van Staden and Brown, 1972, van Staden and Brown, 1977), was the result of ignorance concerning heathland seed biology, in which germination is distinctly linked to short periods immediately following fire in the wild.

The depth to which seeds are buried by ants is unkown, but 20mm is the deepest recommended sowing depth for *Leucospermum* seeds (Meynhardt, 1974). It is not known for how long seeds of myrmecochorous species can survive in ant nests, but this period may exceed 15 years (Rourke, 1976). Data on fire intervals in nutrient-poor environments suggest a natural fire frequency of once in six to 40 years (Kruger, 1983), suggesting that seeds

should have longevities in this range. Recent evidence indicates that ants secrete powerful fungicides which inhibit pollen germination (Beattie et al., 1984). The effects of these chemicals on seed longevity, seed germination or seedling survival are unknown. In addition, data on ant predation on stored seeds seeds is required to fully understand myrmecochorous seed biology.

In contrast to canopy stored seeds, myrmecochorous seeds are relatively safe from predation - unless the ants themselves are major predators - because they are stored underground (Bond and Slingsby, 1984a,b). The storage of myrmecochorous seeds for several fire cycles is thus theoretically possible. Consequently, seed germination may appear low (Brits, 1980). Seeds predestined to survive for longer periods should theoretically be larger and have a thicker testa than seeds that may be expected to germinate after the next fire. Conflicting results relating to the relative short-term germination success of plump-dense verse small-light seeds (van Staden and Brown, 1973a, Brown and van Staden, 1985) may relate to long-term/short-term strategies of seed longlevity. No studies to date have attempted to compare the proportion of dense-plump to small-light seeds in similar habitats of different ages, and relate these to soil nutrient status and probability of a fire in the immediate future.

2.3. Other seed storage strategies

There are two further categories of seeds found in the southern African Proteaceae, both confined to the genus *Leucadendron*, which require mention:

2.3.1. Nuts of *Leucadendron* subsection Nucifera

These very large nut-like seeds have no elaiosome and are apparently dropped into the surface litter. In some instances they may lay in the litter for long periods, but in *L. burchellii* they are extensively predated by rodents (pers. obs). This suggests that they may be cached underground by rodents, with surviving seeds lying dormant until the following fire. It is unlikely that any seeds lying on the soil surface would survive the heat generated by the fire. We may therefore expect these seeds to approach those of the myrmecochorous species in their germination behaviour.

Extensive research into germination of *L. daphnoides* has been undertaken (Brown and van Staden, 1973a,b,c, 1975b, van Staden and Brown, 1973a). Germination was increased by 600% by high oxygen concentrations, 100% by scarification, and 50% by chilling, which suggests that the seed coat may play a role in dormancy. In pattern of

improved germination, therefore, the nut-like seeds resemble myrmecochorous seeds, although the response is greater. Due to this marked response, nut-like seeds resemble serotinous species in their germination rate under high oxygen concentrations, but under 'normal' conditions behave like myrmecochorous seeds. Until more is known about the dispersal and storage mechanisms in nut-like seeds, it is difficult to identify the factors which may influence germination. Two questions, however, deserve attention: Why are nut-like seeds so large?, and, In a nutrient-poor environment, why rely on a seed predator as a dispersal agent?

2.3.2. The soft obovoid achenes of L e u c a d e n d r o n subsection Villosa and the triangulate winged seeds of L. subsection Ventricosa

Seeds in these categories have no elaiosome and are not stored in the canopy, but are liberated within five months of flowering and presumably lie in the litter layer (Rebelo and Rourke, unpublished data). These seeds also germinate after fire and are therefore expected to display many of the features of myrmecochorous and nut-like seeds. However, these seeds apparently have thin coats, more in line with those of the serotinous L e u c a d e n d r o n species. No research has yet been undertaken on the germination or ecology of these seeds.

2.4. Germination during interfire intervals

It is surprising that so few Proteaceae which inhabit sandy habitats near the coast have seeds which germinate readily between fires in constantly disturbed areas, where conditions appear suitable for seedling recruitment in mature vegetation. Interfire recruitment has been observed among some species of S e r r u r i a (pers. obs). The interfire germination of Proteaceae seeds in disturbed areas may be relatively common in the Sand Plain Fynbos (sensu Moll et al., 1984), where the relatively drab or small flowered Proteaceae have not attracted much horticultural or ecological attention.

3. Seed set

The low seed set evident in many of the Proteaceae poses a problem for breeding programmes with some genera. This is especially evident in hybridization experiments for the production of new horticultural strains (Vogts, 1960, Brits, 1984).

There are three major sets of theories explaining the low seed set observed in many plant taxa (Bawa and Webb,

1984). The 'pollination limitation hypothesis' subsumes two distinct hypotheses: low seed set is due to a shortage of pollinators, or, is due to the inadequate transfer of compatible pollen. The 'resource limitation hypothesis' suggests that resultant seed set may be due to spatial and temporal shortages in total resources available to the plant. The 'sexual selection hypothesis' is based on the sexual differences in resource allocation between the two sexual functions of the plant. Male success is usually limited by the ability to gain access to female gametes, whereas female success is limited by the ability of the plant to provide resources for ovules and seeds. Flowers not developing seeds may thus serve only a male function, while embryos may be selectively aborted to regulate the genetic quality of the seeds (Lloyd, 1980).

Seed set in southern African Proteaceae was first investigated by Jordaan (1945) and Horn (1962). Most P r o t e a species were found to be self-infertile, while some L e u c o s p e r m u m species and S e r r u r i a f l o r i d a exhibited low levels of self-fertility (Horn, loc cit.). Current data (Table 1) confirm the trends observed, viz. that while species of most genera have a low seed set, those of the genera A u l a x and L e u c a d e n d r o n tend to have a high seed set. Note that the figures for percentage germination reviewed in van Staden and Brown (1977) are for hand-sorted seeds only (Brown and van Staden, 1973, Horn, 1962, van Staden, 1966). This is not equivalent to percentage seed set, which was calculated in this study (Table 1) as the number of seeds with apparently viable embryos over the total number of flowers per inflorescence. The pattern of seed set in the southern African Proteaceae (excluding B r a b e j u m and F a u r e a) shows a clear dichotomy: species with hermaphroditic flowers have a low seed set, while the dioecious species have a very high seed set on female plants. A further distinction is possible in the remaining genera in that species with conflorescences (inflorescences comprised of numerous capitula) have a significantly higher seed set than species with flowers borne in single inflorescences (Tables 1 and 2), with the exception of 'L e u c o s p e r m u m a' (those L. species bearing large, mainly bird-pollinated, inflorescences).

Because, for example, L e u c a d e n d r o n and P r o t e a have similar plant size ranges, it is hard to argue that resources could limit seed set in the species with hermaphroditic flowers, even though most Proteaceae species grow on nutrient-poor soils. On average, species in the former genus produce ten times as many seeds as the latter (Rebelo and Rourke, unpublished data), although only twice as many seeds are needed in dioecious species. However, while the relative cost of pollen production to

seed production is not known for plants (Bawa and Beach, 1981, Bawa and Webb, 1984), it is unlikely to cost ten times as much as seed production. It is also unlikely that the ability to absorb nutrients ultra-efficiently evolved independently in the two dioecious genera. Rather, these patterns suggest that nutrients are not the limiting factor controlling the proportion of flowers that set seed. In addition, were resources to limit the proportion of seed set, then a negative correlation between seed production per season and the size of the seeds should be evident between Proteaceae species. Figure 1 shows that no such trend is evident.

Two other lines of evidence support the view that nutrients are not the proximal cause of the low seed set observed. Firstly, in *Protea grandiceps* ovules start aborting before anthesis commences (pers. obs.), suggesting that the number of seeds set are under genetic control, and responses to short-term or local changes in nutrient levels are thus precluded. Secondly, were all the flowers in the majority of genera with hermaphroditic flowered species to set seed, there would be insufficient space in the infructescence to contain them. This also appears to be true for some of the Australian Proteaceae (Lamont, 1982). From Table 2 it can be seen that a large proportion of species of the Proteaceae bear seeds in an inflorescence containing two or less seeds. This 'clutch size' appears to have evolved independently in several genera. The exceptions to this clutch size rule are either bird-pollinated, or dioecious. However, the bird-pollinated *Protea* and '*Leucospermum* a' have large inflorescences, and in many cases appear to bear as many fertile seeds as the physical space in the infructescence allows. This suggests that the majority of the flowers, which do not set seed, function only as pollen donors, i.e. the hermaphroditic Proteaceae exhibit functional andromonoecism (Bawa and Beach, 1981, Stephenson, 1981).

If pollen is the limiting factor influencing the seed set in the hermaphroditic Proteaceae, then, because the mode of pollen presentation and reception are similar throughout the family in southern Africa, the dioecous genera, *Leucadendron* and *Aulax*, should have ratios of male to female flowers similar to those of hermaphroditic genera. From Table 3 it can be calculated that the effective seed set in *L. stelligerum* and *L. xanthoconus* is 14% and 7% of all flowers produced, assuming a 100% seed set in female inflorescences. This is not significantly different from the ratio for those Proteaceae with single inflorescences (i.e. not conflorescences) (Table 1).

The high ratio of male to female flowers may stem from

the small surface area of the stigmatic groove. The dynamics of pollen germination on the dry, partially hidden stigmatic papillae are unknown. The stigmatic groove is situated distally to the pollen presenter on the style, where it is exposed to wind and rain, which wash pollen off the pollen presenter (pers. obs.) and presumably the stigma as well. It is therefore possible that the small probability of a pollen grain reaching the groove may require a high pollen to ovule ratio. Vogts (1980, 1982) suggested that pollen had to be forced into the stigmatic groove to effect pollination, but this is not certain. Mechanical cross-pollination may result in a lower seed set than observed in open pollinated flowers (Lamont, pers. comm.).

Since the position of seeds in *Protea* infructescences does not appear to be fixed, it is possible that seeds are being selected, perhaps on the bases of genetic quality of the offspring as suggested by Lloyd (1980). This may require further investigation, especially in the light of the need for hybridization for horticultural cultivars. Species such as *Protea longifolia* which hybridize naturally with a wide range of other *Protea* species (Rourke, 1980), may be suitable subjects.

If the low seed set observed in the Proteaceae is due to a high pollen to ovule requirement, then hopes for increasing seed set for the large scale production of hybrids are misdirected. Increased seed production by plants, under conditions of additional nutrient supply, is therefore predicted to occur by the production of more inflorescences, rather than by an increased seed set. This prediction needs to be tested.

4. Concluding remarks

The ecological approach to solving horticultural problems in the Proteaceae is not new. It has been utilized, for example, to provide clues to some of the nutritional problems encountered by horticulturalists (Hocking and Thomas, 1974, Lamont, 1985). A combined physiological and ecological approach can reduce the required research effort by providing a useful framework in which results can be interpreted, and by allowing a more predictive research approach. Horticultural research in the Proteaceae offers an exceptional opportunity to combine both ecological and physiological studies, because of the large natural populations still available for field studies.

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Table 1 - Average percentage florets setting seed in the genera of southern African Proteaceae. N = species investigated per genus. The genus *Leucospermum* is devided into 'a' (Sect. Crassicaudex, Conocarpodndron, Tumidifolium, Brevifilamentum, and Cardinistyly) and 'b' (Sect. Leucospermum, Diastelloides, Crinitinae and Hamatum). Source of information: Rebelo and Rourke, unpublished data.

Genus	% Seed set			N	Range
	Mean	±	S.D.		
Aulax	100.0	±	0.0	3	100 - 100
Leucadendron	77.1	±	12.2	87	50 - 100
Orothamnus	50.0	±	0.0	1	50
Sorocephalus	26.0	±	10.8	11	15 - 50
Serruria	24.2	±	13.6	46	1 - 66
Leucospermum a	23.5	±	10.5	28	8 - 47
Spatella	21.5	±	7.7	20	10 - 36
Mimetes	21.3	±	8.7	12	9 - 40
Paranomus	12.3	±	4.1	18	5 - 18
Vexatorella	8.4	±	4.6	5	2 - 14
Protea	8.3	±	6.5	43	2 - 30
Leucospermum b	6.6	±	3.9	21	3 - 20
Diastella	6.5	±	2.1	9	4 - 10

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Table 2 - Average number of seeds per inflorescence and distribution of species according to 'clutch size' in the genera of southern African Proteaceae. Genera with inflorescences grouped into conflorescences are indicated by asterixes. The genus *Leucospermum* is devided into 'a' (Sect. Crassicaudex, Conocarpodndron, Tumidifolium, Brevifilamentum, and Cardinistyly) and 'b' (Sect. Leucospermum, Diastelloides, Crinitinae and Hamatum). Source of information: Rebelo and Rourke, unpublished data.

Genus	Number of seeds per conflorescence /inflorescence			N	Number of species in 'Clutch size' categories: Number of seeds						
	Mean	±	S.D.		<1	1	2	3	4	>4	
Aulax	20.3	±	6.8	3	0	0	0	0	0	3	
Orothamnus	15.0			1	0	0	0	0	0	1	
Leucospermum a	13.5	±	5.0	28	0	0	0	0	0	28	
Protea	18.1	±	24.3	43	0	0	2	2	2	37	
Leucadendron	33.4	±	23.4	87	0	1	0	1	0	85	
Vexatorella	3.0	±	1.0	5	0	0	2	1	2		
Leucospermum b	2.1	±	0.9	21	0	5	12	3	0	1	
Diastella	1.0	±	0.0	9	0	9					
Sorocephalus	10.6	±	9.0	11	1	7	2	1			*
Mimetes	68.1	±	50.1	12	1	5	6				*
Paranomus	10.5	±	5.9	18	10	8					*
Serruria	24.4	±	64.1	46	40	0	1	1	1	3	*
Spatella	8.1	±	3.0	20	18	2					*

Table 3 - Relative flower ratios in two species of Leucadendron grown at Kirstenbosch National Botanical Gardens. N is the sample size.

Species	Sex ratio M : F (N = 50)		Mean number of inflorescences per plant (N = 5)	Mean number of flowers per infloresc. (N = 5)
L. stelligerum	1.28	Male	121.8 ± 63.0	153.6 ± 26.6
		Female	55.0 ± 20.7	42.4 ± 12.6
L. xanthoconus	1.20	Male	245.6 ± 41.6	181.5 ± 71.0
		Female	80.4 ± 63.7	35.3 ± 3.6

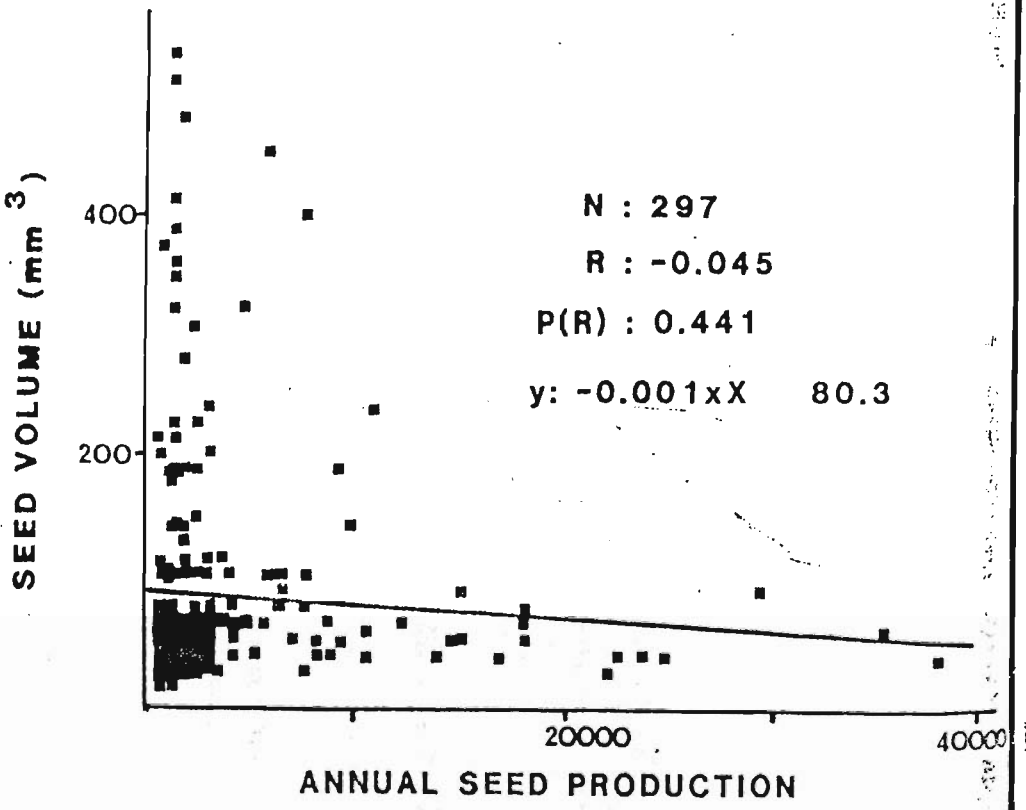

Figure 1 - Seed volume verse annual seed production in species of the southern African Proteaceae. The resource limitation hypothesis predicts a negative correlation between seed production per season and the size of the seeds produced. While the data appears curvilinear, log transformation of the data does not improve the correlation (R = -0.012, P(R) = 0.836, Y = .005 x X + 1.74).

NUTRIENT ALLOCATION IN WINTER RAINFALL PROTEACEOUS HEATHLANDS IN RELATION TO NUTRIENT LOSSES THROUGH WILDFLOWER PICKING AND FIRE

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Summary

Recent interest in heathland nutrient cycling has underlined the extremely low nutrient budgets under which these communities exist. Nutrient additions to and losses from these systems are incompletely quantified and even poorly understood. Based on the limited data available we suggest that intense wildflower picking and frequent veld burning may severely deplete community nutrient reserves.

Data on quantities of wildflowers removed from specific areas and communities are non-existent and therefore accurate quantification of nutrient losses is virtually impossible. Total *Protea repens* head contribution to the aerial nutrient pool in Cape coastal fynbos is in the region of 14,1 (N), 12,6 (P), 10,7 (Ca), 9,6 (Mg) and 25,2% (K) while *Banksia* cones in Kwongan heath, Western Australia represent 25,4 (N), 30,3 (P), 13,5 (Ca), 16,5 (Mg) and 26,3% (K). Casual observations show that moderate picking levels of ±10% per season may remove 4,1 (N) and 9,6% (P) from individual bushes of *Banksia hookerana*. Estimates for nutrient removal from cultivated fynbos stands give annual losses (live cones only) of between 1,6 (P) and 2,3% (K).

Fire-induced nutrient changes for these systems are also poorly documented although indications are that non-volatilisable elements are generally retained in the ash. However concern is expressed at the fates of nutrients after fire, particularly during the winter rains.

We conclude that urgent studies are needed to assess the effect of wildflower picking and fire on the nutrient capitals of heathland communities and that the Wildflower Industry can play an extremely constructive role in this regard.

1. Introduction

The Proteaceae have evolved as a distinct southern family (Johnson and Briggs, 1975), centres of distribution being located in the south-western Cape, South Africa (Goldblatt, 1978, Kruger, 1979 and Taylor, 1978), and south-western and south-eastern Australia (Specht, 1979). The family ranks prominently in the two floras and 320 (3,8%) (Bond and Goldblatt, 1984) and 384 (15,1%) (Beard, 1981 and Lamont *et al.*, 1984) species respectively occur in the heathland zones of the Cape and south-western Australia. Distribution of Proteaceae in the heaths of both these regions is widespread (George *et al.*, 1979, Lamont *et al.*, 1984 and Kruger, 1979) although in the Cape, factors such as high altitude and seasonal waterlogging tend to preclude this family (Kruger, 1979 and Taylor, 1978).

Both regions are characterized by extremely low levels of total soil nutrients (Bettenay, 1984, Kruger, 1979, Low, 1980, Low, 1981, Low, 1984, Low and Bristow, 1983, Low *et al.*, 1984, Milewski, 1983 and Van Daalen, 1984) which are in marked contrast to their "nutrient rich" winter rainfall counterparts in California (chaparral), Chile (matorral) and the Mediterranean Basin (maquis) (Bradbury, 1977, De Bano and Conrad, 1978, Di Castri, 1981, Rundel and Parsons, 1980 and Specht, 1979). The heathland flora has developed a range of adaptations to its low nutrient environment (Lamont, 1983 and Low, 1980) and the Proteaceae in particular are extremely adept at extracting nutrients and moisture from the soil through well developed proteoid roots (Lamont, 1973, Lamont, 1981 and Lamont, 1983).

Only recently have nutrient-linked studies been completed in the Fynbos Biome (Mitchell, 1980) although focus on this aspect was underlined at the 1980 Mediterranean Ecosystems Conference held in Stellenbosch, Cape (Day, 1983 and Kruger *et al.*, 1983). A start has been made on similar studies in the Kwongan heath (Beard and Pate, 1984) of south-western Australia (Low and Lamont, 1985) and preliminary data show some interesting differences in community nutrient allocation between sandplain heaths here and in the western Cape.

Our interest in the Proteaceae stems from their ability to survive admirably under conditions of restricted nutrient supply and often of marked summer moisture stress, at the same time commanding a dominant position in many climax communities of the two subcontinents. In view of the extremely low nutrient capital of these communities, we are concerned about potential (irreversible) nutrient losses in this group which often represents the bulk of the community mass and nutrient pools. In this paper we examine their contribution to heathland nutrient pools and the possible consequences of wildflower picking and fire.

2. Contribution of the Proteaceae to community nutrient pools

2.1 Aerial parts

Table 1 gives aerial masses and major nutrient pools for western Cape mountain and coastal fynbos; non-proteaceous communities are included for comparison. Dense stands of Proteaceae make up >80% of the community mass with heads contribution up to >20%. Contribution to the nutrient pool is correspondingly high. In closed climax coastal fynbos, *Protea repens* contains >93% of all major nutrients, with heads making up 14,1 (N), 12,6 (P), 10,7 (Ca), 9,6 (Mg) and 25,2% (K). We have no like data for mountain fynbos although *Leucadendron* cones at the Kogelberg site (table 1) represent only 1,9% of the aerial mass (Le Maittre, 1981) and Low (unpub. data) found a figure of 5,1% for a *Leucadendron salignum* community in the Winterhoek mountains near Porterville. Neither of the sites could be considered as dense climax proteoid veld. The Australian heaths (table 2) show much lower values than Cape fynbos and in the Kwongan this is thought in part to be a reflection of a lower soil nutrient status (Low and Lamont, 1985). However, of great significance in the *Banksia* community is that cones make up a far higher proportion of the aerial nutrient pool (25,4 (N), 30,3 (P), 13,5 (Ca), 16,5 (Mg) and 26,3% (K)).

Table 1 - Phytomass and major nutrient pools (g m^{-2}) from selected heathland communities in the western Cape winter rainfall region. Compiled from Low (1983 and unpub. data), Le Maittre (1981), Van Wilgen (1982) and Van Wilgen and Le Maittre (1981).

		Dry mass	N	P	Ca	Mg	K
Coastal fynbos							
Kreatfontein 11 y (post-fire age)	non-proteoid (total aerial)	1 458	7,67	0,73	17,47	1,09	3,67
	litter	273	1,26	0,08	1,99	0,16	0,18
Mamre 17 y *Protea repens*	proteoid	6 817	20,80	1,43	26,59	8,28	12,19
	non-proteoid	146	1,00	0,06	1,77	0,29	0,73
	total aerial	6 963	21,80	1,49	28,36	8,57	12,92
% live heads	(of tot. aer.)	0,5	0,7	0,9	0,7	0,5	1,7
% dead heads	(" " ")	10,8	13,4	11,7	10,0	9,1	23,5
% proteoid	(of tot. aer.)	97,9	95,4	96,0	93,8	96,6	94,3
	litter	1 232	6,57	0,27	17,49	1,36	1,37
Mountain fynbos							
Zachariashoek 12 y	non-proteoid (total aerial)	558	2,44	0,08	1,10	0,44	2,03
	litter	182	0,87	0,03	0,50	0,10	0,10
Kogelberg 20-22 y *Leucadendron laureolum*	proteoid	385	-	-	-	-	-
	non-proteoid	648	-	-	-	-	-
	total aerial	1 033	3,89	0,20	2,87	1,48	2,85
	% cones	1,9	-	-	-	-	-
	% proteoid	37,3	-	-	-	-	-
	litter	390	2,11	0,07	0,86	0,21	0,20
Jonkershoek 21 y *Protea repens* *P. nerii-folia*	proteoid	3 240	-	-	-	-	-
	non-proteoid	409	-	-	-	-	-
	total aerial	3 649	10,52	0,64	6,99	1,56	8,65
	% proteoid	88,8	-	-	-	-	-
	litter	1 430	9,27	0,29	2,99	0,71	0,57

Table 2 - Phytomass and major nutrient pools (g m^{-2}) from two selected heathland communities in the winter rainfall region of Australia. Compiled from Low *et al.* (1984 and unpub. data), Low and Lamont, (1985) and Specht *et al.* (1958)

		Dry mass	N	P	Ca	Mg	K
Eneabba	proteoid	1 476	3,63	0,19	2,95	0,89	1,89
(SW Australia)	non-proteoid	288	1,65	0,06	1,54	0,25	0,60
Banksia							
attenuata	total aerial	1 764	5,28	0,25	4,49	1,14	2,49
B. hookerana							
B. menziesii	% live cones	2,2	4,2	6,3	1,8	2,7	4,5
	% dead cones	15,1	21,2	24,0	11,7	13,8	21,8
	% proteoid	83,7	68,8	76,0	65,7	78,0	75,9
	litter	323	1,16	0,04	1,35	0,11	0,12
Keith	proteoid	745	3,69	0,14	1,02	1,12	1,54
(SE Australia)	non-proteoid	1 100	6,49	0,16	3,30	2,05	2,91
15 y							
Banksia ornata	total aerial	1 845	10,18	0,30	4,32	3,17	4,45
	% proteoid	40,4	36,2	46,7	23,6	54,6	34,6
	litter	675	3,94	0,07	2,95	1,72	0,47

2.2 Flowering stems

Nutrient quantities present in certain flowering stems utilized by the Wildflower Industry (WFI) in fynbos and Kwongan heath are shown in table 3. Amounts in *Banksia hookerana* are clearly higher than in *Protea* and this is due chiefly to a greater contribution of cone and leaves to the flowering stem coupled with higher concentrations for certain nutrients, notably N and P.

3. Nutrient losses through wildflower picking

3.1 Utilization of Proteaceae in the WFI

3.1.1 Importance of the Proteaceae

Despite the ubiquitous occurrence of Proteaceae in the south-western Australian and associated sclerophyll vegetation (George *et al.*, 1979 and Lamont *et al.*, 1984) less than 30% of this family's species is utilized in the WFI, representing 21% of the total number of species employed in the latter (Burgman and Hopper, 1982). For the Cape these figures are about 25 and 38% respectively (Van der Walt *et al.*, 1984).

A large part of the WFI is dedicated to the marketing of proteaceous species with large, attractive heads, most of which have the added advantage of being suitable in the dried state (Van der Walt

Table 3 - Dry mass (g) and major nutrient content (mg) of flowering stems of *Protea* (western Cape) and *Banksia* (south-western Australia). Stems 30-50 cm long, mean +35 cm (*Protea*) and current and previous year's growth (*Banksia*). Nutrient concentrations from Low, Struthers and Le Maittre (all unpub. data), and Van Wilgen and Le Maittre (1981).

		Mass (g)	mg N	P	Ca	Mg	K
Protea repens	Head	17	45,9	3,4	11,9	6,8	62,9
(mountain fynbos)	Leaves	11	60,5	2,2	44,0	5,5	33,0
	Stem	14	23,8	1,4	42,0	7,0	46,2
	Total	42	130,2	7,0	97,9	19,3	1
Protea repens	Head	17	80,1	6,2	92,6	21,4	10
(coastal fynbos)	Leaves	11	58,9	3,0	89,6	13,2	27,
	Stem	14	45,6	3,3	79,2	18,1	22,
	Total	42	184,6	12,5	261,4	52,7	
Protea compacta	Head	14	37,8	2,8	9,8	5,6	
(mountain fynbos)	Leaves	17	77,0	2,8	56,0	7,0	
	Stem	7	11,9	0,7	21,0	3,5	2
	Total	35	126,7	6,3	86,8	16,1	116,9
Protea neriifolia	Head	21	56,7	4,2	14,7	8,4	77,7
(mountain fynbos)	Leaves	10	55,0	2,0	40,0	5,0	30,0
	Stem	7	11,9	0,7	21,0	3,5	23,1
	Total	35	123,6	6,9	75,7	16,9	130,8
Banksia hookerana	Cone	29	106,7	10,8	32,5	30,1	59,4
(Kwongan heath)	Leaves	17	112,2	5,1	41,7	17,2	42,5
	Stem	7	27,5	0,9	18,3	3,2	27,5
	Total	53	246,4	16,8	92,5	50,5	129,4

et al., 1984). Large-headed Proteaceae (*Protea*, *Leucadendron* or *Leucospermum*) invariably form an open to closed canopy in mature mountain fynbos where conditions permit the development of a three-layered community (Kruger, 1979 and Taylor, 1978). In the Kwongan (sandplain heath) of south-western Australia, *Banksia* is the *Protea* "analogue", although *Dryandra* (*Leucospermum*-like in looks) may also fill this position.

3.1.2 Quantities picked

Records of numbers and/or kg of stems picked per species are well documented for Western Australia (Burgman and Hopper, 1982) but much less so for the Cape (Van der Walt *et al.*, 1984 and SAPPEX

newsletters (1976 to 1984). The latter, unlike the Western Australian report, gives only total exports with no breakdown into species or regions. Quantities for annual fresh flower exports (Proteaceae and Cape greens (chiefly Ericaceae, Bruniaceae and Asteraceae)) range between 1,4 and 1,7x10^6 kg (SAPPEX newsletters 1977 to 1984) of which 70% may be ascribed to *Protea* and *Leucospermum* (Davis, 1984). During the 1980-81 season in Western Australia 13,8x10^6 stems were reported picked. Of the 20 species most heavily exploited, 7 were Proteaceae, comprising 3,5x10^6 stems or 25,4% of the total (Burgman and Hopper, 1982).

3.1.3 Nutrient losses

No flower picking data are available for Cape proteoid stands although P. Slingsby (pers. comm.) has observed removal rates of 3 to 4% per annum near Kleinmond. At the other extreme, nearly 100% removal has been noticed by C. Burgers (pers. comm.) in the Riversdale area and this is probably due to pickers on leased land showing little concern for the well-being of the community (Davis, 1984). Information gathered from producers in the Kleinmond-Hermanus area gives some idea of mass removal through picking off stands of cultivated Proteaceae. During the 1984-85 season some 5 500 stems ha^{-1} were picked giving a nutrient removal rate in the order of 2 006 (N), 103 (P), 1 418 (Ca), 268 (Mg) and 1 956 (K) g ha^{-1} (extrapolated from table 4). This represents 1,9 (N), 1,6 (P), 2,0 (Ca), 1,9 (Mg) and 2,3% (K) of the aerial nutrient pool in dense *Protea* growth (table 1) at Jonkershoek.

Table 4 - Estimated nutrient losses (g ha^{-1}) to wildflower picking from cultivated proteaceous stands in the Kleinmond-Hermanus area. Number of stems reported for 1984-1985. Nutrient data for individual heads from table 3. Total Proteaceae data (see above) extrapolated from *Protea* stems (34%) and assuming similar nutrient contents in *Leucadendron* and *Leucospermum* (2 613 (47%) and 1 063 (19%) stems respectively).

Stem with heads	no. stems ha^{-1}	dry mass (kg ha^{-1})	N	P	Ca	Mg	K
Protea compacta *P. longifolia*	982	34,4	124,4	6,2	85,2	15,8	114,8
P. neriifolia	248	8,7	30,6	1,7	18,8	4,2	32,4
Protea grandiceps *P. lacticolor* *P. magnifica*	485	20,4	63,1	3,4	47,4	9,4	68,9
Stems without heads							
Protea compacta	160	4,0	14,3	0,6	12,4	1,7	10,4
Protea total	1 875 (34%)	67,5	232,4	11,9	163,8	31,3	226,5

Recently compiled data for *Banksia hookerana* heath at Eneabba, south-western Australia (Struthers, unpub. data and Turner, 1984) indicate that live cones from this species were removed at a rate of 9,7% (1984 season) which amounts to a 4,1 and 9,6% loss in N and P respectively per shrub.

Picking of dead heads, including *Banksia*, for dried flowers or even seed collection forms a major part of the WFI in Western Australia (Burgman and Hopper, 1982). In the Cape WFI, of the 50 proteaceous species with large heads or cones recorded by Van der Walt *et al.* (1984) (Appendix 4), 41 (82%) are used as dried and fresh, or solely as dried flowers. Dead heads make up between 9,1 (Mg) and 23,5% (K) of the aerial nutrient pool in coastal fynbos (*Protea repens*) (table 1) while dead cones comprise between 11,7 (Ca) and 24,0% (P) of the same fraction in Kwongan heath (*Banksia*). Regular removal of large quantities of dead heads or cones is thus likely to deplete the nutrient stocks in climax proteoid communities. Parallel with this practice is the removal of seed-containing heads from serotinous species and in particular where seed survival is short. Near Kleinmond, Slingsby and Bond (1980) have shown that post-fire regeneration by *Protea compacta* was severely reduced where intensive picking of live heads had previously occurred. Under continued intensive picking local populations of obligate seed-regenerating species would therefore become extinct.

4. Nutrient losses through fire

Fire is an acknowledge natural factor in heathlands which at the same time are regarded as being fire-prone (Specht, 1979). Our concern with regard to fire in these systems stems from possible net nutrient losses which we believe may occur under current high fire frequencies. The latter are man-induced whether through present management policies, accident or vandalism. To date comments on the subject have been rather speculative due to an extreme paucity of data in both subcontinents. Van Wilgen and Le Maittre (1981) estimated post-fire nutrient releases from aerial and litter material in mountain fynbos of between 50 and 80%. Evans and Allen (1971) demonstrated considerable nutrient losses in British *Calluna* heath for N and S which are easily volatilised. They concluded that critical elements such as P showed little change as they were retained in the ash. Van Wyk (1985) monitored nutrient in- (rain and dry deposition) and output (streamflow) in a mountain fynbos catchment and even after fire, found input to exceed output for several cations examined. N and P were not detected but then again loss through smoke or ash was not investigated.

We argue that heathland systems may be partly "leaky" due to extremely poor colloidal statuses (e.g. low clay contents in fynbos soils (Lambrechts, 1979)) and that leaching of nutrients after fire and an ensuing heavy spate is exacerbated. Nutrient replenishment from parent material in these systems is insignificant (Rundel *et al.* 1983) and input through rainfall is considered too small to have any redeeming effect (Allen *et al.*, 1969, Chapman, 1967 and Groves, 1981) particularly where higher fire frequencies are found (Stock, 1985). N replacement through symbiotic (Bowen, 1956 and Haxen, 1978) and free-living (Low, 1984) N-fixation is however likely, but it is the geochemically cycled elements, notably P, which cause the greatest concern.

Table 1 - A comparison of quality of soil and water in Israel (coastal sandy soil and national water pipe respectively) and Stellenbosch, South Africa.

	Soil		Water	
	Israel	S A	Israel	S A
pH	>7.0	<6.0	>7.0	<6.0
EC (mmho's . cm^{-1})	>0.4	<0.4	>0.6	<0.2
Free lime	present	absent	present (hard)	absent (soft)

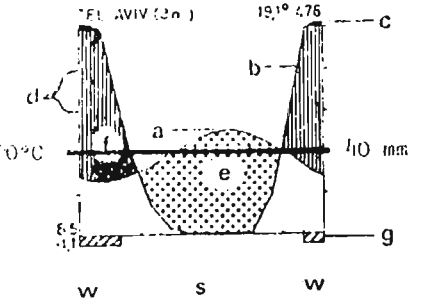
Table 2 - List of fungi isolated from Proteas and Banksias in Israel.

Isolated from roots		Isolated from leaves	
Name of fungus	No of cases	Name of fungus	No of cases
Fusarium sp.	51	Alternaria	14
Fusarium moniliforme	1	Botrytis	2
Fusarium solani	1	Cladosporium	1
Phycomycetes (unidentified)	9	Colletotrichum	1
Phytophthora sp.	3	Gloeosporium	5
Phytophthora citrophtohra	1	Helminthosporium	2
Phytium	11	Didiopsis	1
Rhizoctonia solani	4	Stemphylium	1
Rhizopus	2		
Sclerotium bataticula	9		
Verticillium	2	Diplodia (isolated from stems)	13

Table 3 - Protea and Banksia production in Israel 1982 - 1985. Hectarage, quantities and prices.

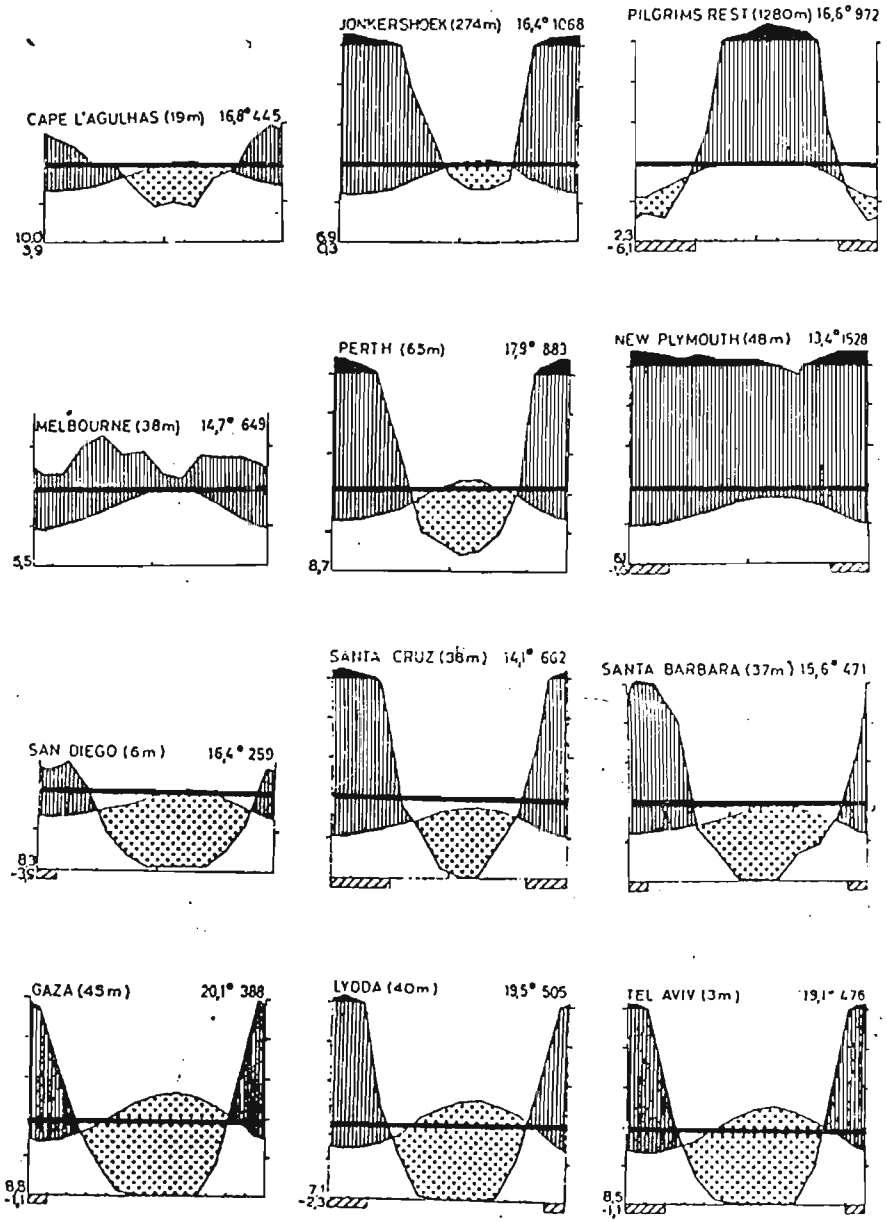
	Hectarage (hectares)			Quantities (000 flowers)			Price F.O.B. (U.S. cents)		
	82/83	83/84	84/85	82/83	83/84	84/85	82/83	83/84	84/85
Leucadendron discolor	0.5	1.0	3.5	70	80	100	15	13	13
Protea obtusifolia	0.5	1.0	1.5	3	6	15	60	50	55
Banksias	15.0	13.0	12.0	80	120	120	75	45	50
Leucospermum	0.5	1.0	2.0	30	70	20	16	22	16
Total	16.5	16	19	183	276	255	-	-	-

Figure 1 - A key to climate diagram



a - monthly mean temperatures (C°)
b - monthly mean precipitation (mm)
c - monthly mean precipitation above 100 mm in a scale of 1:10
d - equal 10°C and 20 mm precipitation
e - water shortage
f - excess water
g - months when absolute minimum lies below 0°C
s - summer
w - winter
Tel-Aviv - location of station
(3m) - altitude
19.1° - mean annual temperature (C°)
476 - mean annual precipitation (mm)
8.5 - mean daily minimum of coldest month (C°)
-1.1 - absolute minimum (C°)

Figure 2 - Climatic diagrams of main Protea growing areas in South Africa, Australia and New Zealand, California and Israel (revised from Walter and Helmut, 1967).



THE EFFECT OF SUCROSE IN A VASE SOLUTION ON LEAF BROWNING OF PROTEA NERIIFOLIA R. BR.

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Abstract

Leaf browning of several P r o t e a spp. after harvesting is one of the most important problems in the protea industry.

The use of a flower preservative is essential to retard leaf browning of proteas. The objective of this study was to determine the effect of sucrose in a vase solution on leaf browning of harvested P r o t e a n e r i i f o l i a. Sucrose is an easily assimilable substrate and replaces the depleted intracellular carbohydrates and also retards the degradation of other organic components.

P. n e r i i f o l i a stems were placed in a vase solution containing labelled ^{14}C-sucrose (U ^{14}C) for 18 hours. A greater amount of ^{14}C accumulated in the flower heads than in the leaves. When placed in a vase solution containing ^{14}C-sucrose and 1% sucrose a significant quantity of ^{14}C accumulated in the flower head within 12 hours. A pulsing period of 12 hours would thus ensure an efficient distribution of sucrose throughout the whole inflorescence.

In experiments with only sucrose in the vase solution it was found that concentrations of up to 2% sucrose effectively delayed the onset of leaf browning of P. n e r i i f o l i a inflorescences. Concentrations greater than 1% sucrose were harmful to the leaves and enhanced leaf browning.

1. Introduction

Leaf browning of several P r o t e a spp. after harvesting is one of the most important problems in the protea industry. According to De Swardt (1977), Mulder (1977) and Uys (1980) the two main factors associated with leaf browning are the presence of flavonoids such as pro-anthocyanidins and the loss of water due to transpiration. Paull et al. (1980) state that water stress in cut proteas always precedes leaf browning. A water stress at the cellular level leads to an increase in membrane permeability (Bell et al., 1971), which plays an important role in tissue browning (Thomas et al., 1973). The rate of leaf browning can possibly be related to the rate at which the membrane system collapses (Mulder, 1983).

The continued supply of nutrients such as sucrose, to cut flowers is essential for the maintenance of membrane integrity (Coorts, 1973). Sucrose is a readily assimilable substrate and can be used effectively as a preservative in a vase solution (Gay and Nichols, 1977). Sucrose replaces the depleted intracellular carbohydrates and also retards the degradation of other organic components (Marousky, 1968).

The present investigation was carried out to determine the effect

in leaf blackening.

The leaf is, however, not the only component of the protea inflorescence which depletes the food reserve. The bracts and florets also need substrates for respiration. Moreover, the respiration of the less developed florets tends to be higher than that of the leaves, bracts and fully developed florets (table 2), and would therefore demand more substrates for respiration than the other components of the inflorescence. Chin and Sacalis (1977) reported that in roses these substrates were translocated from the leaves to the flower tissue. The respiration rate of the florets may therefore have an influence on leaf blackening. An investigation into the influence of the stage of development of a protea inflorescence on the respiration rate of the florets on the peduncle, revealed the results shown in figure 3. The respiration rate of both the group of florets in the centre and on the periphery of the peduncle evinced a typical climacteric pattern when plotted against the stages of development. The florets in the centre of the peduncle tend to have a higher respiration rate than those on the periphery of the peduncle, while the climacteric minimum and maximum occurred at later stages of development of the inflorescences. The florets in the centre were less developed than those on the periphery of the peduncle and that probably explains the difference in respiration rate patterns. When the inflorescences were harvested at stage 3 of their development and kept in water for 13 days, a different pattern emerged (figure 4). The change in the respiration rate of the florets on the periphery corresponds well to the respiration pattern observed in figure 3, starting at stage 3. However, the change in the respiration rate of the florets on the centre of the peduncle did not display a sharp increase as observed in other cases. This might have been caused by the sampling periods (3 days apart) or because of a depletion of the substrates available for respiration.

The vase-life of protea inflorescences including a decrease in the rate of leaf blackening, can be extended when the flowers are kept in a preservative solution containing sucrose, 8-hydroxy-quinoline sulphate and citric acid (Ferreira, unpublished results). Based on the results obtained in this investigation it is suggested that, apart from water loss, an abnormal high respiration rate due to high temperature can also initiate leaf blackening of proteas. Flowers should therefore be cooled soon after harvest and kept in cold storage, preferably also during the time of transport. The flowers should furthermore not be packed in, or covered with polyethylene.

A determination of the changes in the substrates available for respiration under conditions described above is needed to confirm the influence of respiration on leaf blackening, while the development of a pulsing-solution should enhance the vase-life of cut protea flowers.

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Table 1 - Respiration rate of leaves of P. n e r i i f o l i a at different temperatures, one day after harvest of the inflorescences.

Temperature (°C)	Respiration rate (cm³ oxygen absorbed/kg fresh tissue/hour)	Standard error
25	176.2	27.4
40	611.5	96.2
50	1 877.3	412.6

Table 2 – Respiration rate of various components of a *P. n e r i i f o l i a* inflorescence one day after harvest

Inflorescence component	Respiration rate (cm³ oxygen absorbed/kg fresh tissue/hour)	Standard error
leaves	170.4	24.3
bracts	152.6	21.2
florets:		
outer	166.4	25.0
middle	191.3	29.4
inner	239.9	32.1

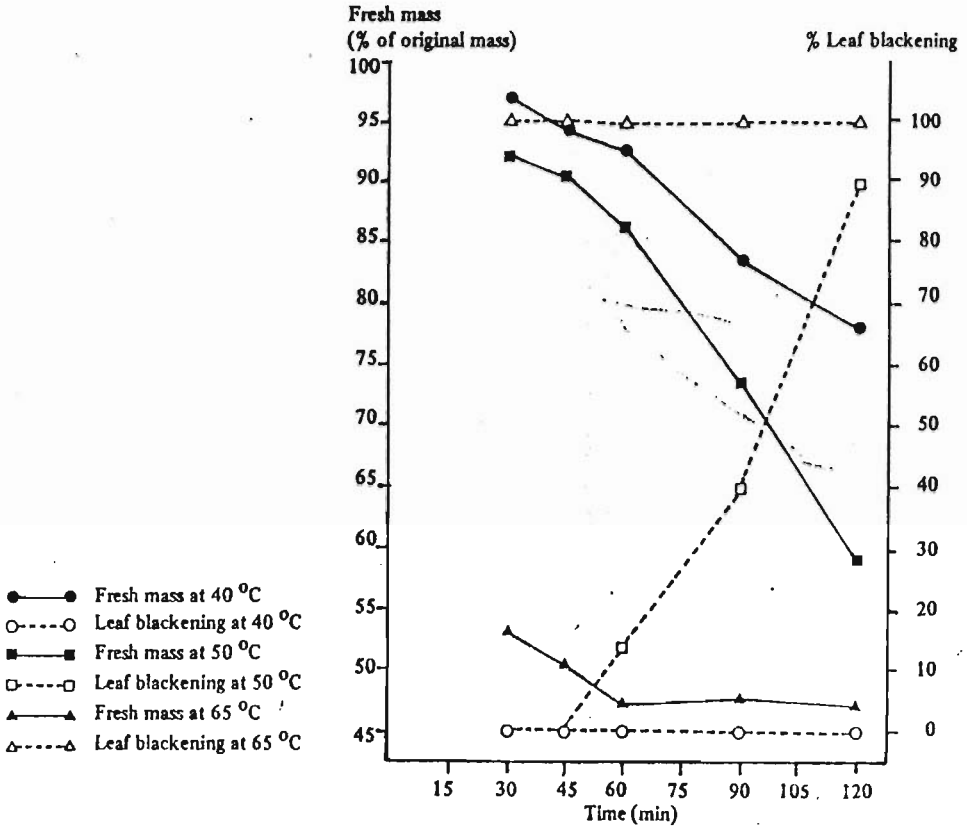

Figure 1 – Change in fresh mass and percentage of blackening of leaves of *P. nerlifolia* at different temperatures for various periods

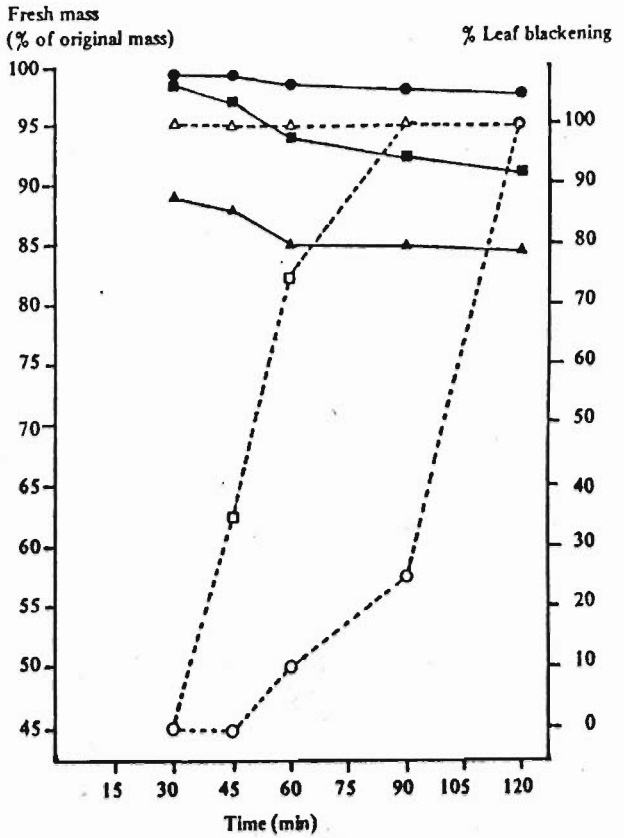

Figure 2 – Change in fresh mass and percentage of blackening of leaves of *P. nerlifolia* packed in polyethylene bags at different temperatures for various periods

- Fresh mass at 40 °C
- Leaf blackening at 40 °C
- Fresh mass at 50 °C
- Leaf blackening at 50 °C
- Fresh mass at 65 °C
- Leaf blackening at 65 °C

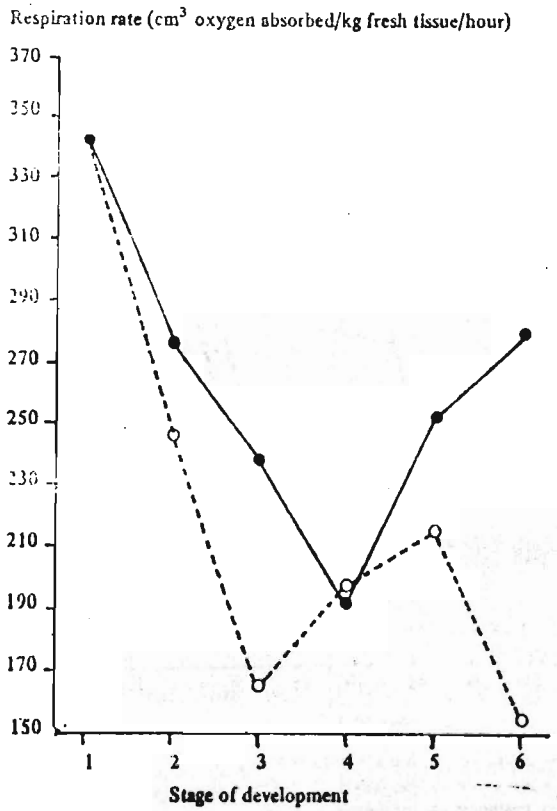

Figure 3 – Respiration rate of florets of a *P. neriifolia* inflorescence at different stages of development

florets in the centre

florets on the periphery

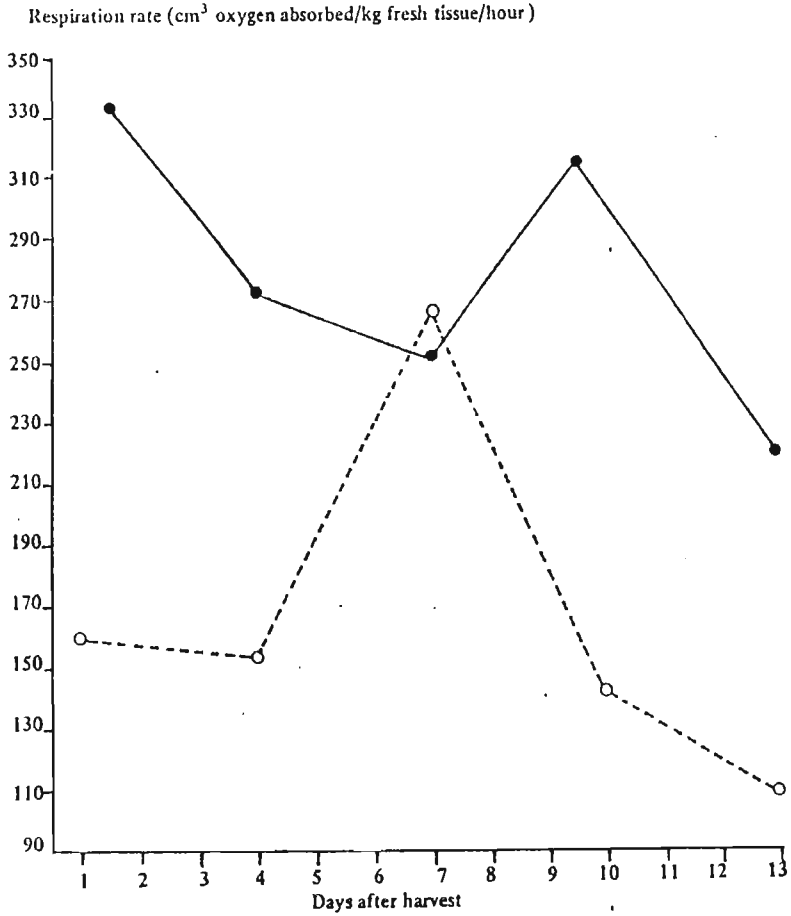

Figure 4 – Change in the respiration rate of florets from *P. neriifolia* inflorescences after harvest

florets in the centre

florets on the periphery

POST HARVEST INFORMATION FROM A PROTEA GROWER, SHIPPER AND IMPORTER'S VIEWPOINT

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Abstract

This paper is written in an effort to help commercial Protea growers to:

- build each individual's reputation with their buyers as a producer of quality cut flowers
- justify highest and best prices paid to growers
- increase the demand for cut Protea
- operate at a profit

In the writers' opinion proper post harvest procedures must be adhered to in order to ensure these goals. The methods and suggestions shared herein have evolved over more than ten years of experiences and experiments by the writers in a profitable commercial Protea growing and marketing operation. A great deal of information has been published on post harvest treatment of cut flowers; however, the writers suggest that thorough scientific investigations should be done specifically on each aspect of Proteas -- from the selection of proper mature flowers, when and how to cut, post harvest treatments, packaging, and the care and handling by buyers. Until these studies have been completed and reported, we Protea growers will not be able to obtain the aforementioned goals and therefore will be greatly handicapped in the highly competitive worldwide flower markets.

1. Introduction

The writers (husband and wife) own a one hundred acre farm in central California adjacent to the Pacific Ocean. In 1972, we planted ten acres of Protea including twenty different species. Since then, we have increased our Protea plantings to approximately thirty acres. Our climate is frost free, but very windy. Our soil types are less than ideal ranging from heavy clay loam to shale, all of which range from PH 4.1 to 6.2. We have always marketed our own flowers direct to wholesalers throughout the U.S.A., Hawaii and Canada. In an effort to improve our product, we have continued to experiment in growing and cultural methods, post harvest procedures, and marketing. Because we have more demand

than we can supply, we started importing cut Protea from Australia and New Zealand four years ago. This importing, because of the reverse blooming seasons, has enabled us to furnish our buyers Proteas year-round.

We concluded in the early years that it made little sense to go to the effort and expense to produce beautiful flowers if they were to reach the ultimate consumer in poor condition with a short vase life thereby reducing future demand. We have read all the printed material we know of on post harvest treatments. From this material and from our own experiments, we believe the most important factors affecting cut flowers are: temperature, water supply, food supply, ethylene, disease, maturity, light, handling, and packaging.

Our slide presentation will illustrate most of the above factors. These slides were prepared by Dr. Michael Reid of the Department of Environmental Horticulture at the University of California at Davis in conjunction with his work on post harvest handling of cut flowers. His conclusions, we believe, are pertinent to cut Proteas. We hopefully await conclusions to future studies which we might use to improve our methods.

2. Field cutting

2.1 Time of day to cut

Because we want each cut flower to arrive at the packing shed while it is still cool from the night temperatures and also when the stem and head are still full of water and food, we start cutting early each day. Starting early also allows harvest before the honey bees begin collecting, especially in Protea repens. If flowers must be cut while wet from dew or rain, be sure they are dry before cooling.

2.2 Mature flower selection

We cut only after the flower head has matured but before it has had a chance to open. Each species is different but there is an optimal time for each when the bracts are ready but have not yet sprung loose. Cutting at this stage allows us to prolong the shelf life on many species up to two or three weeks longer than if we harvested open flowers. This method can also allow harvesting if rain is forecast. Our post treatments can also adjust the flower opening time of most species.

2.3 Flower care while field harvesting

Flower cutters collect into their arms a comfortable carrying load before placing the arm load into a cardboard picking box (12"x20"x44", 30x51x112 cm) which

is always kept out of direct sunlight. Each half hour the flowers are taken to the packing shed. Because the flower cutters are looking for the right stage of opening for market demands, their only pruning is limited to unsaleable flower heads. Other necessary pruning is done at another time. Cutters are required to bring to the foreman's attention unusual conditions such as insects, rodent pests and any change in general plant appearance.

3. Packing shed procedures

3.1 Stripping and selection

Upon arrival at the packing shed, the flowers are carefully placed on work tables for the first culling selection and stripping of leaves on the lower one-third of the stem. This stripping is done to ensure that leaves will not be covered by the water solution. In most species this stripping is done by hand. Some species require each leaf to be removed to be cut by clipper, eliminating severe damage to stems. We now know that hand stripping does cause damage to stems and can result in poor quality market flowers. Unmarketable flowers are destroyed as we make our first quality selection. We consider stem length and straightness, leaf condition, flower maturity, size and uniformity factors.

3.2 Recutting stems

We have only recently begun to recut stems while held under water. Recutting stems under water greatly reduces the chance of air entering the stem water passage ways. A great deal of work will be necessary to improve on speed and efficiency in our procedures. We have been talking with other flower growers and find that they also have problems in this regard. We normally cut off approximately one inch or two and one-half cm. to reopen the trachea in the stems. Our question, "is it best to make a straight cut or a diagonal cut," remains unanswered.

3.3 Preservatives and pulsing

Once stems are recut, each is placed immediately into a solution of warm water (90-100°F, 38-40C) and a commercially prepared flower preservative (Florever produced by Smither-Oasis) containing citric acid, sugar and silver thiosulphate salt (STS) along with a fungicide and biocide. Always use good clean water. The containers are always cleaned and sanitized before use. The flowers are then left at room temperature for two to three hours before they are placed in the cold room. This time, before cooling, is necessary so the stems have a chance to draw in the warm perservative solution.

3.4 Cold box storage

Our cold box is kept at approximately 40-50°F, 4-6C and the cool air is kept circulating at all times. We also leave the lights on to help the flowers continue to open. We had problems some years ago with leaf blackening or browning on P. exima and P. neriifolia until we began leaving the lights on. We do not know if the lights solved the problem and, if so, how, but we always have plenty of light in the cold room. The box is also kept clean and we maintain around ninety-five percent humidity. All flowers are coded overnight before shipping.

3.5 Insect control

We do not have a large problem with insects, however, when we do find any insects, the flowers are sprayed with a commercial insecticide before cooling. We do not export flowers but if we did, we would begin a regular insect control program.

4. Packing flowers for shipment

4.1 What to send

The packers make final quality selection sending only those flowers meeting our specific requirements. We have built our reputation with our buyers by shipping only first quality flowers cut at the right maturity stage to give the ultimate consumer the longest shelf life. We recommend that all growers sell only top quality flowers.

4.2 Type of boxes

Ninety-five percent of our shipping boxes are 44"x20"x12", with five percent one-half that size. They are full telescoped where the entire top slides all the way down over the packed box. Depending on which flowers are being packed, our usual mixed box will weigh between thirty-five to sixty pounds (14 kg to 24 kg). We use strong wood cleats to hold the flowers from slipping around while in transit. The cleats are nailed or stappled in place before the top is put on.

4.3 Moisture control while in transit

We prepare our boxes before packing to ensure insulation and control dampness. We line each box with dry newspapers on the bottom and sides, leaving the side papers so that, when the box is fully packed, the side sheets also fold over the top of the flowers. Over the newspaper, we also line each box with waxed paper for moisture control. We pack only dry, cooled flowers.

4.4 Insect control while in transit

We do not have insect problems. However, we do import Protea and have worked out with our overseas growers several ways to ensure that no live insects arrive in the import boxes. The best insect control is field spraying on a regular basis and control at all times while preparing to ship. The New Zealand growers are now using a small sponge holding insecticide and several are put throughout each box and continue to kill any insects as the box moves to its destination.

4.5 Temperature control while in transit

Most of our shipments are transported by refrigerated trucks throughout the United States. Keeping the flowers cool dramatically reduces respiration and aging. If flowers are allowed to heat up and then be recooled, then heated up again, the aging process seems to accelerate and the ethylene gas effects cause rapid decay. If you must ship by air or non-refrigerated trucks, try to deal only with shipping agents who understand the fresh cut flower needs and who will provide rapid transit.

4.6 Following flower shipments

We have made it a habit to follow our shipments when we begin transporting to a new buyer in an area we have not shipped to before. We try to be at the buyer's place of business on arrival, and at any transfer point from one truck to another, to determine if the boxes are being handled correctly. Poor or improper handling in transit can only lead to unhappy buyers.

5. Care and handling instructions to buyers

5.1 Wholesalers, retailers or consumers

No matter who you sell to, be sure that each buyer, in turn, gets instructions as to how to handle Proteas. Instructions provided by you, the grower, are very important to ensure reorders in the future. Make up printed information that can be passed on explaining to recut the stems, to use preservatives, to allow leaves to be covered by water, and to change the water regularly. We even explain that most Proteas dry easily and how best to do drying.

6. Experiences & problems of importing Protea into the United States

If growers around the world will utilize the information shared herein, they should have fewer problems trying to import to the U.S.A. All imports must be completely free of disease and insects to pass U.S.

agriculture inspections. Communications with your buyers must be simple and understood by each party. We have prepared informational instructions (based on experience) which we send to growers. These instructions have kept misunderstandings to a minimum.

Summary

If you are a commercial Protea grower or if you are one who grows Protea for sheer joy, you must become proficient in proper post harvest treatment of your flowers. You must also support with your money additional research by the experts within the educational institutions and agricultural related industries that can help solve our problems, increase our awareness, and add to our profits. We must combine the practical experience and knowledge of Protea growers with the research by technical experts to improve our product.

A PRELIMINARY STUDY OF INTERACTIONS BETWEEN NITROGEN, POTASSIUM AND PHOSPHORUS IN THE MINERAL NUTRITION OF SEEDLINGS OF LEUCADENDRON SALIGNUM BERG. (PROTEACEAE).

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Abstract

The ammonium nitrogen, nitrate/ammonium nitrogen, potassium and phosphorus mineral nutrition of Leucadendron salignum Berg. (Proteaceae) seedlings in water culture were investigated by monitoring their growth and nutrient levels under varying concentrations of supplied nutrients. Ammonium nitrogen supplied in relatively high levels promoted growth, nitrate nitrogen at high levels was toxic, and optimum growth occurred at intermediate potassium and phosphorus concentrations. Interesting interactions were also found and are discussed.

Despite the preliminary nature of the studies, in view of large amounts of material lost during bloom harvesting, the fertilisation of cultivated proteas is recommended.

1. Introduction

The demand for a regular supply of high quality protea blooms has resulted in a change in production methods. Historically, blooms were removed from the veld but in recent years blooms have been produced under intensive cultivation. This, in turn, has resulted in extensive research on cultivation practices, but there is still a critical shortage of data on nutrient requirements.

In their natural habitat most proteas grow on nutrient deficient soils of low pH and their success may be related to their ability to survive and compete under such conditions. However, it is possible that proteas may benefit from added nutrients. Moreover, it is likely that, because of the removal of nutrients by bloom harvesting, proteas under cultivation require fertilisation. The annual yield (1984 - 1985) of five year old Protea neriifolia R.Br. bushes grown in the Eastern Transvaal, South Africa, at a density of 1000 bushes ha^{-1} was two tonnes fresh or 700 kg dry weight material ha^{-1}. In comparison, for maize in South Africa in 1981 an average of 120 kg ha^{-1} fertiliser was applied for an average yield of two tonnes ha^{-1} (Billet, 1985). For cultivated proteas producing a similar yield there is no nutrient return. The question therefore arises as to whether nutrient return is necessary to maintain production at present levels. It is possible that fertilisation may even result in increased growth and production.

Little is known of the nutrient requirements of proteas other than that they are sensitive to high levels of both nitrate and phosphorus (Claassens, 1981; Nichols, 1981; Vogts, 1982). This investigation was designed as a preliminary study into the nutrient requirements of proteas.

2. Materials and methods

Six month old *Leucadendron salignum* seedlings were grown in water culture for 91 days. The basic nutrient solution is given in Table 1. Nutrient solutions were kept at a constant volume of 10 l by the addition of de-ionised water and after 30 days, all solutions were replaced. Culture solutions were aerated using a low air flow rate to minimise solution turbulence and hence root disturbance. Nutrient concentrations were varied independently in a logarithmic manner, with the basic medium supplying the highest concentration. To study the effect of nitrate, the nitrate/ammonium ratio was varied, with total N being maintained at 3 mmols l^{-1}. As a control seedlings were grown in de-ionised water only. Treatments were replicated five times.

Experiments were conducted in a greenhouse with a mean temperature and relative humidity of 26° C and 70%. Wind was supplied using an electric fan.

Seedlings were harvested at regular intervals and dry weights and contents of N (Kjeldahl), K (atomic absorption) and P (molybdenum blue) were determined on individual replicates. Results were expressed as mean relative growth rate ($\bar{R}$) over the period between harvest intervals. This describes plant growth in terms of the initial amount of material present and over a given time interval, mean relative growth rate ($\bar{R}$) may be calculated as:

$$\bar{R}\ (1\text{-}2) = \frac{\log_e W(2) - \log_e W(1)}{t(2) - t(1)}$$

where W = plant dry weight and t = time.

3. Results and Discussion

Figure 1 illustrates $\bar{R}$ of *L. salignum* seedlings grown in de-ionised water only. For the first 50 days seedlings grew on accumulated reserves and only then was there a marked drop in $\bar{R}$. It was assumed that only after 50 days did seedlings become nutrient limited and therefore, effects of the various nutrients on $\bar{R}$ and nutrient absorption were confined to the 50 - 91 day growth period.

Figure 2 illustrates the $\bar{R}$ of seedlings in the four experiments. There was an increase in $\bar{R}$ with increasing supply of ammonium N (Figure 2a). The highest ammonium N concentration tested was 3 mmols l^{-1} but present studies suggest that growth responds to at least 10 mmols l^{-1} ammonium N.

Where N was supplied as both nitrate and ammonium, high levels of nitrate yielded low $\bar{R}$ values (Figure 2b). Three of the five replicates at the highest nitrate/ammonium ratio died, and the $\bar{R}$ for this treatment is the mean of the surviving two plants.

Intermediate levels of K and P gave maximum $\bar{R}$ values with growth reduction apparent at the highest concentration for both elements (Figures 2c and d). Thus, it would appear that high levels of ammonium N combined with moderate levels of K and P are optimum for growth.

These observed effects of nutrients on growth could have been a direct result of the individual elements or an indirect effect due to inhibition of uptake of the other essential ions. Possible interactions were assessed from

concentrations of the different elements in the plants grown under the four different treatments. N concentrations increased with increasing supply of ammonium N, but high nitrate levels depressed N absorption (Figures 4a and b). This confirms that ammonium N is beneficial to *L. salignum* but nitrate N, especially at high levels, is growth detrimental. Varying K and P levels did not influence N absorption. Plant K levels increased under conditions of increasing K supply (Figure 4a) and, while varying concentrations of both ammonium N and P did not affect K uptake, high nitrate levels resulted in reduced K absorption (Figure 4b). P supply did not greatly affect plant P concentration except for the highest level of supplied P, at which there was a marked increase in plant P concentration (Figure 5). The presence of other nutrients had no influence on P uptake.

For both K and P, although highest plant concentrations and total amounts occurred in plants growing on the highest nutrient concentration, growth was sub-optimal under these conditions. Under conditions of supra-optimal supply *L. salignum* appears to absorb both K and P in excess of immediate requirements. These stored nutrients may be available for later growth if the supply becomes limiting. Such a phenomenon has been demonstrated in the P nutrition of *Banksia ornata*, an Australian member of the Proteaceae (Jeffrey, 1964), but has not before been reported for proteas or K nutrition.

Specific utilisation rate (U, growth rate per unit plant nutrient content) provides an estimate of the efficiency of utilisation of absorbed nutrients. U of ammonium N increases slightly with ammonium N supply (Figure 6a). All the absorbed N is being utilised, supporting the suggestion that these plants are N limited. When N is supplied as nitrate and ammonium there was no effect on U until the highest nitrate level at which point U was actually negative (Figure 6b). It is probable that for the other nitrate/ammonium treatments the plants were growing at the expense of the ammonium N absorbed. For both K and P (Figures 6c and d) the high absorption but reduced growth is reflected in low U at highest levels of K and P supply.

As part of an investigation into the desirability of fertilising intensively cultivated proteas, the response of *Leucadendron salignum* seedlings to added nutrients was as follows: optimum growth occurred at ammonium N concentrations greater than and equal to 3 mmols l^{-1}, K concentrations of 0.08 - 0.31 mmols l^{-1}, and P concentrations of 0.008 - 0.125 mmols l^{-1}. Nitrate N was not an efficient N source and at a concentration of 2.5 mmols l^{-1} was toxic. It is suggested that intensively cultivated proteas may benefit from fertiliser application and further investigations into the nutrient budget of cultivated proteas are under way.

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Nichols, D., 1981. The phosphorus nutrition of proteas. In: The Growing and Marketing of Proteas. Report of the First International Conference of Protea Growers. P. Mathews (editor). Proteaflora Enterprises (Pty.)Ltd., Melbourne: 81 - 100.

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C. Struik (Pty.)Ltd., Cape Town: 216 - 230.

Table 1 - Chemical composition of the basic nutrient solution

Macronutrients	Concentration (mmols l^{-1})	Micronutrients	Concentration (mmols l^{-1})
Ammonium sulphate	3.0	Boric acid	0.00725
Potassium chloride	1.25	Manganese chloride	0.0045
Potassium dihydrogen phosphate	0.5	Copper sulphate	0.002
Calcium chloride	1.5	Zinc sulphate	0.00055
Magnesium sulphate	1.5	Molybdic acid	0.0005
Iron sulphate	0.25		

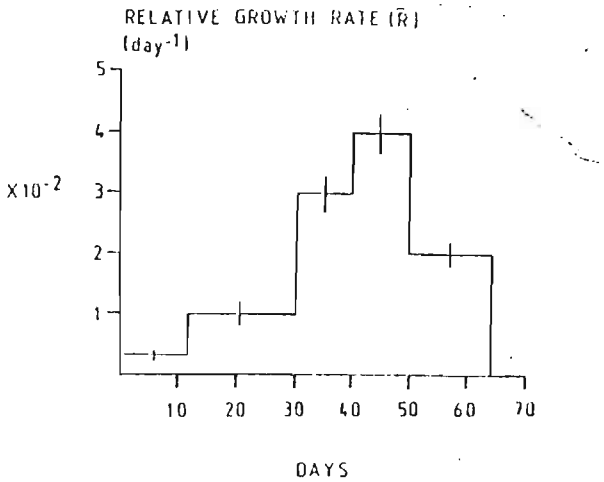


Figure 1 - Generalised growth pattern of L. s a l i g n u m seedlings grown in de-ionised water only.

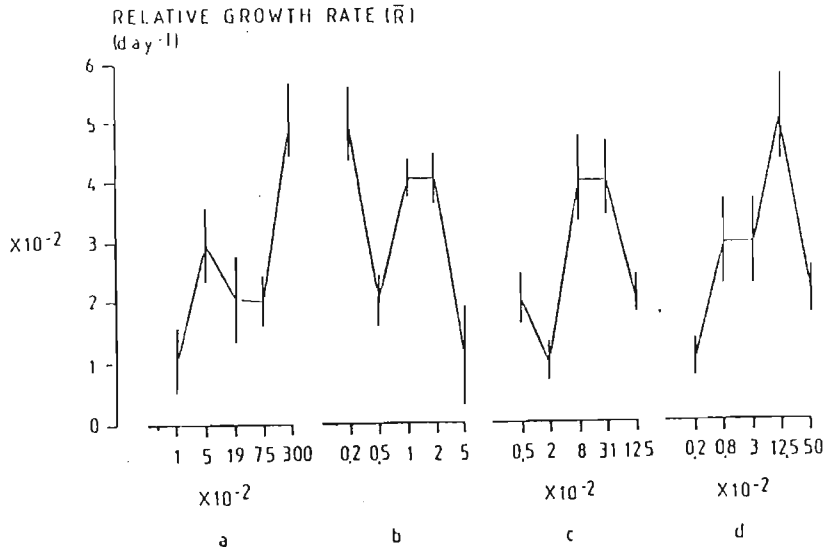


Figure 2 - Relative growth rates of L. s a l i g n u m seedlings grown under varying:
(a) Ammonium nitrogen concentrations (mmoles l^{-1})
([K] at 1.25 and [P] at 0.5 mmoles l^{-1} kept constant)
(b) Nitrate/ammonium ratios
([N] at 3.0; [K] at 1.25 and [P] at 0.5 mmoles l^{-1} kept constant)
(c) Potassium concentrations (mmoles l^{-1})
([N] at 3.0 and [P] at 0.5 mmoles l^{-1} kept constant)
(d) Phosphorus concentrations (mmoles l^{-1})
([N] at 3.0 and [K] at 1.25 mmoles l^{-1} kept constant).

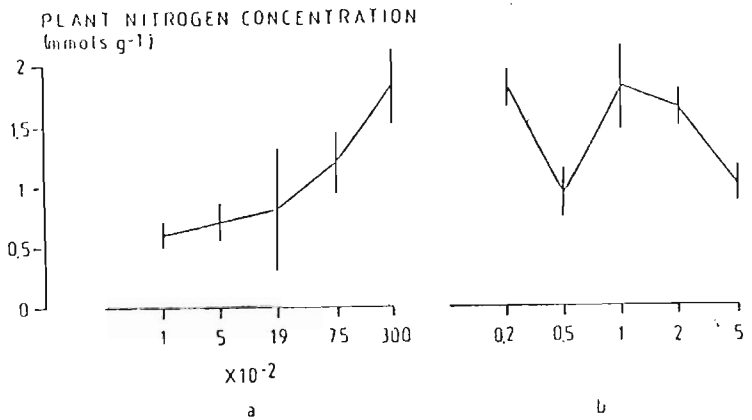


Figure 3 - Plant nitrogen concentration of L. s a l i g n u m seedlings grown under varying:
(a) Ammonium nitrogen concentrations (mmoles l^{-1})
([K] at 1.25 and [P] at 0.5 mmoles l^{-1} kept constant)
(b) Nitrate/ammonium ratios
([N] at 3.0; [K] at 1.25 and [P] at 0.5 mmoles l^{-1} kept constant)

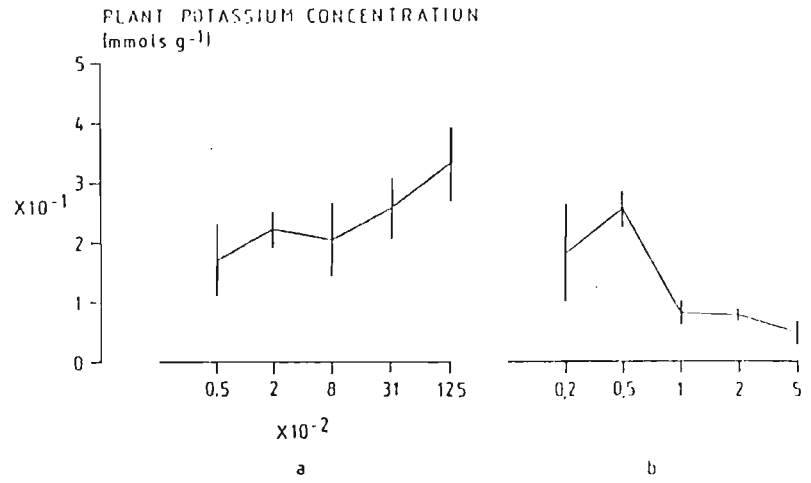


Figure 4 - Plant potassium concentration of L. s a l i g n u m seedlings grown under varying:
(a) Potassium concentrations (mmoles l^{-1})
([N] at 3.0 and [P] at 0.5 mmoles l^{-1} kept constant)
(b) Nitrate/ammonium ratios
([N] at 3.0; [K] at 1.25 and [P] at 0.5 mmoles l^{-1} kept constant)

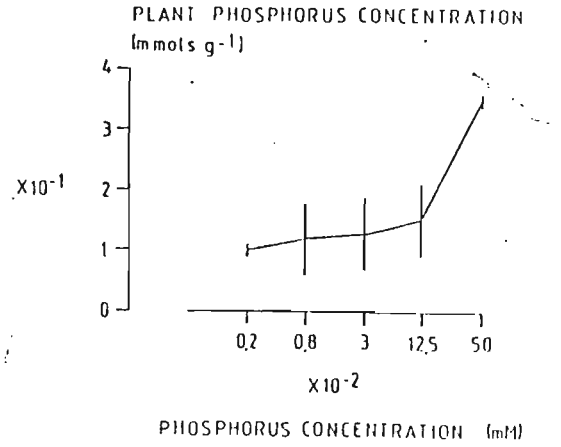
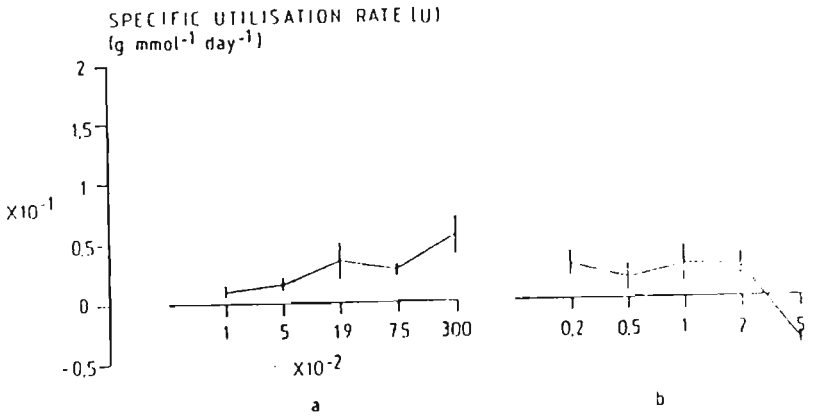


Figure 5 - Plant phosphorus concentration of L. s a l i g n u m seedlings grown under varying phosphorus concentrations (mmoles l^{-1})
([N] at 3.0 and [K] at 0.5 mmoles l^{-1} kept constant).



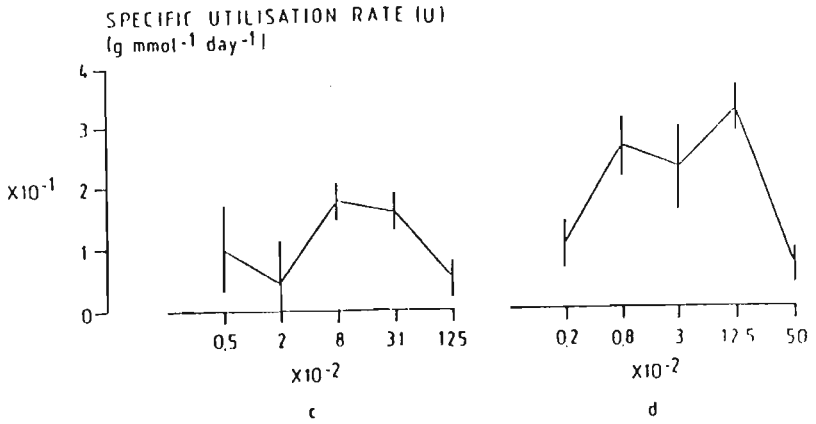


Figure 6 - Specific utilisation rate of L. s a l i g n u m seedlings grown under varying:
(a) Ammonium nitrogen concentrations (mmoles l^{-1})
([K] at 1.25 and [P] at 0.5 mmoles l^{-1} kept constant)
(b) Nitrate/ammonium ratios
([N] at 3.0; [K] at 1.25 and [P] at 0.5 mmoles l^{-1} kept constant)
(c) Potassium concentrations (mmoles l^{-1})
([N] at 3.0 and [P] at 0.5 mmoles l^{-1} kept constant)
(d) Phosphorus concentrations (mmoles l^{-1})
([N] at 3.0 and [K] at 1.25 mmoles l^{-1} kept constant).

USE OF TISSUE AND SOIL SAMPLES TO ESTABLISH NUTRITIONAL STANDARDS IN PROTEA

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Abstract

The first proteas in Hawaii grown for commercial cut flower production were planted in Kula. Few nutritional disorders were encountered. The soil in the Kula series is a member of an ashy, isothermic family of Typic Entrandepts. As the area for protea production expands, an increasing variety of soil types are being encountered, and what appears to be nutrient deficiency symptoms are appearing in certain species. In order to try and establish nutritional standards for proteas in Hawaii, a series of soil and plant tissue sampling was inaugurated to provide baseline data for both "normal" green plants and "abnormal" chlorotic plants.

Each plant was sampled 4 times over a 12 month period, starting in July, 1984. Juneviles and recently matured leaves were analyzed on an X-Ray fluorescent quantameter. Comparisons were made between age of leaf and between green and chlorotic leaves. Soil from around each plant was analyzed by the Soil Testing Service, U.H., using the rapid chemical method, and the Plant Disease Clinic, U.H., tested additional soil samples and root sections for the presence of nematodes.

Species sampled included Leucospermum cordifolium, Protea cynaroides, P. eximia, P. neriifolia, and P. hybrids "Yellow Rebe" and "May Day".

1. Introduction

The nutritional requirements of species of Proteaceae cultivated for commercial cut flower production are ill defined (Claassens, 1980) (Groves et al., 1976) (Parvin et al., 1973) (Tibbits et al. 1981) (Thomas, 1979, 1980, 1981) (Vogts, 1982). Much attention has been directed to the role of proteoid roots in the growth and development of the plant (Britz, 1984) (Lamont, 1983) (Vogts, 1982) (Voster, 1984).

Phosphorus, with a very low concentration required in the leaves of some species for maximum photosynthesis (Barrow, 1977), has been reported as a factor in death rates of Western Australian Banksias (Ellyard et al., 1978) and to reduction in yield of Leucospermum roots grown in sand culture (Claassens, 1980). Nichols et al. (1979) reported symptoms of phosphorous toxicity in some native Australian Proteaceae, and showed that high calcium aggravated the necrotic leaf symptom of high phosphorous while high nitrogen and potassium levels alleviated them (Nichols et al., 1981). Parvin et al. (1973) reported

a decrease in calcium levels in leaf samples comparing green leaves with red leaves.

As protea production in Hawaii expands from loamy soils to volcanic cinders and ash, the need for establishing nutritional guidelines as a basis for fertilizer recommendations is becoming of increasing importance.

2. Material and methods

Three commercially important genera of Proteaceae were selected: Banksia, Leucospermum and Protea. For the first stage of the project, both juneville and mature leaves were collected from each plant sampled. "Juneville" leaves had expanded to almost full size, but were very soft, and were collected within the apical 5 to 8 cm of the stem. "Mature" leaves were fully expanded, firm, and collected from the basal portion of the most recent vegetative flush of growth. "Recently matured" leaves is also an apt description. A sufficient number of leaves were collected to yield 5 gms of oven dried tissue. Leaves were weighed, washed, patted dry with paper towels and placed in a drying oven for 20 hours at 45 C. They were then weighed again for % moisture determination. Number of leaves required to yield 5 gms dry weight varied from 3 mature leaves of Protea cynaroides to 150 juneville leaves of Leucospermum cordifolium. Except for Leucospermum cordifolium, for which only green leaves were sampled, both "Green" - normal healthy foliage, and "Chlorotic" - yellow to red foliage, were collected from each species sampled. Tissue was analyzed on an X-Ray fluorescent quantameter in the Plant Diagnostic Center, University of Hawaii.

Duplicate 0.5 liter soil samples were collected from the root zone of each plant sampled. One was analyzed for nutrient levels by the U. H. Soil Testing Service, using the quick chemical method, and the other sample was analyzed for the presence of nematodes by the Plant Disease Clinic, U.H.

Plants sampled were located both on the Experiment Station and in adjacent growers fields. Where data is reported for all eleven plants (table 1 and table 2)the first Protea cynaroides G & C, and the first and last Protea neriifolia G & C, are from the Experiment Station. The second P. cynaroides and the second and third Protea neriifolia are from commercial fields, as are the Banksia occidentalis and Protea eximia samples. Where data is reported for three species (table 3, 4, 5) the samples were averaged together, regardless of location.

3. Results

Moisture percentages varied from a low of 50% for mature green Protea neriifolia leaves to a high of 68% for juneville chlorotic Protea cynaroides leaves.

With only 4 samplings over a 12 month period completed, the data is inadequate to establish nutritional standards at this time. Sampling

is scheduled to continue for 2 more years, after which some conclusions may be drawn. In comparing the tissue analysis of green and chlorotic leaves of three genera of Proteaceae (table 1), no consistent trends are apparent except for calcium and manganese, which again show significant decrease in levels from green to chlorotic. The soil analysis (table 2) does not show a similar decrease in calcium.

The comparison of nutrient levels in junevile and mature leaves (table 3) reports data from analysis of green leaves, only, while the comparison of nutrient levels in green and chlorotic leaves (table 4) averages together the appropriate juvenile and mature leaf samples. Seasonal comparisons (table 5) report the average values of junevile and mature leaf samples for green leaves, only.

4. Discussion

Concerns regarding appropriate fertilizer applications to commercial protea plantations have arisen as production areas expand byond native habitats. Proteas, having evolved on soils of low fertility, are uniquely adapted to survive with little or no supplemental feeding. However, with the extremely high cost of land in Hawaii, "survival" is not enough. It is the goal of the commercial grower to do what ever is required to produce the highest quality cut flower possible. Long stems, vivid colors, good vase life, all are essential ingredients for survival in the highly competitive international marketplace. Appropriate fertilizer recommendations must necessarily be based on an understanding of the nutritional requirements of the crop. In Hawaii, we are embarked on a three year testing program to develop some information on the nutritional status of the crops we are growing. We welcome suggestions from any quarter and will be pleased to discuss the possibility of cooperative projects on proteas.

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Table 1. Proteaceae Tissue Analysis of 3 Genera

SPECIES	Percent							Parts per Million			
	N	P	K	Mg	Ca	S	Si	Cl	Al	Cu	Fe	Mn	Zn
BANKSIA													
occidentalis G[1]	1.22	0.10	0.30	0.35	0.56	0.12	0.08	0.36	624	5	177	111	18
occidentalis C[2]	1.20	0.11	0.31	0.35	0.50	0.10	0.08	0.57	626	6	299	102	22
LEUCOSPERMUM													
cordifolium G	1.18	0.09	0.49	0.22	0.53	0.14	0.03	0.25	190	6		248	30
PROTEA													
cynaroides G	0.81	0.08	0.30	0.12	0.87	0.08	0.01	0.10	42	6	91	145	18
cynaroides C	1.14	0.08	0.36	0.10	0.26	0.06	0	0	28		52	48	10
cynaroides G	1.13	1.05	0.70	0.18	0.80	0.07	0.01	0.15	36	7	97	100	19
cynaroides C	1.24	0.11	0.62	0.17	0.46	0.06	0.02	0.16	45	8	96	49	19
eximia G	1.28	0.11	0.59	0.14	0.77	0.09	0.02	0.15	50	6	114	78	22
eximia C	1.19	0.10	0.59	0.13	0.44	0.07	0.02	0.17	99	8	107	38	18
May Day G	1.10	0.09	0.56	0.17	0.77	0.10	0.01	0.14	87		204	78	24
May Day C	1.48	0.11	0.63	0.10	0.38	0.08	0	0	198		208	74	16
Yellow Hebe G	1.02	0.10	0.66	0.05	0.60	0.11	0.01	0.10	168	8	119	130	17
Yellow Hebe C	0.91	0.08	0.68	0.07	0.35	0.11	0.02	0.16	207	9	84	94	18
neriifolia G	1.13	0.10	0.64	0.15	0.56	0.11	0.02	0.11	155	6	112	89	21
neriifolia C	1.00	0.08	0.52	0.14	0.39	0.08	0.02	0.10	114	8	108	71	16
neriifolia G	0.96	0.11	0.69	0.16	0.84	0.08	0.02	0.15	92	8	152	98	21
neriifolia C	1.06	0.10	0.76	0.13	0.40	0.07	0.02	0.19	102	8	126	48	21
neriifolia G	0.98	0.09	0.47	0.13	0.57	0.08	0.02	0.13	83		94	64	19
neriifolia C	1.08	0.10	0.48	0.12	0.27	0.08	0.02	0.15	156		100	31	20
neriifolia G	0.92	0.08	0.50	0.17	0.40	0.09	0.02	0.13	69		92	49	18
neriifolia C	1.29	0.10	0.68	0.16	0.30	0.09	0.02	0.17	90		98	36	18

[1]Green Leaves; [2]Chlorotic Leaves

Table 2. Soil Analysis-Root Zone of 7 Species of Proteaceae

SPECIES		pH	Pounds Per Acre P	K	Ca	Mg
BANKSIA						
occidentalis	G[1]	6.2	<25	120	4800	1700
occidentalis	C[2]	7.1	<25	220	6000	2000
LEUCOSPERMUM						
cordifolium	G	6.47	<25	110	5250	1000
PROTEA						
cynaroides	G	6.77	<25	130	5000	1250
cynaroides	G	6.75	<25	140	6000	1100
cynaroides	C	6.6	<25	165	5850	1350
eximia	G	6.45	<25	180	5850	1100
eximia	C	6.4	<25	112	5750	875
May Day	G	6.8	<25	240	5800	1000
Yellow Hebe	C	6.47	<25	120	5800	1000
neriifolia	G	6.87	<25	160	5500	2000
neriifolia	C	6.7	<25	150	5250	>2250
neriifolia	G	6.75	<25	220	5900	900
neriifolia	C	6.6	<25	200	5900	1100
neriifolia	G	6.57	<25	205	5700	950
neriifolia	C	6.47	<25	80	5650	550
neriifolia	G	6.55	<25	193	5833	1100
neriifolia	C	6.2	<32	225	6000	1350

[1]Green Leaves: [2]Chlorotic Leaves

Table 3. Comparison of Analysis of Juvenile and Mature leaves in Three Species of Proteaceae

ELEMENTS	L. cordifolium[1]		P. cynaroides[2]		P. neriifolia[3]	
	Juvenile	Mature	Juvenile	Mature	Juvenile	Mature
% N	1.10	1.27	1.07	0.88	1.05	0.94
% P	0.10	0.08	0.11	0.08	0.10	0.09
% K	0.44	0.55	0.44	0.56	0.51	0.63
% Mg	0.19	0.24	0.12	0.19	0.15	0.16
% Ca	0.38	0.67	0.62	1.05	0.53	0.63
% S	0.11	0.16	0.08	0.08	0.08	0.10
% Si	0.04	0.03	0.01	0.01	0.02	0.02
% Cl	0.32	0.17	0.12	0.13	0.13	0.13
PPM Al	195	186	22	56	77	119
PPM Cu	6	6	6	6	6	8
PPM Fe	119	117	92	96	117	106
PPM Mn	187	309	93	152	63	83
PPM Zn	35	24	18	19	20	19

[1]Average of 4 sampling dates from 1 plant.
[2]Average of 4 sampling dates from 2 plants.
[3]Average of 4 sampling dates from 4 plants.

Table 4. Comparison of Analysis of leaves from Green and Chlorotic Plants of 3 Species of Proteaceae

ELEMENTS	L. cordifolium[1]		P. cynaroides[2]		P. neriifolia[3]	
	Green	Chlorotic	Green	Chlorotic	Green	Chlorotic
% N	1.13		0.97	1.22	0.99	1.13
% P	0.09		0.10	0.11	0.09	0.10
% K	0.49		0.50	0.56	0.57	0.62
% Mg	0.22		0.15	0.16	0.15	0.14
% Ca	0.53		0.83	0.42	0.58	0.34
% S	0.14		0.08	0.06	0.09	0.08
% Si	0.03		0.01	0.01	0.02	0.02
% Cl	0.25		0.13	0.12	0.13	0.16
PPM Al	190		39	40	98	114
PPM Cu	6		6	8	7	8
PPM Fe	118		94	87	112	107
PPM Mn	248		122	48	73	44
PPM Zn	30		18	17	20	19

[1]Average of juvenile & mature leaves on 3 sampling dates--1 plant.
[2]Average of juvenile & mature leaves on 3 sampling dates--2 plants.
[3]Average of juvenile & mature leaves on 3 sampling dates--4 plants.

Table 5. Comparison of Analysis of leaves sampled at 4 seasons of Year.

SPECIES	Fall[1]	Winter[2]	Spring[3]	Summer[4]
Leucospermum cordifolium				
N	1.24	1.14	1.20	1.08
P	0.12	0.08	0.08	0.07
K	0.48	0.55	0.52	0.42
Mg	0.16	0.14	0.16	0.33
Ca	0.82	0.52	1.09	0.82
Protea cynaroides				
N	0.84	0.96	1.14	0.95
P	0.12	0.10	0.11	0.68
K	0.43	0.49	0.68	0.41
Mg	0.16	0.18	0.12	0.17
Ca	0.27	0.44	0.66	0.92
Protea neriifolia				
N	0.81	0.78	1.37	1.11
P	0.08	0.06	0.10	0.10
K	0.56	0.52	0.64	0.59
Mg	0.06	0.24	0.24	0.13
Ca	0.40	0.46	0.56	0.66

[1]September; [2]November; [3]March; [4]June

PHOSPHORUS NUTRITION OF LEUCADENDRON "SAFARI SUNSET"

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Abstract

A range of available soil phosphorus concentrations was obtained by adding superphosphate to potting mixtures and field soil or by the application of amendments to field soil.

Growth was good over a range of available phosphorus concentrations suggesting that Leucadendron was tolerant to high rates of applied phosphate. Growth was increased at the lower application rates in pots but not in the field.

Available phosphorus was related to application rate but not to phosphorus uptake. Amendments reduced soil pH and phosphorus uptake but did not give a yield response.

1. Introduction

High soil phosphorus (P) has been generally accepted as detrimental to Proteaceous plants (Claassens, 1981) and shown to be harmful in some situations (Thomas, 1974; Nichols et al., 1979) but no critical soil P values specifically for Leucadendron "Safari Sunset" were available in the literature.

Following a resurgence of interest in Proteaceous cut flower production in New Zealand sites previously used for market gardening were being considered for the cultivation of these crops particularly Leucadendron. These sites were high in soil P due to previous phosphate fertiliser applications.

Consequently, pot and field experiments were conducted to determine the growth response to a range of available soil P concentrations. In addition, plant and soil responses to soil amendments aimed at reducing P availability on a high P site were assessed.

2. Materials and methods

One glasshouse and two field experiments were done.

2.1. Glasshouse study

Rooted seven node cuttings were grown in 0.7 litre containers in a four replicate randomised block designed experiment with six P rates, and two media.

The rates of superphosphate (9% P) were 0, 50, 300, 450, 600 and 750 mg/l. The media (by volume) were (i) Hauraki Peat 90% and soil 10% (ii) Pumice 60% and soil 40%.

The soil used was Levin silt loam which had a high P retention (80%) and low available P (8 ppm). A base fertiliser application (per litre) consisting of ammonium sulphate 2.0 g, potassium sulphate 1.25 g dolomitic limestone 4.0 g, and fritted trace element FM255 400 mg, was applied to all treatments.

During the last three months of the experiment supplementary liquid fertiliser of N 200 ppm and K 150 ppm was given at fortnightly intervals. The plants were grown at 16°C heat and 22°C ventilation set points. The experiment was started on 21 August 1981.

2.2. P rates field study

Two year old container-grown plants in a peat/pumice medium (equal proportions by volume) were used in an eight P rate, three replicate experiment on Levin silt loam. The superphosphate rates of 0, 2, 4, 6, 8, 10, 13 and 16 t/ha were applied 12 months prior to planting. Plots were 6 m^2 and contained two equally spaced plants. A nitrogen fertilizer (Osmocote 26-0-0) was applied at a rate of 50 g per plot at the start of each season. Since this soil had a moderately high level of exchangeable K (220 ppm) no fertilizer K was added.

This study commenced in December 1983 and plant performance followed for two years. Plant analyses were done on 21 May 1984 and 21 March 1985 and soil analyses on 6 December 1983 and 2 April 1984.

2.3. Soil amendment study

Twelve month old container-grown plants in the same medium as in 2.2 above were planted on 28 August 1982 into 1 m^2 single plant plots. The amendments had been uniformly applied to the soil surface one month before planting. The treatments were; (i) sulphur 2 t/ha, (ii) ferrous sulphate 5 t/ha, (iii) a combination of (i) and (ii), and (iv) a non-treated control. A randomised block design with eight replications of treatments was used. The amendments were repeated on 21 June 1983.

No fertilizers were added during the experiment because the exchangeable K was high (346 ppm) and the site had previously been in pasture for some years.

2.4. Assessment of effects

Growth was assessed in both field experiments by stem width measurement with callipers (calliper) at 150 mm above ground level and by counts of shoot production either total shoots (P rates study) or those at least 100 mm in length. The amendment study also included yield and quality measurements. For yield, flowering stems were cut when the cone showed at least 25% of its length beyond the inner surround of bracts. First grade stems were at least 300 mm in length, straight, unblemished, uniformly coloured, with a minimum primary 'flower' diameter of 60 mm. Non-flowering stems were not graded.

The extent and intensity of red pigmentation in the shoot tips was rated on a 1-5 scale.

Leaf samples were taken of at least 20 youngest mature leaves on non-flowering shoots. They were dried, ground and digested with H_2SO_4 and selenium and analysed for P, N, K, Ca and Mg by standard methods (O'Neill and Webb, 1970). Soil analyses were done on samples drawn from 6 random 0-150 mm depth cores for each plot. After the samples were dried and ground, P was extracted with sodium bicarbonate (Olsen et al., 1954) and determined colourimetrically. Methods for the determination of soil K, and pH were those given in M.A.F.

(1979).

In the greenhouse study, shoot dry weight was determined after drying above-ground parts of the plant at 105°C for 24 hours. The relationships between dry weight production and both soil available P and leaf P was found by fitting a square root second order function of the form $y = a + bx^{\frac{1}{2}} + cx$.

3. Results

3.1. Glasshouse study

The growth response to available soil P (figure 1) was similar for both media though the size finally achieved was greater for the peat/soil medium. While the response was steep for the lower values it reached a plateau at about 25 ppm available P. Leaf P was negatively correlated with growth but only for the peat/soil medium ($r = -0.35$)

For plants in the peat/soil medium leaf P ranged from 0.017 to 0.175% dry matter (dm) and was not significantly related to available soil P. In soil/pumice leaf P was related to available P ($r=0.36$, $P=0.05$).

3.2. P rate field study

The concentrations of available soil P from a sample taken on 6 December 1983 were significantly correlated with those from a sample taken 2 April 1984 ($r = 0.99$, $P = 0.001$) and only the results from the first sampling will be reported.

There was a relationship between the amount of superphosphate applied for both available soil P ($r = 0.99$, $P = 0.001$) and leaf P concentration (21 Mar 1985) the latter being negative ($byx<0$, $P = 0.05$) Leaf P concentration declined between samplings.

Since stem calliper and shoot number were highly correlated ($r = 0.85$, $P = 0.01$) only shoot data (table 2) will be given. Shoot numbers showed no significant differences between the levels of phosphate applied nor was there indications of an upwards or downward trend in the means using linear regression. No symptoms suggestive of P toxicity were apparent at any time in the experiment.

3.3. Soil amendment study

3.3.1. Soil and plant analyses

Compared with the control, all three amendment treatments significantly reduced soil pH one month after planting (table 3). The greatest reduction occurred with the sulphur and ferrous sulphate combination. This combination was more effective at lowering the pH than was each component separately. Immediately before re-application of the amendments, 10 months after initial treatment, similar effects on pH were still apparent except that the pH under the sulphur treatment had fallen further, and no longer differed from the combination treatment.

The available soil P following planting did not differ between treatments (table 3) but at the second sampling prior to re-application it was significantly higher under both treatments containing sulphur. Ferrous sulphate alone did not reduce available soil P significantly.

Approximately a month before the second soil sampling (21 June, table 3), significant reductions in leaf P content were found in both treatments receiving sulphur even though available soil P was increased. Ferrous sulphate did not significantly affect the P content of the leaves.

There was a highly significant relationship between leaf P at 25 May (table 3) and pH at 21 June ($r = 0.73$).

3.3.2. Growth and yield

Stem calliper, shoot counts and yield in the first season revealed no significant differences between any of the treatments. Mean stem calliper and shoot count per plant over all treatments were 8.3 mm and 6.6 in October, 10.3 mm and 6.0 in December and 15.1 mm and 9.5 in April. Total flowering stem yield ranged between 2 and 3 per plant.

In the following season a significant yield difference was apparent between sulphur and the combination in the non-flowering component (table 4). Although the mean yield of total flowering stems was highest on the $FeSO_4$ treatments there was no significant difference between treatments.

There was no significant correlation between leaf P on 25 May and the number of flowering ($r = 0.04$) or non-flowering ($r = 0.05$) stems. The range in leaf P concentrations was from 0.055 to 0.145% dm.

3.3.3. Pigmentation

In both seasons the treatment receiving sulphur alone resulted in a significant increase in redness of the shoot tips when compared with the control (table 5). Treatments containing ferrous sulphate were not different from the control in this feature. The treatment receiving sulphur showed a significant increase in redness compared with the combination treatment.

4. Discussion

Leucadendron "Safari Sunset" grown in containers was not very susceptible to high P uptake provided realistic levels of phosphate were applied. At no time was there any indication of toxic symptoms on the foliage attributable to excess phosphate such as those reported by Nichols et al., (1979). On the contrary, our trials showed that low available soil P would impede the growth of Leucadendron "Safari Sunset". Values of available P of over 25 ppm were adequate. In addition the field trial showed that leaf P was not positively correlated with superphosphate rate over the range used and on this soil. Consequently, it was not possible to propose critical leaf P values for this crop.

These results contradict the general view that members of the Proteaceae are very sensitive to phosphate concentration in the soil. Growth reduction at the highest rates of superphosphate was not as

pronounced as those found by other authors for Proteaceous plants in containers. Both Thomas (1980, 1974) and Nichols et al., (1979) used very high rates of soluble P (300 and 177 mg P/litre) and these would be high even for the usual range of container grown nursery stock and potted plants. For example the recommended rates of soluble P added to mixes in Europe and U.S.A. ranged between 26 and 120 mg per litre (Bunt, 1976) and in New Zealand 90 mg was recommended (Prasad, 1983).

While reductions in soil pH, brought about by the amendments, were associated with reduced leaf P concentrations no major yield responses attributable to this change in pH occurred. Providing a yield response was likely within the range of leaf P concentrations found, then it is possible that the sulphur amendment in particular inhibited an expression of this effect. The increase in shoot redness (table 5), when interpreted as induced chlorosis, supports this interpretation.

The application of sulphur amendments to soils of this type would not be an appropriate strategy to adapt sites with high available P for Leucadendron production.

The increase in soil P availability suggested by the increase in Olsen P under the sulphur amendments was possibly an artefact of the extraction method.

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Table 1 - The effect of superphosphate application rate on available soil P and leaf P concentration for Leucadendron "Safari Sunset".

Rate (t/ha)	Soil P 6 Dec 1983 (ppm)	Leaf P 21 May 1984 (% dm)	Leaf P 21 Mar 1985 (% dm)
0	11. 3	0. 16	0. 07
2	20. 4	0. 14	0. 07
4	27. 0	0. 14	0. 06
6	34. 0	0. 16	0. 06
8	40. 9	0. 16	0. 06
10	60. 6	0. 14	0. 05
13	72. 7	0. 14	0. 05
16	83. 8	0. 11	0. 06
MSD (5%)	8. 3	0.053	0.012

Table 2 - Effect of superphosphate application rate on the production of new shoots for Leucadendron "Safari Sunset".

Rate (t/ha)	Shoot numbers (count/plant) 21 Dec 83	2 Apr 84	4 Mar 85
0	1. 7	8. 5	33. 8
2	1. 7	8. 5	37. 3
4	1. 2	9. 0	41. 3
6	1. 8	6. 3	39. 5
8	2. 3	6. 7	34. 7
10	1. 7	7. 8	33. 8
13	2. 3	8. 2	44. 5
16	1. 2	8. 2	32. 8
MSD (5%)	1.79	4.19	11.29

Table 3 - Soil and plant analyses in the soil amendment study

Treatment	Soil 26 Sep 82 pH (H_2O)	Soil 26 Sep 82 P (ppm)	Soil 21 Jun 83 pH (H_2O)	Soil 21 Jun 83 P (ppm)	Plant 25 May 83 P (%)
S	5. 01	48	4. 21	55	0.0778
$FeSO_4$	4. 93	45	4. 86	43	0.0980
S + $FeSO_4$	4. 71	45	4. 29	56	0.0708
Control	5. 28	46	5. 18	46	0.1129
MSD (5%)	0. 20	3. 1	0. 26	5. 2	0.0159

Table 4 - Yield of stems (count/m^2) for the soil amendment study in 1984

Treatment	Flowering Total	Flowering First Grade	Non-Flowering Total (count/m^2)
S	10. 0	3. 5	6. 9
$FeSO_4$	15. 3	6. 9	5. 4
S + $FeSO_4$	9. 8	4. 8	3. 4
Control	13. 6	5. 6	4. 8
MSD (5%)	11. 4	6. 1	3. 04

Table 5 - Red pigmentation on shoot tips at two dates. (1 pale, 5 intense)

	21 Jun 1983	13 Apr 1984
S	4. 00	3. 69
$FeSO_4$	2. 63	2. 63
S + $FeSO_4$	3. 13	2. 89
Control	2. 63	2. 75
MSD (5%)	0.668	0.679

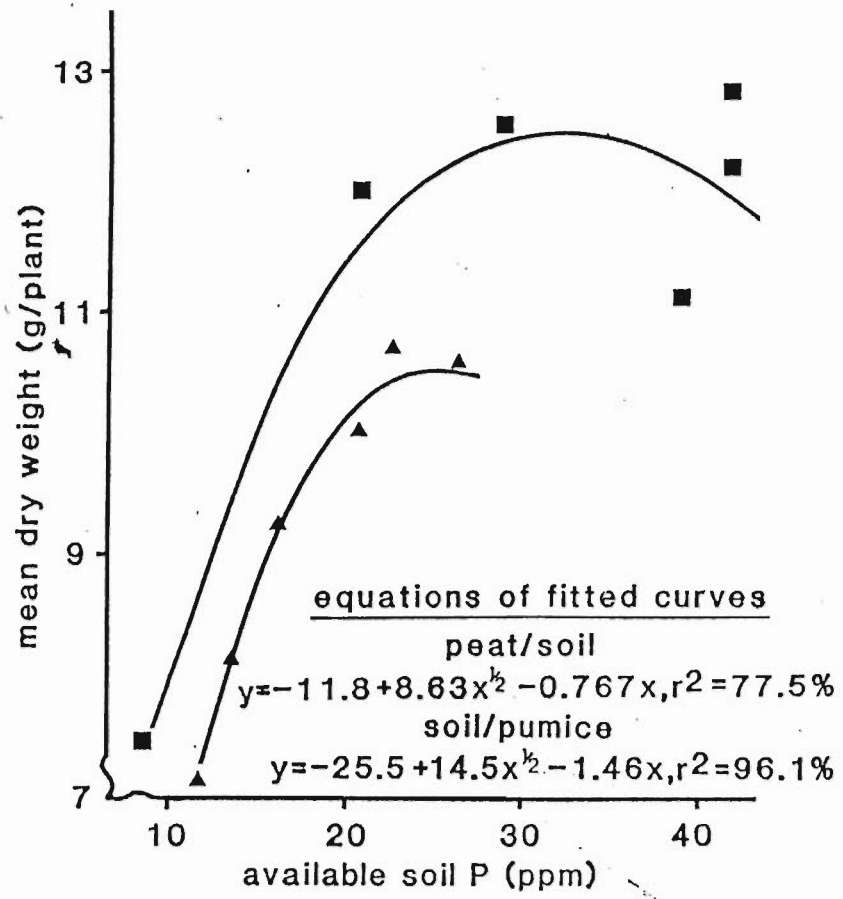

Figure 1. Relationship between growth (dry weight) of Leucadendron 'Safari Sunset' and available Soil P for two composts.

■ peat/soil ▲ soil/pumice

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Summary

Dense clusters of hairy rootlets, called proteoid roots, are a feature of all cultivated species of protea. They form a 2-5 cm thick mat at the soil surface and are most prolific where there is decomposing litter. They are most abundant under the plant's canopy but can extend for much greater distances. Their prime function is to enhance nutrient uptake but they probably have a major role in water uptake as well. Their formation is suppressed by high nutrient availability, clayey soils, waterlogging and drought and enhanced by organic matter, soil bacteria (which do not invade the root) and moisture. Crop management practices should emphasise minimal root disturbance: a) rotavating is not recommended, b) weed control is important, via slashing or contact herbicides, c) restraint should be exercised with applications of chemicals, especially fertilizers high in phosphates, d) build up of a surface mulch diminishes the need for fertilizers, e) plants in fertile soils will need more regular watering during dry periods, f) delay fertilizer-application immediately after transplanting.

1. Introduction

Proteoid roots are dense clusters of rootlets that are produced by all cultivated species of protea. Individual proteoid roots vary in length from a few mm to over 10 cm in length and may consist of hundreds or even thousands of hairy rootlets (figure 1). The aim of this paper is to review the current status of knowledge about these peculiar roots, with particular reference to their role in horticultural practice.

2. Taxonomic distribution

All species and plants of proteas in cultivation probably possess proteoid roots. Every species so far examined in the following commercially-grown genera has proteoid roots: L e u c a d e n d r o n, L e u c o s p e r m u m, M i m e t e s, P r o t e a, S e r r u r i a, B a n k s i a, D r y a n d r a, G r e v i l l e a, I s o p o g o n and T e l o p e a, and all others which so far are only grown in gardens or picked for the trade from the wild (Lamont, 1982, 1983a).

3. Occurrence in root system

Seedlings usually possess scores of proteoid roots by the end of their first growing season. By the second year they may account for up to 56% of the weight of the root system (Lamont, 1972b; Brits, 1983). As the plant ages, proteoid roots make up an increasing proportion of

annual growth of the surface root system. They tend to be concentrated in a 2-5 cm thick band at the soil surface (Jeffrey, 1967; Lamont, 1973; Lamont et al. 1984; Brits, 1983). When decomposing litter is present they are even more concentrated in this than in the humus-containing layer beneath. Proteoid roots will grow up into the litter under the plants as the litter decomposes. All species tend to form a surface mat of proteoid roots, but it is most extensive in Banksias and Hakeas (Jeffrey, 1967). Proteoid roots can arise either from ongoing growth of the laterals - they have been located up to 9 m away from 1.5 m wide plants of several Banksia species (Lamont et al., 1985). They also develop on new laterals produced adventitiously, often near the base of the parent plant (Lamont, 1972a). Proteoid roots are much more concentrated under the plant's canopy than outside (Lamont, 1973), but many may belong to other plants.

4. Function

The surface area to weight ratio of proteoid roots is almost 15x that of the parent roots in *Leucadendron laureolum* (Lamont et al., 1984). This large relative surface area was early on held responsible for up to 13x greater uptake of ^{32}P added under experimental conditions (Green, 1976 in Lamont, 1982). More recently, I have shown that this structure provides greater access to soil particles and so shortens the diffusion path for nutrients (Lamont, 1983b; Lamont et al., 1984). In a series of outstanding chemical papers, Gardner and his colleagues have demonstrated for the legume, *Lupinus albus*, that its proteoid roots have a strong reducing, acidifying and chelating capacity for poorly-soluble sources of manganese, iron and phosphorus (Gardner et al., 1981, 1982a, 1983) - this results in increased rates of nutrient release, diffusion to and exchange at the root surface. Proteoid roots act like a sponge as well as a mat, but their undoubted role in water absorption has received little attention from researchers. They readily form in localized wet pockets of soil, even during summer when the rest of the surface root system is dry (Lamont, 1976).

5. Factors affecting proteoid root formation

The number of proteoid roots in the root system varies greatly with soil type: as the proportion of clay to sand was increased, shoot growth fell slightly in three *Banksia* species, but proteoid root production dropped markedly - even to 0 in *B. aemula* (Siddiqi and Carolin, 1976). As plant growth increases in response to increasing soil nutrient availability, the number of proteoid roots at first increases, then it decreases (figure 2). If the initial levels of the same or other nutrients in the soil or plant are higher, the only response observed may be a decrease in proteoid root production when extra nutrients are applied (also see Gardner et al., 1982b). When given organic fertilizer high in phosphate, 18 month-old plants of *Leucadendron laureolum* in sand-peat grew 20% larger, but the number of proteoid roots fell from 390 per g root weight to 0 (Lamont et al., 1984).

Hakea prostrata was grown in sand culture for 6 months at different levels of nitrogen (N) and phosphorus (P). Plants at high

levels of nutrients lacked proteoid roots and had high shoot/root ratios compared with those possessing proteoid roots (figure 3). In this case, absence of proteoid roots implies increased susceptibility to drought, for a given shoot weight is supported by a much weaker root system than in plants with proteoid roots. In *Grevillea rosmarinifolia*, *Hakea suaveolens* and two *Banksia* species, plants only produced proteoid roots when N and P were omitted from the nutrient solution in sand culture, usually accompanied by an increase in root growth but not always a drop in shoot growth (Nicholls, Jones and Beardsell, pers. comm. 1979; Nichols et al., 1981).

There is an inverse relationship between nutrient content of the shoots and percentage of the root system that is proteoid (Lamont, 1973; Gardner et al. 1982b). Cuttings of *Grevillea* 'Poorinda Firebird' were grown in soil mixes which received 1.5 or 3.0 kg 240-day resin-coated fertilizer per m^3 or blood and bone at 2.5 kg/m^3. Plants which attained 10-20 g shoot weight possessed 10-20 proteoid roots, while those less than 10 g possessed only 0-3 proteoid roots (figure 4a). The former results were achieved when clay-loam soil was added to the soil mix (1:3) - the soil fixes P and buffers its potential toxic effects. The poor growth of the plants in unamended soil was clearly due to P toxicity, and this is associated with low proteoid root production (figure 4b).

Top-dressings or localized pockets of partly decomposing organic matter stimulate root growth generally and proteoid root production in particular (Lamont, 1973; Lamont and McComb, 1974; Lamont et al., 1984). This appears to be related to the extra nutrients available, as there is no stimulus when plant nutrients are already high. Another related cause is the greater microbial activity in these layers: there is now reasonable evidence that certain soil bacteria have an inductive role in initiation of proteoid roots. However, these microorganisms never invade the roots, and there is no truth in earlier ideas that proteoid roots are a type of mycorrhizal symbiosis (Lamont, 1972a).

In seasonal climates, proteoid root production is seasonal as it is tied to growth of the surface parent roots (Lamont, 1976; 1983). Limited additional water in summer can produce new shoot growth without new roots. Greater amounts of water will induce new root growth, including proteoid roots, as well. Total root growth, as well as percentage of the root system that is proteoid, is greatest at 1-2x field capacity and least at permanent wilting point in two *Hakea* species (Lamont, 1976). The root system and total proteoid root production are retarded at even higher levels of water application, although the number of proteoid roots per unit weight of root system may actually increase. There is limited evidence that pruning of young plants may reduce general root growth as well as the contribution of proteoid roots to the root system, but this needs study at the adult level (Lamont, 1973).

6. Management implications

Proteoid roots, and their supporting lateral roots, form a dense mat at the soil surface. This is best developed under the plant canopy but can extend 6x beyond the width of the canopy in old plants. This

surface mat appears to have a vital role in nutrient and water uptake by the plant, especially during the growing season. For example, 17 week-old plants of H a k e a l a u r i n a grew 26% larger when the proteoid root mat was in the uppermost 12 cm of the soil profile, than when it was shifted artificially to a depth of 24-36 cm (figure 5).

The mat develops at the soil surface, whether it is high in organic matter or not. However, it is much better developed in the presence of actively-decomposing litter. Use of black plastic as a mulch/weed suppressant has the disadvantage that it stops the proteoid roots growing up into the litter as it accumulates on the surface. The more recently-marketed woven matting has more to recommend it in this regard, but to what extent it strangles older roots has not been tested.

These observations imply that rotavating, especially close to the plant, could be lethal - the most important part of the root system is in danger of destruction. Other approaches to weed control must be adopted - post-emergence contact herbicides or mowing are to be favoured. It also follows that control of weeds is important - their shallow roots will actively compete with the proteoid roots. If hand-pulling is unavoidable, this should be done in such a way as to minimize root damage.

The presence of the mat implies that the plant is particularly sensitive to chemical treatments applied at the soil surface: applications of fertilizers, nematocides and fungicides have all been known to induce toxicity symptoms at levels recommended for other plant groups. It is especially important to delay applications of these after any type of root disturbance, as the damaged rootlets lose control over rates of uptake. Goodwin (1983) found that some species previously considered phosphorus-sensitive were not so in his experiments. He considered that plants only became sensitive to P when exposed to root damage, eg through transplanting, weeding, water deficits, frost, root pathogens and pests. Goodwin therefore advocated pasteurization of nursery soil and delaying fertilizer application until at least two weeks after transplanting. Even so, there is much to be said for the sparing use of fertilizers and those low in available P, such as hoof and horn and isobutylidenediurea in soil-less potting mixes (Nichols and Beardsell, 1981). An alternative approach is to incorporate material with high P-fixing properties, such as humus and clay-loam soil. These should also be valuable as top-dressings for row-crop plants.

Another approach to avoiding a sudden and lethal uptake of nutrients in response to heavy fertilizing, is to have high initial levels of nutrients in the potting mix or field soil. This reduces the presence of proteoid roots in the root system and buffers the effects of a sudden influx of chemicals. However, it carries the risk of nutrient toxicity, reduction in growth and flowering and increased susceptibility to drought, through an increased shoot/root ratio. There can be no denying that the presence of abundant proteoid roots is a sign of a healthy plant, whether in a pot or in the field. Much more attention needs to be given to the importance of the root system in affecting the welfare of the whole plant.

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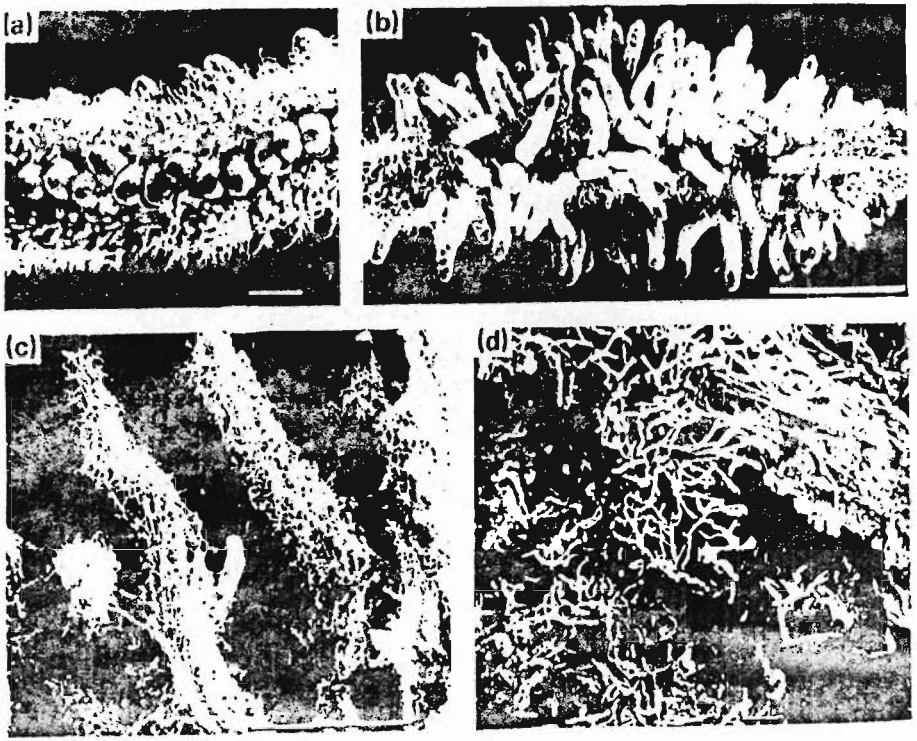

Figure 1. Scanning electron micrograph of proteoid roots of L e u c a d e n d r o n l a u r e o l u m. a) Proteoid rootlets just emerging from parent root. Scale 0.2 mm. b) Young proteoid root. Scale 1 mm. c) Mature proteoid rootlets densely covered in root hairs. Scale 1 mm. d) Proteoid rootlets affixed to sand grains and soil films via root hairs. Scale 0.1 mm. From Lamont et al. (1984).

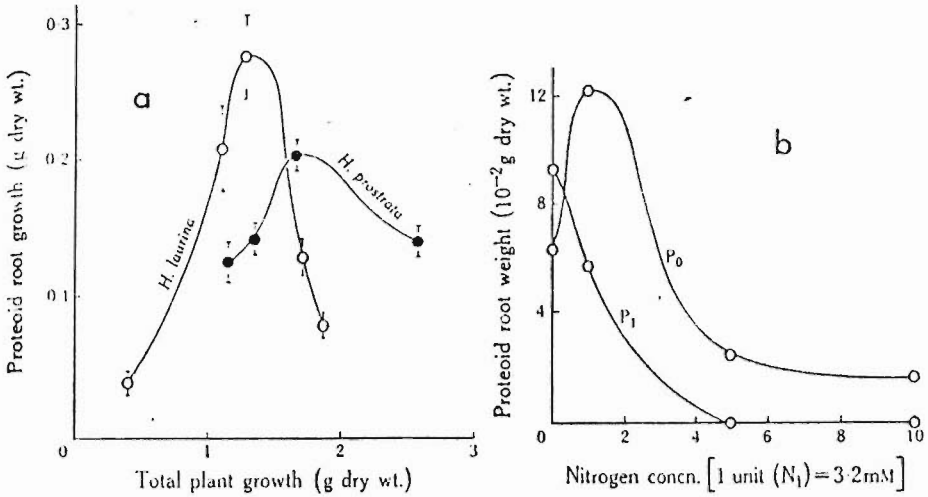

Figure 2. a) Variation in production of proteoid roots by two H a k e a species with increase in total plant growth. The points were obtained for greenhouse plants grown in a range of naturally-occurring soils. b) Increase then decrease in production of proteoid roots by H a k e a p r o s t r a t a as nitrogen concentration of the nutrient solution is increased in sand culture at low phosphorus-nutrient solution (P_0). At higher levels of phosphorus (P_1) proteoid root production is lower at any level of nitrogen. After Lamont (1972).

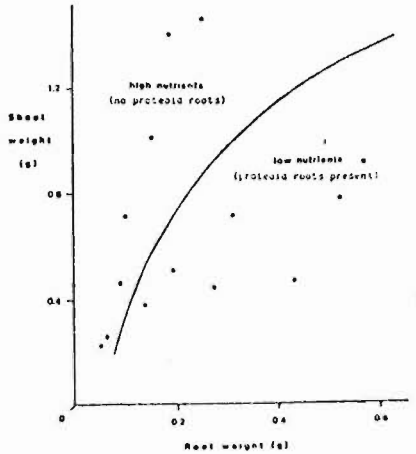

Figure 3. Shoot and root growth of H a k e a p r o s t r a t a grown in sand culture at varying levels of nitrogen and phosphorus in the nutrient solution. The curve separates those plants possessing proteoid roots (to the right) and those without them (to the left). After Lamont (1985).

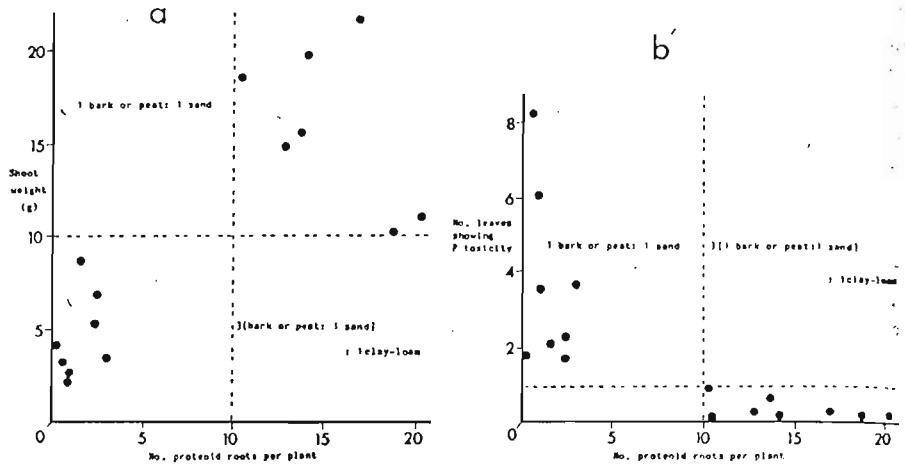

Figure 4. Relationship between occurrence of proteoid roots and a) shoot growth and b) number of leaves showing phosphorus toxicity, for potted plants of G r e v i l l e a 'Poorinda Firebird'. The broken lines separate plants grown in a bark/peat: sand mix plus resin-coated fertilizer or blood and bone (on the left), and the same mix with 25% clay-loam added (on the right). Drawn from data in Nichols et al. (1979).

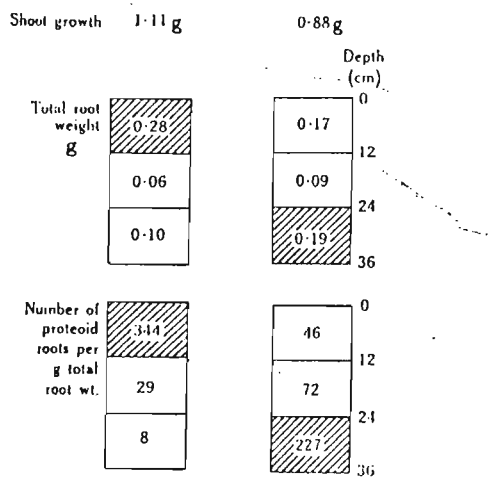

Figure 5. Variation in root weight and numbers of proteoid roots through the soil profile for H a k e a l a u r i n a grown in cylinders. 'Normal' and proteoid roots are concentrated in the layer high in decomposing litter (hatched) in contrast to the rest of the profile (yellow sand) independent of its position in the profile. From Lamont (1973).

SOME ASPECTS OF THE NUTRITION OF PROTEAS

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Abstract

Several protea species were grown in sand cultures where the influence of salt concentration, N, P, K and Na supply and N source on their growth and nutrient uptake were studied. Nutrients were supplied by means of a half strength Hoagland nutrient solution modified to supply N mainly as NH_4.

Species differences in response to the treatments were observed and these differences were also found for a single species from different localities.

The largest differences were obtained by varying the N supply. Some species did not grow well with NO_3 only while all did well with NH_4 only. Relatively high concentrations of NH_4 could be tolerated. With the addition of Na to the nutrient solution even higher NH_4 concentrations could be tolerated.

All species were sensitive to high P concentrations. Relatively high total salt concentrations could be tolerated if the P concentration was within acceptable limits. Relatively low concentrations of the various nutrients are required for normal growth.

1. Introduction

In recent years the cultivation of proteas for cut flower production has developed considerably. In South Africa, where it is common practice to harvest flowers from the veld, the situation is changing because of competition and quality demands from overseas markets and it has become necessary to produce more and better quality flowers under intensive cultivation. However, information on the nutrient requirements of proteas is limited. Up to now very little fertilization has been done on proteas because under natural conditions it is observed that growth is usually favourable on highly leached, well drained acid soils (Vogts, 1958; 1977a; 1977b). This has, in fact, also been observed for other plants of the proteaceae family (Jeffrey, 1964; Moore, 1966; Hocking and Thomas, 1974). Although the nutrient demands of the protea plants may be low conciderable amounts of nutrients may be removed by regular harvesting of flowers. The question arises however, whether continued production of good quality flowers can be maintained without replenishing these nutrients.

The primary objective of this investigation was therefore to gain more information on the nutritional requirements for the satisfactory growth of proteas, with particular reference to salt concentration and variation in nutrient element supply.

Materials and Methods

Different experiments were carried out in a glasshouse in sand culture. Sixteen kg washed quartz sand was used in Mitscherlich vegetation vessels, with one plant per pot which was supplied with nine

dm^3 of nutrient solution. Excess nutrient solution was recycled regularly and water loss due to evapo-transpiration replenished with deionised water. The nutrient solutions were replaced every eight weeks.

As test material, rooted cuttings of different protea species were used. After an initial period of growth in a modified half strength Hoagland No 2 nutrient solution (Bonner & Galston, 1952), plants were selected for uniformity before applying the treatments. Plants were harvested prior to the flowering stage, four to six months after planting. Dry mass (65°C) of top growth was recorded and this was pooled for chemical analysis.

Ca, Mg and K were determined on wet ashed samples by atomic absorbtion spectrophotometry (Chapman & Pratt, 1961;) N, S and P by auto analyzer (Basson & Bölmer, 1977; Technicon Auto Analyzer II, 1977).

Variation in nutrient element supply was based on modifications of the Hoagland No 2 culture solution to provide for different total salt levels, P, K and N and NH_4 vs NO_3 ratios. As a control an approximately 0,6 strength Hoagland solution (0,6 H) was used with N mainly as NH_4 being balanced by SO_4. No effect of varying SO_4-supply was expected on the basis of earlier work (Hamner, 1940; Mullison, 1941; Grobler, 1976).

In experiment 1 a protea hybrid known as Ivy (Protea longiflora x P lacticolor) and Leucospermum cordifolium were used. The objective of this experiment was to determine the influence of variation in total salt concentration, P-supply and nitrogen source. The treatments were replicated four times and are given in Table 1.

Table 1 Nutrient treatments, experiment 1.

Treatment	Ion concentration me/dm^{-3}							
	Ca	Mg	K	NH_4	NO_3	H_2PO_4	SO_4	Cl
1	12	6	9	9	3	1,5	28,5	3
2	8	4	6	6	2	1	19	2
3 (control)	4	2	3	3	1	0,5	9,5	1
4	1	0,5	0,75	0,75	0,25	0,13	2,37	0,25
5	4	2	3	7	0	0,5	14,5	1
6	4	2	3	6	1	0,5	12,5	1
7	4	2	3	5	2	0,5	10,5	1
8	4	2	3	4	3	0,5	8,5	1
9	4	2	3	2	5	0,5	5,5	0
10	4	2	3	0	7	0,5	1,5	0
11	4	2	3	3	1	0,13	9,87	1
12	4	2	3	3	1	2,0	8,0	1

The species L cordifolium (locality, Highlands) and L patersonii (locality, Witvoetskloof) were used in experiment 2. The objective of this experiment was to determine the influence of varying the P supply with different nitrogen sources and varying the total nitrogen supply. Treatments were replicated three times and are given in Table 2.

In experiment 3 Protea repens, from two different localities was used (Pearly Beach and Oudebosch). Treatments were replicated three times and the objective was to determine the effect of varying the total salt concentration, nitrogen source, K and Na supply as given in Table 3.

Table 2 Nutrient treatments, experiment 2

Treatment	Ion concentration (me/dm^{-3})							
	Ca	Mg	K	NH_4	NO_3	H_2PO_4	SO_4	Cl
1 control	4	2	3	3	1	0,25	9,75	1
2	4	2	3	0	7	1,0	0,5	0,5
3	4	2	3	0	7	0,5	0,5	1
4	4	2	3	0	7	0,25	0,75	1
5	4	2	3	0	7	0,1	0,9	1
6	4	2	3	3	4	1,0	6,0	1
7	4	2	3	3	4	0,5	6,5	1
8	4	2	3	3	4	0,25	6,75	1
9	4	2	3	3	4	0,1	6,9	1
10	4	2	3	9	3	0,25	13,75	1
11	4	2	3	6	2	0,25	11,75	1
12	4	2	3	1	0,3	0,25	8,45	1

Table 3 Nutrient treatments, experiment 3

Treatment	Ion concentration (me/dm^{-3})								
	Ca	Mg	K	Na	NH_4	NO_3	P	SO_4	Cl
1	1	0,5	0,75	0	1,75	0	0,125	3,625	0,25
2 (control)	4	2	3	0	7,0	0	0,25	13,75	1
3	12	6	9	0	14	0	0,25	38,75	2
4	4	2	3	0	4	3	0,25	8,75	1
5	4	2	3	0	0	7	0,25	0,75	1
6	4	2	1	0	7	0	0,25	13,75	1
7	4	2	1	3	7	0	0,25	15,75	1
8	4	2	3	3	7	0	0,25	17,75	1
9	4	2	6	0	7	0	0,25	17,75	1
10	4	2	6	3	7	0	0,25	20,75	1

In experiment 4 the objective was to determine the amount of nutrients removed by the regular harvesting of flowers each year by weighing and analyzing flower heads ready for marketing.

Significance of yield differences between nutrient treatments was calculated according to Duncan's multiple range test (Steel & Torrie, 1960).

3. Results and discussion

Experiment 1

Dry matter yield of top growth and nutrient levels are given in Table 4. Treatments one to four evaluated the total salt effect. Ivy plants died in the highest salt treatments (T_1 and T_2) while the control (T_3) grew fairly normally. Lower salt treatments (T_4) resulted in poor growth. Failure of growth with high salt supply should, however, not necessarily be attributed to a high salt effect per se. In comparison with treatments at a lower and higher P supply (T_{11} and T_{12}) than in the control (T_3), the P was probably at a harmful level in T_1 and T_2 since T_{11} with a lower P-supply yielded better than the control (T_3). It seems that the control also received an excessively high P supply and the higher P content of (T_3 vs T_{11}) confirms this deduction. The lower yield in T_4 compared to

the control is probably due to a low nutrient supply, especially of N, as indicated by its lower leaf N value.

Table 4 Dry yield (65°C) and nutrient levels for Ivy and Leucospermum cordifolium (Experiment 1)
(Means with the same letter are not significantly different at the 5% level by Duncan's multiple range test).

Treatment No	Mean yield	Ivy % in leaves (dry mass basis) Ca	Mg	K	N	P
1	0	-	-	-	-	-
2	0	-	-	-	-	-
3	60,9 ab	0,44	0,06	0,98	1,14	0,14
4	18,7 dc	1,06	0,1	0,85	0,85	0,03
5	45,2 bcd	0,54	0,06	1,02	1,72	0,29
6	52,4 abc	0,47	0,07	1,13	1,15	0,2
7	71,8 ab	0,48	0,07	0,88	1,49	0,17
8	86,9 ab	0,64	0,08	0,97	1,28	0,1
9	0	-	-	-	-	-
10	0	-	-	-	-	-
11	96,8 a	0,47	0,05	0,89	0,78	0,02
12	0	-	-	-	-	-
		Leucospermum cordifolium				
1	0	-	-	-	-	-
2	91,5 a	1,13	0,23	1,85	1,38	0,19
3	95,0 a	1,05	0,2	1,39	0,86	0,12
4	49,9 bc	1,69	0,28	0,66	0,68	0,04
5	90,9 a	0,75	0,16	1,45	1,3	0,14
6	96,6 a	0,96	0,19	1,36	1,23	0,16
7	88,7 a	1,03	0,23	1,42	1,16	0,06
8	90,2 a	1,25	0,24	1,51	1,26	0,11
9	94,8 a	1,25	0,23	1,4	1,0	0,06
10	16,8 c	1,52	0,47	1,85	1,56	0,23
11	79,8 ab	0,95	0,21	1,47	0,87	0,05
12	0	-	-	-	-	-

With L cordifolium salt effect and P-supply is apparently a lesser problem than with Ivy, although excessive P also appears to be a problem. Only at the highest salt concentration (T_1) did the plants die. At the lowest salt level T_4 yield was reduced, probably due to N deficiency as described for Ivy. As with Ivy, any harmful effect of high salt concentration could be masked by the excessively high P-supply in T_1 where growth failed. It would appear that the critical level of P is higher for L cordifolium than for Ivy but in T_{12} the high P supply also appeared to be harmful.
With regard to N source, (NH_4 vs NO_3, T_5 - T_{10}), exclusion of either ion species resulted in lower yields, particularly when NO_3 was the only N-source, in which case growth of Ivy failed and that of L cordifolium was extremely poor. Yields of Ivy increased as the ratio of NO_3:NH_4 increased (T_5 to T_8) but at high ratios (T_9 and T_{10}) growth failed.

As mentioned previously P supply was probably too high in the NH_4 vs NO_3 comparisons and could have masked some of the real effects involved. Other workers also reported that increasing NO_3 supply reduces the harmful effect of P (Hamner, 1940; Mullison, 1941; Grobler, 1976); this could also explain the higher yield of Ivy with increasing NO_3:NH_4 ratios. This advantage probably counteracted the growth limiting effects of NO_3 per se, as in T_9 and T_{10} where plants died. A reduced uptake of P with increasing NO_3 supply is indicated by a lowering of leaf values in T_5 to T_8. The real problem with NO_3-N could not be determined from these data because the N content showed little variation and the NO_3 content (not given here) was negligible. L cordifolium was less effected by the N source than Ivy and higher NO_3 concentrations could be tolerated.

Experiment 2

Table 5 Dry yield (65°C) and nutrient levels for L patersonii and L cordifolium (Experiment 2).
(Means with the same letter are not significantly different at the 5% level by Duncan's multiple range test).

Treatment No	Mean yield g/pot	L patersonii % in leaves (dry mass basis) Ca	Mg	K	N	P
1	122,4 abc	0,65	0,22	1,41	1,06	0,07
2	227,1 a	0,56	0,24	0,92	0,54	0,08
3	178,9 abc	0,69	0,32	1,19	0,77	0,06
4	105,3 c	0,63	0,29	1,11	0,64	0,04
5	155,4 abc	0,59	0,31	1,13	0,63	0,02
6	152,7 abc	0,71	0,27	1,37	0,77	0,15
7	220,8 ab	0,46	0,22	1,12	0,70	0,08
8	151,7 abc	0,73	0,24	1,29	1,13	0,06
9	173,6 abc	0,49	0,23	1,10	0,78	0,03
10	130,0 abc	0,47	0,13	1,34	2,20	0,08
11	124,7 abc	0,54	0,22	1,12	0,89	0,04
12	93,8 c	0,57	0,29	1,49	0,24	0,04
		L. cordifolium				
1	144,6 abc	0,44	0,11	1,32	0,70	0,08
2	68,2 bc	0,71	0,27	1,67	1,50	0,29
3	69,1 bc	0,72	0,29	1,36	1,30	0,18
4	141,8 abc	0,64	0,23	1,16	1,01	0,07
5	55,6 c	0,72	0,33	2,02	1,71	0,09
6	141,8 abc	0,47	0,13	1,27	0,84	0,19
7	129,2 abc	0,47	0,14	1,11	1,12	0,11
8	142,2 abc	0,53	0,15	1,48	1,24	0,08
9	185,0 a	0,36	0,11	1,10	1,10	0,06
10	165,5 ab	0,42	0,13	1,36	2,03	0,08
11	187,7 a	0,43	0,11	1,17	1,32	0,09
12	60,0 bc	0,57	0,16	1,32	0,40	0,09

In this experiment another species L patersonii (locality Witvoetskloof) was compared with L cordifolium (locality Highlands) and data for yield performance and nutrient uptake are given in Table 5.

L patersonii showed no differential effect on yield or nutrient uptake due to variation in P supply and N source (T_2 to T_4). In this experiment, however, the highest P level was lower than in experiment 1 (1me against 2me H_2PO_4/dm^{-3}). This species could also, contrary to findings in experiment 1, grow with NO_3-N only but these plants showed symptoms of chlorosis and did not appear to develop as many flower buds as the plants that received NH_4 and NO_3.

L. cordifolium also showed no consistent yield response to variation in P supply (T_2 - T_9). Excepting for a lowering of the P content of leaves with reducing P supply other nutrient element contents were not affected.

On average, yields were higher with a combination of NH_4 and NO_3 than with NO_3 only (T_2 - T_5 vs T_6 - T_9). Plants receiving NO_3 only also showed symptoms of chlorosis and very little flower bud development. These results again showed that NO_3 is not an ideal source of N.

Yield of both species decreased with decreasing N supply (compare T_{10}, T_{11}, T_1 and T_{12} in order of decreasing N supply). In the case of L. cordifolium the highest N-supply depressed yield, probably due to the high NH_4 concentration.

Experiment 3

Because of the great difference in response to differential nutrient supply between species, and even within species from different localities, the behaviour of Protea repens, from two localities (Pearly Beach and Oudebosch) was investigated in this experiment.

Table 6 Soil analyses, from sites where plant material was collected

	pH(H_2O)	Resistance (ohm)	P Bray 2 ppm	Ammonium acetate extractable (ppm) Ca	Mg	Na	K
P repens (Pearly Beach)	7,15	4 450	7,5	885	29	8	9
P repens (Oudebosch)	5,9	2 760	7,5	311	96	57	32

The sandy soil from Pearly Beach is derived from sandstone overlying a calcrete deposit. The soil from Oudebosch is a loamy sand on shale and quartzite. Except for a lower pH(H_2O) and electrical resistance at Oudebosch, there appears to be little difference in chemical properties between the two soils. (Table 6).

Yield and nutrient uptake data for these species are given in Table 7. With P repens from Pearly Beach no marked differences in yield are apparent from increased salt level of the nutrient medium (T_1 - T_3). Even T_3 with a high NH_4 concentration (14 me/dm^{-3}) had no differential effect over the control (T_2). P repens from Oudebosch, however, showed markedly depressed growth with increasing salt levels; even the control failed completely. This detrimental effect could be due to a high NH_4 concentration, rather than a high salt level, because growth was better where some N was supplied as NO_3 in contrast to N supplied as NH_4 only (T_4) at the same salt level.

The detrimental effect of high NH_4 supply was reduced by the addition of Na for P repens from Oudebosch. Comparing T_6 and T_7 no growth occured in the absence of Na as opposed to some growth with Na. This pattern was even more apparent at higher K and Na levels (T_8, T_9 and T_{10}).

With P repens from Pearly Beach the effect of N was not apparent, probably because the critical NH_4 level for the species from this site had not been exceeded. This effect of Na and K on P repens from Oudebosch, must have been indirect since no real differences could be found in the plant nutrient levels. A possible explanation could be that the addition of another cation (such as Na) prevented NH_4 from being taken up at a rate which caused it to accumulate at harmful levels. This could have occurred shortly after renewal of the nutrient solutions every eight weeks, at which time NH_4 uptake is rapid. From experience with proteas, growth normally improves markedly when N is applied after a period of withholding it.

Table 7 Dry yield (65°C) and nutrient levels for Protea repens from Pearly Beach and Oudebosch (Experiment 3)
(Means with the same letter are not significantly different at the 5% level by Duncan's multiple range test).

Treatment No	Mean yield g/pot	P repens from Pearly Beach % in leaves (dry basis) Ca	Mg	K	Na	N	P	S
1	99,7 a	0,42	0,08	0,76	0,1	0,62	0,27	0,03
2	87,5 a	0,38	0,11	0,64	0,046	2,06	0,18	0,16
3	88,5 a	0,42	0,12	0,81	0,06	2,48	0,35	0,3
4	108,4 a	0,5	0,12	1,15	0,06	1,96	0,32	0,09
5	137,7 a	0,67	0,15	1,02	0,08	2,72	0,32	0,1
6	70,9 a	0,38	0,11	0,5	0,08	2,02	0,12	0,35
7	68,9 a	0,53	0,11	0,7	0,12	2,28	0,16	0,17
8	89,8 a	0,38	0,1	0,8	0,008	2,1	0,14	0,14
9	76,6 a	0,38	0,1	0,79	0,004	2,44	0,14	0,2
10	93,6 a	0,27	0,1	0,63	0,009	2,17	0,09	0,23
		P repens from Oudebosch						
1	53,1 ab	0,25	0,08	0,9	0,008	1,09	0,48	0,06
2	0	-	-	-	-	-	-	-
3	0	-	-	-	-	-	-	-
4	65,8 a	0,27	0,08	1,13	0,005	2,13	0,63	0,1
5	46,2 ab	0,26	0,08	0,81	0,006	2,51	0,59	0,16
6	0	-	-	-	-	-	-	-
7	20,2 b	0,23	0,08	0,52	0,01	1,95	0,28	0,23
8	33,6 b	0,2	0,08	0,59	0,01	1,97	0,19	0,72
9	43,4 ab	0,16	0,06	0,69	0,006	2,11	0,26	0,22
10	41,2 ab	0,17	0,07	0,59	0,01	1,98	0,26	0,3

The N source did not have an influence on P repens from Pearly Beach, while the yield of P repens from Oudebosch was depressed when N was provided in the form of NO_3 only (T_4 vs T_5).

Experiment 4

In this investigation the amounts of nutrients removed by flowers, are calculated according to average yields of dry mass, amount of flowers harvested, and chemical analysis (Table 8).

P neriifolia removes approximately 5,3 kg N, 0,8 kg P and 4 kg K. This is a relatively small amount. However the 20 000 flower heads as a production figure is quite conservative and higher yields are possible. In the case of L cordifolium the removal figure is more or less the same for flowers picked from the veld. This figure agreed fairly well with figures obtained in a culture medium with low nutrient supply which gave relatively low dry mass production.

When more nutrients were supplied, yields increased drastically as well as the nutrient content of some elements. This indicated that for a high yield, higher nutrient levels were necessary which means higher nutrient removal as well.

From this data it is obvious that proteas do not remove a very large amount of nutrients with the harvest but under certain circumstances the soil would not be able to replenish these nutrients, especially in highly leached acid sandy soils. In these cases fertilization of nitrogen would certainly be beneficial for production.

Table 8 Calculated nutrient removal with harvesting of Protea flower heads

Species	Nutrient content of flower heads %		Dry mass of flower head (g)	For a yield of (flowers /ha)	Nutrient removal (kg/ha)
P neriifolia	N	0,53	50	20 000	5,3
(Unfertilized	P	0,08			0,8
veld plants)	K	0,4			4,0
	Ca	0,4			4,0
	Mg	0,04			0,4
L cordifolium	N	0,5	30	50 000	7,5
(unfertilized	P	0,08			1,2
veld plants)	K	1,4			2,1
	Ca	0,6			9,0
	Mg	0,2			3,75
L cordifolium	N	2,0	30	50 000	30,0
(In culture	P	0,15			2,25
	K	1,6			2,4
	Ca	0,6			9
	Mg	0,25			3,75

4. Conclusions

It appears that considerable differences can be expected in growth response to nutrient elements in sand culture, particularly N-supply, between protea species, and even within the same protea species collected from different sites.

Although several species are usually found on highly leached soils under natural conditions, a relatively high concentration of nutrients does not appear to be a problem in culture medium. However, problems may occur with a high level of a particular element.

The P requirement of proteas is low and this is associated with low P levels in leaves where growth is normal. Although differences occur between species, P supply appears to be harmful even at a level of halfstrength Hoagland solution (0,5 me H_2PO_4/dm^{-3}). N appears to be a nutrient of particular importance in protea cultivation. More favourable growth was always associated with increasing N supply, particularly of NH_4. The species studied could all use NH_4-N even at levels which may be harmful to many other plants. Although species like L patersonni and P repens from Pearly Beach could use NO_3 to some extent, NH_4 was in most cases preferable, while Ivy failed to grow with NO_3 only.

Inclusion of Na in the nutrient medium apparently improved growth of certain species, particularly at excessively high NH_4-levels. This may be due to Na lowering the relatively high and harmful rate of

NH_4 uptake.

Proteas remove relatively small amounts of nutrients with the harvest, but these can become considerable over the years and fertilization, especially with nitrogen, would be beneficial.

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THE FLOWER PICKING INDUSTRY IN RELATION TO MOUNTAIN CATCHMENT MANAGEMENT IN THE FYNBOS

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Abstract

Private land in proclaimed catchment areas must be managed to ensure an optimum sustained yield of high quality water through maintainance of the vegetation. Wildflower picking is a form of landuse practised in many catchment areas. Current restrictions call for the removal of not more than 50% of the blooms of a plant each year, provided that no picking is carried out for one year prior to a planned fire. This paper presents data on the utilization levels of Proteaceae on private land in the western Cape. These levels are often well above the recommended 50%. The viability of canopy stored seeds declines at varying rates depending on the species. More realistic rules should prescribe different levels of utilization for different species to ensure sustained yields, but the problem is complicated by the effects of season of fire which cause considerable variation in seedling recruitment. Unplanned fires burn 60% of the mountain areas, and heavy picking followed by unplanned fires can result in very poor regeneration. The lack of a sound understanding of seed biology and an inability to prevent unplanned fires currently make the picking of wild populations of serotinous Proteaceae risky. The practice should therefore be discouraged in favour of cultivation.

1. Introduction

The Mountain Catchment Act (Act 63 of 1970) provides for the formal proclamation of privately owned land in recognised catchment areas. Proclaimed catchments must be managed to ensure an optimum sustained yield of high quality water. Practices which result in degradation of the catchment or which affect water quality are discouraged. Privately owned land in 9 catchment areas in the Western Cape Forestry Region amount to c. 500 000 ha (61% of areas identified as catchments). This land is divided among c. 800 owners, of whom a minimum of 11% utilize the land for flower picking in some form or another.

The wildflower picking industry has moved from its early beginnings as a purely opportunistic trade to a relatively more ordered state today. During the season of 1980, European traders spent about R3 million on fresh fynbos material,

approximately 60% of it infloresences of the Proteaceae. The industry is, however, one where the activities of participants are not readily accounted for, and one whose structure allows no easy means of monitoring the flow of produce (Davies 1984).

The long-term effects of wildflower picking are not known. The natural fynbos vegetation is the most cost-effective catchment cover and should therefore be maintained (Wicht and Kruger 1973). The possible detrimental effects of flower picking in natural vegetation in catchment areas include serious depletion of seed stores, trampling and erosion, mortality through serious damage to individual plants, the spread of diseases such as *Phytophthora* and a drain on nutrient pools from the ecosystem. Fires are common in the Cape mountains, and many species of Proteaceae rely on canopy stored seed reserves to regenerate after fire. Picking intensities should be at a level which will leave sufficient seed to provide for adequate regeneration. Preliminary restrictions, which call for the removal of not more than 50% of the blooms or of 50% of the foliage of any plant (including members of the Proteaceae) each year were set, provided that no picking is carried out for one year prior to a planned fire. This rule has not yet been critically reviewed. The setting of meaningful rules and the monitoring of flower picking activities are both major problems facing catchment managers in the fynbos.

This paper presents some data on the utilization levels of Proteaceae on private land in the western Cape and the decline in viability of canopy stored seed in two selected species. Other available data on the seed biology of Proteaceae are discussed in relation to their value for drawing up guidelines for wildflower picking.

2. Methods

2.1 Estimation of utilization levels

The utilization of dominant *Protea* species for flower picking was estimated at a number of sites. Shrubs were selected using the wandering quarter method (Catana 1963) at each site. On each shrub the degree of utilization was estimated by counting the number of cut marks from the current season and remaining current flowers.

2.2 Estimation of seed viability in remaining cones

Seeds were taken from flowerheads of 20 *P. neriifolia* plants in August 1982 and 25 *Leucadendron xanthoconus* plants in February 1980. Cones and flowerheads were aged according to year of seed set for each species. Seeds set in the years 1978 - 1981 for *P. neriifolia* and 1976 - 1979 for *L. xanthoconus* were collected. In the case of *P. neriifolia* only plump, filled seed were used. Five hundred seeds from each year were planted into trays and watered. In the case

of *P. neriifolia* only 490, 290 and 220 seeds were planted from the 2, 3 and 4 year old flowerheads respectively. Planting dates were April 1983 for *P. neriifolia* and May 1980 for *L. xanthoconus*. The trays were monitored daily for germination, until no further germination occurred.

3. Results

3.1 Utilization levels

Utilization levels of some *Protea* species are presented in table 1. The mean percentage utilization at all sites surveyed was 48.9%, but species such as *P. magnifica* and *P. cynaroides* which fetch good prices are often heavily utilized. In cases where utilization exceeds 70% (as for *P. magnifica* in the Langeberg mountains) serious depletion of seed reserves may lead to poor regeneration following fires.

Table 1 - Mean number of flowers per plant and percentage of flowers harvested for various populations of wild *Protea* species in the western Cape Province.

Catchment area	Species	Mean number of flowers per plant	Percentage flowers harvested
Langeberg	*P. magnifica*	4.9	70.4
Langeberg	*P. holosericea*	1.6	49.5
Langeberg	*P. magnifica*	3.0	45.0
Langeberg	*P. magnifica*	1.1	23.8
Winterhoek	*P. magnifica*	3.5	59.0
Winterhoek	*P. magnifica*	5.1	34.0
Winterhoek	*P. magnifica*	5.0	56.0
Hawequas	*P. repens*	7.5	32.4
Hawequas	*P. cynaroides*	3.6	64.8
Hawequas	*P. neriifolia*	32.0	54.1

3.2 Seed viability

Results of the germination experiments are shown in figure 1. Seed viability declined from 49.4% in one-year old seed to 33.2% for four-year old seed of *P. neriifolia*. Van Staden (1978) showed that seed viability declined from 86% in 8 month old *P. neriifolia* seed to 40% in one year old seed. We did not test fresh seed as these were not ripe at the time of collection. The decline in viability was far more marked in *L. xanthoconus*, from 31.8% to 3.2% for 1 to 3 year-old cones. *L. xanthoconus* would therefore appear to rely far more heavily on the current seed crop than *P. neriifolia* for regeneration following fires.

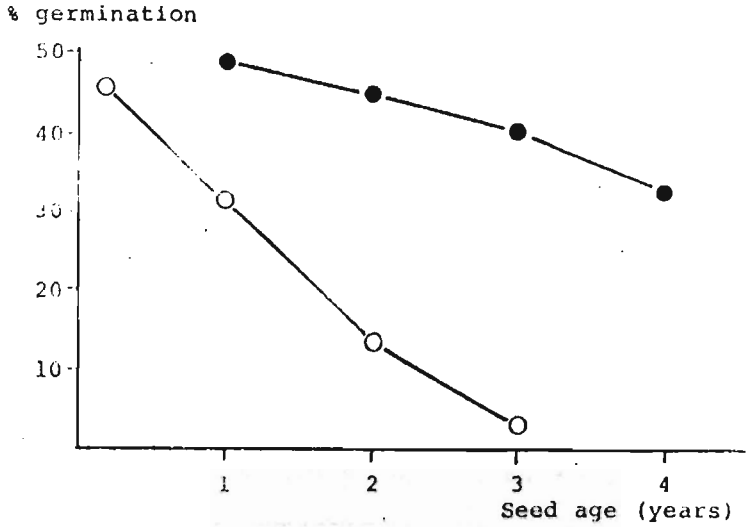

Figure 1 - Percentage germination for different ages of seed from two species. (●) = *P. neriifolia*, (0) = *L. xanthoconus*.

4. Discussion

4.1 Seed stores in serotinous Proteaceae

Serotiny in Cape Proteaceae is comparitively weak and a large proportion of the store of viable seed is found in the current crop of flowers (Bond 1985). The degree of serotiny varies between species. The longevity of viable canopy stored seed (figure 1) contributes significantly to the degree of serotiny. Bond (1985) showed that seeds from earlier seasons contributed half the total viable canopy-stored seed reserves in five out of 10 species of the genera *Protea* and *Leucadendron*, but that this was between 50 and 25% in three other species and less than 25% in the remaining two species. Provided that the current crop of flowers are not harvested one year before a planned fire, seed reserves will amount to the whole current crop plus 50% of previous years seeds (which will be reduced through loss of viability). From our data, it seems that more cones must be left on *L. xanthoconus* than flowers on *P. neriifolia* to ensure the same level of seed availability following fire, as seed viability declines far more rapidly in the former species. Populations of species which survive fire by sprouting, for example *P. cynaroides*, can survive occasional unplanned fires even if most flowers have been removed. Different picking intensities for individual species would therefore seem advisable, but reliable figures for the loss of viability need to be collected for various species to determine realistic picking intensities in wild populations.

4.2 The importance of fire season

The problem of determining the level of seed necessary to ensure adequate regeneration following fire is complicated by season of fire effects. There can be more than a three-fold difference in the number of viable canopy-stored seed depending on the time of year (Coetzee 1984, Bond 1985), but there are often 10 to 100 times more seedlings per parent plant following autumn fires when compared to spring fires (Bond *et al.* 1984, Van Wilgen *et al.* 1985). These differences result from attrition of seeds following release. Fire season may therefore have more of an effect on populations of serotinous Proteaceae than the level of flower picking. The period of maximum seed availability and of maximum seedling recruitment co-incides with the period when most fires occur (January - March). The current rule assumes that wild flowers produce a harvestable surplus of seeds, but this is unlikely seen in an evolutionary context, as wild populations would not gain benefit from such a strategy. If the level of seed availability at the time when fires are most likely optimises seedling recruitment, then depletion of these seeds through excessive picking will erode populations over a number of fire cycles. Fires in unfavourable seasons, for example spring, will simply accelerate the rate of decrease in population numbers.

4.3 The frequency of unplanned fires

The present rule requiring that only 50% of blooms are removed from a plant each year was set as an insurance against accidental fire. It relies heavily on the assumption that most fires will be planned. Unplanned fires are, however, a common feature of the Cape mountain environment.

Table 2 - Areas burnt in planned and unplanned fires from 1 April 1981 to 31 March 1984 in 9 catchment areas in the western Cape Province.

Catchment area	Total area burnt (ha.) Unplanned fires	Planned fires
Cederberg	14 108	9 984
Groot Winterhoek	5 285	2 610
Kouebokkeveld	6 939	9 614
Matroosberg	23 299	1 656
Hawequas	40 263	15 704
Riviersonderend	8 970	7 381
Hottentots-Holland	15 356	9 964
Langeberg-West	6 444	9 203
Langeberg-East	1 711	10 730
Total	122 375	76 846

Table 2 shows data for fires over 3 years in the western Cape Province (from Departmental records, unpublished). More than 60% of the total area burnt was burnt in unplanned fires. An unplanned fire following shortly after picking will mean that fresh, viable seed available for regeneration will be reduced.

4.4 Setting realistic guidelines for sustained yields

Before realistic rules for flower picking can be formulated, the degree of serotiny for each species and the number of seeds necessary to replace populations needs to be known. Data on seedling survival to maturity and the factors affecting it need to be collected. The data currently available show that 50 to 75% or more of available seed comes from the current crop of flowers, depending on the species. An unplanned fire following heavy picking will result in low seed numbers despite some flowers being left from previous years. Better fire control to reduce the frequency of unplanned fires will ensure that a protected crop of current flowers can be burnt in a planned fire, thereby ensuring adequate seed levels. Until adequate fire control is achieved, however, flower picking in wild populations for sustained yields is risky. In addition, it is difficult to control wildflower picking activities in catchment areas. Prescriptions laid down are often exceeded in private catchments and the theft of flowers from state-owned land is common. The other problems associated with wildflower picking (mentioned above) add to the undesirability of allowing the practice. Sustained yields in the long term will be best achieved from plantations of Proteas.

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DISEASES OF PROTEAS AND THEIR CONTROL IN THE SOUTH-WESTERN CAPE

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Summary

Most local protea diseases are caused by fungi belonging to the Loculoascomycotina and Deuteromycotina. There are no records of any rusts, smuts, powdery mildews, downy mildews, or bacterial or viral diseases. Many leaf specks, leaf blotches and leaf spots reduce the value of cut flowers. Important leaf spot diseases are those caused by Mycosphaerella proteae on Protea neriifolia and Protea grandiceps, by Leptosphaeria protearum on Protea magnifica and by Batcheloromyces proteae on certain Protea cynaroides ecotypes. Canker, die-back, anthracnose and blighting of shoots and twigs are especially common in older plantations. Colletotrichum gloeosporioides is important on Protea compacta and other species, whereas a Drechslera sp. causes blighting of certain Leucospermum cordifolium cultivars. The role of Botryosphaeria spp. is not clear, though they seem to be extremely successful opportunistic colonizers of protea shoots, flower parts and seeds. Scab is caused by an Elsinoe sp. Corky lesions develop on stems and leaves, particularly of L. cordifolium, and flowering is reduced. Control of above-ground fungal diseases is largely by applying sanitation measures, by avoiding susceptible species and cultivars, and by strategic use of fungicides. Witches' broom is an important disease of P. cynaroides, P. neriifolia and P. compacta X P. neriifolia hybrids. Control is by controlling the mite Aceria proteae and by strict sanitation. Damping-off and seedling blight occur sporadically. Some common pathogens are involved, but only C. gloeosporioides has been studied to any extent. It is controlled by thiram seed treatment. Phytophthora cinnamomi root rot is particularly severe on Leucadendron argenteum, Leucospermum cordifolium, Leucadendron discolor and Leucadendron tinctum. Losses are reduced by avoiding soils with a history of root rot and by planting tolerant species or cultivars. Cuttings sometimes die in mistbeds. A preplant treatment with captafol has given promising control. Postharvest diseases include rhizopus and botrytis decay of L. cordifolium blooms and blackening of Protea leaves. Use of disease-resistant cultivars is an important general disease control measure. But erosion of disease resistance in breeding programs means that shifts in importance of the different pathogens could occur. There is also the danger that indigenous pathogens will be disseminated on breeding material distributed to growers.

1. Introduction

It is generally recognized that the South-Western Cape Province of South Africa has a distinctive vegetation (the Cape Floral

Kingdom) which became isolated after the break-up of the Gondwanaland supercontinent and the intrusion of the cold Benguela ocean current between Africa and South America. The break-up of Gondwanaland began 100 million years ago (King, 1978). At the same time many groups of plant-pathogenic fungi (especially Ascomycotina and related Deuteromycotina) were diversifying and co-evolving with their hosts (Pirozynski, 1976). In addition to higher plants, there are therefore also very many fungal pathogens unique to the South-Western Cape (Knox-Davies, 1981).

The first South African proteas to be commercialized were collected in their natural habitats. Today, though, large numbers of proteas are being grown in pure stands in commercial plantations. The species and cultivars used are selected largely on the basis of flower characters. Little attention is given to disease resistance. With this crowding together of genetically uniform material, growers are being confronted with increasing numbers of disease problems. On the one hand are the wide-host-range diseases commonly associated with agricultural crops; on the other are the indigenous protea-specific diseases.

This paper briefly reviews the occurrence and control of important diseases of proteas (Protea, Leucospermum and Leucadendron spp.) in the South-Western Cape.

2. Diseases not recorded on proteas in South Africa

Fungal diseases not recorded on proteas in South Africa include rusts, smuts, powdery mildews and downy mildews. No bacterial disease has been recorded, despite reports of bacterial leaf spots on Protea cynaroides in England (Paine & Stansfield, 1919) and Australia (Wimalajeewa et al., 1983). There is also no record of any disease caused by a virus, viroid or nutritionally fastidious prokaryote.

3. The main groups of protea diseases

We have grouped the different protea diseases as follows :

- Leaf speck, leaf blotch and leaf spot diseases
- Shoot blight, canker and die-back diseases
  - a. Drechslera blight
  - b. Anthracnose
  - c. Botryosphaeria canker and die-back
  - d. Leaf browning and die-back of cuttings
  - e. Other
- Scab
- Witches' broom and fasciation
- Soil-borne diseases
  - a. Damping-off and seedling blight
  - b. Root decay
  - c. Decay of rooting cuttings
  - d. Other soil-borne disease problems
- Postharvest diseases
- Other

3.1 Leaf speck, leaf blotch and leaf spot diseases

Dark mycelium and fruiting structures (sporodochia, ascocarps) of many fungi develop superficially on protea leaves. Fruiting structures occur as discrete leaf specks on green leaves. Or, together with the mycelium, they form dull grey, lustreless blotches or smudges. Sometimes the underlying tissue becomes yellowed. In still other cases the superficial mycelium is so compact and dark that the disease is more aptly described as a leaf spot. Leaf spots range from these superficial sooty spots to necrotic, often extensive lesions.

Leaf speck, leaf blotch and leaf spot diseases reduce the value of cut flowers. Particularly spectacular are the leaf spots caused by Mycosphaerella proteae (Syd.) Von Arx on Protea neriifolia and Protea grandiceps, by Batcheloromyces proteae Marasas, Van Wyk & Knox-Davies on certain P. cynaroides ecotypes and by Leptosphaeria protearum Syd. on Protea magnifica and cv. Sheila, a natural hybrid (probably between P. magnifica and Protea burchelli). But the relative importance of the different diseases could change with shifts in emphasis on the different protea species and cultivars grown. Fungi recorded as leaf speck, leaf blotch and leaf spot pathogens on proteas in South Africa are given in Table 1. The authors are at present updating the host list of these fungi.

Only a few leaf disease fungi (Batcheloromyces, Leptosphaeria, Vizella) have been cultured in the laboratory. Unfortunately they all grow extremely slowly under standard cultural conditions, so that little is known about infection processes and the environmental factors favouring leaf diseases.

Control is achieved by avoiding highly susceptible cultivars, by applying sanitation measures and by using fungicidal sprays. For the past six years G.J. Brits (H.R.I. and Tygerhoek Experimental Farm, Riviersonderend, personal communication) has been using mancozeb alternated with a benomyl/captab mixture. Seedlings and young plants are sprayed at 2-week intervals when wet weather coincides with a growth flush.

3.2. Shoot blight, canker and die-back diseases

3.2.1. Drechslera blight

Von Broembsen (1985) recently recorded drechslera blight on Leucospermum spp. and cultivars from many parts of the South-Western Cape. Commercially cultivated pincushions are especially severely affected, with symptoms including leaf lesions, stem cankers and premature death of flower heads. She described the causal fungus as Drechslera dematioidea (Bubak & Wroblewski) Subram. & Jain. Suggested control measures are the use of resistant cultivars, seed treatment, and spraying with fungicides such as iprodione.

This drechslera blight is probably identical to the 'leaf spotting and shoot die-back' caused by Drechslera biseptata on Leucospermum spp. in Australia (Greenhalgh, 1981). 'Rovral (iprodione) appears to reduce disease severity' (Greenhalgh, 1981).

3.2.2. Anthracnose

Anthracnose, caused by Colletotrichum gloeosporioides (Penz.) Sacc., was first described locally on Protea compacta (Benic & Knox-Davies, 1983b). Symptoms include cankers and other lesions on stems and shoots, leaf blight, seedling blight and pre- and post-emergence damping-off. Since then, the first author (P.S. Knox-Davies, unpublished data) has recorded C. gloeosporioides on blighted Protea (P. cynaroides, P. eximia, P. longifolia, P. speciosa, P. stokoei) seedlings. Schwabe (W.F.S. Schwabe, FFTRI, Stellenbosch, personal communication) has also found C. gloeosporioides associated with die-back of Protea, Leucospermum and Serruria spp. P. magnifica was particularly susceptible, but Leucadendron spp. were resistant. In Australia, Greenhalgh (1981) listed the following Protea spp. susceptible to colletotrichum die-back : P. magnifica, P. compacta, P. neriifolia, P. cynaroides, P. coronata, P. longifolia, P. obtusifolia, P. stokoei and P. repens.

C. gloeosporioides has many hosts besides proteas, and there is considerable data available on conditions favouring disease and on disease control.

Seed treatment is advised to control damping-off and seedling blight. Benic & Knox-Davies (1983b) obtained good seed germination and seedling survival after the following seed treatments : 24h 30°C thiram soak; thiram dusting; 30 min hot water (50°C) treatment followed by thiram dusting.

Foliage fungicides have also been used in anthracnose control. Some years ago Schwabe (personal communication) controlled protea die-back on an experimental basis with captafol, captab and mancozeb. In Australia, where colletotrichum die-back of Protea seedlings has been described as a 'major disease of economic importance' (J. Maughan, Plant Research Institute, Burnley, mimeographed data, undated), difolatan and prochloraz were the most effective of 31 fungicides tested against the disease, though nursery trials were less successful than those in the glasshouse.

Benic & Knox-Davies (1983b) suggested that the practice of burning plantations as they become unproductive reduces Colletotrichum and Botryosphaeria inoculum.

3.2.3. Botryosphaeria canker and die-back

A number of different Botryosphaerias (some with Dothiorella anamorphs) have been isolated from shoot lesions, seed heads and seeds of different proteas (Knox-Davies, Marasas, Wingfield & Von Broembsen, unpublished data). Benic & Knox-Davies (1983b) frequently isolated 'Botryosphaeria' from anthracnose lesions on P. compacta plants and suggested that it is 'a secondary invader which colonizes tissue after infection by C. gloeosporioides'. Von Broembsen (1985) found Botryosphaeria dothidea (Moug. ex Fr.) Ces. & de Not to be 'an important secondary pathogen of the stem canker caused by D. dematioidea'. It seems that a variety of

Botryosphaeria spp. occur as extremely successful opportunistic colonizers of protea shoots, flower parts and seeds, with environmental stress factors possibly increasing the susceptibility of host tissue to infection (cf. Schoeneweiss, 1981).

3.2.4. Leaf browning and die-back of cuttings

Leaf browning and die-back of cuttings are sometimes a problem while cuttings are being rooted in mistbeds. Jacobs (1981a) suggests that most disease problems of rooting cuttings can be related to immature wood, too close spacing, poor air circulation and overwatering. Nevertheless, both he (1981a, and personal communication) and J.C. Steenkamp (Protea Heights, Stellenbosch, personal communication) suggest that rooting cuttings should be sprayed regularly and routinely with fungicides. Steenkamp alternates a mixture of captab and benomyl with one of mancozeb and iprodione at weekly intervals. Sub-irrigation whould also reduce the incidence of foliage diseases while cuttings are rooting.

3.2.5. Other shoot blight, canker and die-back diseases

Blighting, cankering and die-back of shoots and stems are seen in many older protea plantations. They have still to be diagnosed and evaluated. The Phoma sorghina stem canker described by Gorter (1976) on L. cordifolium in the Transvaal has not been recorded in the South-Western Cape.

3.3 Scab, caused by an Elsinoe sp. (with a Sphaceloma anamorph)

Scab is an important disease of Leucospermum cordifolium, and has also been recorded on other Leucospermum spp. (L. conocarpodendron, L. lineare, L. oleaefolium), a Leucospermum hybrid (L. cordifolium X L. tottum), two Leucadendron spp. (L. laureolum, L. platyspermum) and Serruria florida (Benic & Knox-Davies, 1983a and unpublished data). Different cultivars and seedlings differ greatly in susceptibility to scab. L. cordifolium cv. Red Sunset is extremely susceptible.

Symptoms resemble those of citrus scab. Corky lesions develop on the leaves, but they are most conspicuous on shoots and flowering branches. Heavily infected shoots become twisted and distorted, and flowering is reduced. Infection apparently occurs in wet weather during a growth flush (Benic & Knox-Davies, 1983a).

Measures suggested for scab control (Benic & Knox-Davies, 1983a) include the use of resistant cultivars, choosing sites with good air drainage, judicious overhead irrigation and spraying during a growth flush with fungicides such as captafol and mancozeb (contact) or benomyl (systemic).

3.4. Witches' broom, fasciation

Witches' brooms occur on a number of Protea spp. They are

especially common on P. cynaroides and P. nitida, but can be locally important on other species. We do not know what causes the disease, though the mite Aceria proteae is involved in some way (Rust, 1984). There is no experimental evidence to support the suggestion (Rust & Myburgh, 1976) that witches' broom is caused by a mycoplasma.

Rust (1984) gives the following control measures for witches' broom :

a.) legislation preventing the sale of diseased plants;
b.) care by growers to buy disease-free propagating material from nurseries that have been free from the disease for at least a year;
c.) spraying with carbaryl at three-weekly intervals.

Fasciation is rare enough to be regarded as a curiosity rather than a disease. Shoot tips become broadened and flattened, sometimes with twisting and curling. The cause is unknown.

3.5. Soil-borne diseases

3.5.1. Damping-off and seedling blight

Seed-borne C. gloeosporioides causes damping-off and seedling blight of a number of Protea spp. (Benic & Knox-Davies, 1983b, and unpublished data). Seed treatment is effective in disease control and is discussed in relation to anthracnose.

Linda Benic and the first author (unpublished data) have also frequently isolated common wide-host-range pathogens such as Rhizoctonia solani Kühn, Botrytis cinerea Pers. ex Fr., Macrophomina phaseolina (Tassi) Goid., Fusarium oxysporum Schlect. and other Fusarium spp. from damped-off and blighted protea seedlings.

There is little information on damping-off or seedling blight in commercial undertakings, but numerous seedling diseases have been experienced at the Kirstenbosch Botanic Garden, the Harold Porter Botanic Garden at Betty's Bay and the Assegaaibosch Nursery of the Cape Department of Environment Affairs. At Kirstenbosch the problem has largely been resolved by treating nursery soil with methyl bromide and seeds with thiram dry seed dressing (Linda Benic, personal communication).

In Australia, Greenhalgh (1981) reported that a soil drench with Benlate (benomyl) was effective in controlling damping-off caused by Fusarium and Rhizoctonia.

3.5.2. Root decay

Phytophthora cinnamomi Rands is the most important protea root decay fungus. Van Wyk (1973a,b) described it as the cause of a sudden death of Leucadendron argenteum, and provisionally listed the reactions of 13 Protea spp., 7 Leucadendron spp. and 2 Leucospermum

spp. to the fungus (Van Wyk, 1973a). P. cynaroides was resistant and he suggested that the antifungal substance, p-Hydroxybenzoylcalleryanin, which he and Koeppen (1974) extracted from the bark of P. cynaroides roots, is important in conferring resistance to P. cinnamomi.

Von Broembsen & Brits (1985) isolated P. cinnamomi from 22 Leucadendron, 24 Leucospermum and 9 Protea spp. from commercial fields in the South-Western Cape. In inoculation studies they confirmed the relative resistance of Protea spp. but extreme susceptibility of many Leucadendron and Leucospermum spp., as previously reported by Van Wyk (1973a) and Greenhalgh (1981). They also reported that Leucadendron and Leucospermum spp. were subject to phytophthora root rot even on well-draining sites, whereas Protea spp. were rarely affected.

In Australia, Greenhalgh (1981) found L. cordifolium and many Leucadendron spp. (e.g. L. discolor, L. daphnoides, L. laureolum, L. argenteum, L. eucalyptifolium, L. salicifolium) to be highly susceptible to P. cinnamomi. Protea spp. were generally more tolerant : 'Observations indicate that P. neriifolia and P. repens are tolerant to the fungus and that P. magnifica, P. compacta and P. cynaroides are susceptible'.

Soils suppressive or conducive to P. cinnamomi have frequently been recorded elsewhere, but there are no data on P. cinnamomi suppressive/conducive protea soils in the South-Western Cape.

Control is difficult, especially if, as Von Broembsen & Kruger (1985) suggest, P. cinnamomi is 'an indigenous component of the native ecosystems'. Recommended control measures at present (Brits & Von Broembsen, 1978; Von Broembsen & Brits, 1985; G. Jacobs, personal communication) include :

a.) avoiding poorly draining soils and soils with a history of root rot;
b.) using resistant material (e.g. Protea spp.) on suspect soil;
c.) using disease-free nursery material.

Systemic fungicides have given inadequate control or are phytotoxic, and decontaminating river water for irrigation is too costly (Von Broembsen & Brits, 1985).

3.5.3. Decay of rooting cuttings

Protea cuttings in mistbeds often turn brown from the base and from wounds caused when leaves are removed during preparation of the cuttings. Isolations made from the lesions have yielded many saprophytes and wide-host-range pathogens such as Rhizoctonia solani, Botrytis cinerea and various Fusarium spp. (unpublished data).

Preliminary tests with P. repens suggest the following control

measures (G. Jacobs, personal communication). Cuttings are stripped of their lower leaves, dipped in 0.05-0.15% (m/v) captafol in H_2O and dried briefly. The bases are then dipped in rooting compound and the cuttings are planted in mistbeds.

3.5.4. Other soil-borne disease problems

Most local research effort has been concentrated on phytophthora root rot, and there has been a tendency to ascribe all cases of sudden death or poor growth of protea plants to P. cinnamomi. It is becoming apparent, though, that other pathogens might sometimes also be involved - as well as abiotic factors such as moisture or heat stress, and nutritional factors.

3.6. Postharvest diseases

A Rhizopus sp. and Botrytis cinerea are sometimes problems on L. cordifolium blooms after harvest. Suggested control measures at present include dipping the flowerheads in dicloran and benomyl and drying them thoroughly before packing (G. Jacobs, 1981b and personal communication). In Hawaii, Cho (1977) recovered benomyl tolerant B. cinerea from L. cordifolium plants and other Proteaceae sprayed routinely with benomyl. Benomyl dip treatments to control Botrytis postharvest decay would almost certainly lose their effectiveness if benomyl were used routinely as a foliage fungicide in the field.

Blackening of protea leaves during storage was discussed by Jacobs (1981b). Protea spp. particularly prone to leaf blackening included P. compacta, P. eximia, P. magnifica, P. repens and P. neriifolia.

Leaf blackening is a 'complex problem', '...though the severity can be reduced by (a) selection of less prone genotypes (b) proper handling during transit especially temperature control and (c) the use of preservative solutions' (Jacobs, 1981b).

3.7. Other

3.7.1. Phosphorus toxicity

Phosphorus levels normal for other plants are toxic to many Proteaceae (Nichols, 1981). Phosphorus toxicity could therefore be a problem where old agricultural lands are used for protea cultivation. Symptoms include leaf necrosis and death of young plants, and can be confused with those caused by soil-borne pathogens. Nichols (1981) listed the sensitivities of 33 species of Proteaceae to phosphorus toxicity and suggested that there might be some genetic variation in tolerance within a species. Phosphorus toxicity is apparently not an important factor in protea production in the South-Western Cape (G. Jacobs, personal cummunication).

4. Concluding remarks

It is accepted that protea breeding programs should be more concerned with flower characters than disease resistance. But one consequence of this must also be realized - that the natural disease resistance of wild parents is inevitably eroded during breeding and selection. Examples of this are the extreme susceptibility of cv. Sheila, a presumed P. magnifica X P. burchellii hybrid to leptosphaeria leaf spot and of L. cordifolium cv. Gold Dust to Elsinoe.

Loss of wild host resistance will have particular significance near the protea centres of origin (South-Western Cape) where minor pathogens on the wild plants could become major pathogens on the 'improved' cultivars, and be disseminated with them. Local protea breeding programs should recognize this and evaluate the resistance of breeding material to a wide range of indigenous pathogens, but at the same time ensure that the material is disease-free when distributed to growers. The local protea industry should also consider maintaining a cultivar bank isolated from both commercial plantations and wild proteas in their natural habitat.

P. cinnamomi is a major pathogen in the cultivation of proteas. Little is known locally about the susceptibility of proteas to other wide-host-range fungi such as Rhizoctonia solani, Fusarium oxysporum and Macrophomina phaseolina. The impact of these pathogens will become more apparent as more seedlings and cuttings are raised in nurseries and as more use is made of old agricultural lands for protea production.

Despite the many leaf speck, leaf blotch and leaf spot diseases, there has been only sporadic research on the use of fungicides in disease control. In most cases we need to know much more about the causal organisms and disease cycles before we can plan meaningful strategies in protea disease control with fungicides.

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Table 1 - see next page.

TABLE 1 - Leaf speck, leaf blotch and leaf spot pathogens on proteas.

Pathogen	Synonym	Reference
Batcheloromyces leucadendri Van Wyk, Marasas & Knox-Davies		Van Wyk et al. (1985a)
Batcheloromyces proteae Marasas, Van Wyk & Knox-Davies		Marasas et al. (1975), Smit et al. (1983)
Coleroa senniana (Sacc.) Von Arx	Aphysa senniana (Sacc.) Doidge	Doidge (1950), Van Wyk et al. (1975a)
Clasterosporium proteae M.B. Ellis		Van Wyk (1973a)
Coniothyrium sp.		Van Wyk (1973a)
Didymosporium congestum Syd.		Doidge (1950)
Helicosingula leucadendri Van Wyk, Marasas, Baard & Knox-Davies		Van Wyk et al. (1985b)
Leptosphaeria protearum Syd.		Doidge (1950), Van Wyk et al. (1975a)
Mycosphaerella jonkershoekensis Van Wyk, Marasas & Knox-Davies		Van Wyk et al. (1975b)
Mycosphaerella proteae (Syd.) Von Arx	Oligostroma maculiformis (Wint.) Doidge	Doidge (1950), Van Wyk et al. (1975a)
Phyllachora proteae Wakef.	Unpublished studies by the authors suggest that this fungus is a Botryosphaeria sp.	Doidge (1950), Van Wyk et al. (1975a)
Stigmina protearum (Cooke) M.B. Ellis	Cercospora protearum Cooke	Doidge (1950), Ellis (1972), Van Wyk (1973a)
Teratosphaeria fibrillosa Syd.		Doidge (1950), Van Wyk et al. (1975a)
Teratosphaeria proteae-arboreae Van Wyk, Marasas & Knox-Davies		Van Wyk et al. (1975b)
Trimmatostroma macowanii (Sacc.) M.B. Ellis	Coniothecium macowanii Sacc.	Doidge (1950), Ellis (1976), Van Wyk (1973a)
Vizella interrupta (Winter) Hughes	Entopeltis interrupta (Wint.) Von Höhn.	Doidge (1950), Van Wyk (1973a), Van Wyk et al. (1976)

CONTROL OF PHYTOPHTHORA ROOT ROT OF PROTEAS IN SOUTH AFRICA

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Summary

Root rot caused by *Phytophthora cinnamomi* is a limiting factor in the production of cut flowers from *Leucospermum*, *Leucadendron*, *Serruria* and *Banksia* spp. in South Africa. Prevention remains the most effective method of controlling this disease. However, the widespread occurrence of *P. cinnamomi* in mountain fynbos vegetation and rivers of the southwestern Cape Province poses special problems in preventing root rot. Cultural methods which reduce or avoid conditions favourable for disease are also an important means of control. Attempts to develop fungicide treatments which give good field control for highly susceptible proteas have been largely unsuccessful. Plant breeding is probably the most promising approach to disease control. There is considerable resistance in the genus *Protea* and the more resistant *Protea* spp. can be used on infested lands. There is also tolerance in the genus *Leucospermum* which might be utilized in breeding programs and for rootstock development.

1. Introduction

Phytophthora cinnamomi Rands was first associated with sudden die-back of silver trees (*Leucadendron argenteum*) and other Proteaceae occurring in the southwestern Cape Province in 1973 (Van Wyk). Phytophthora root rot was subsequently recognized as a serious disease problem in commercial protea plantings (Von Broembsen and Brits, 1985). The disease occurs in the main production areas throughout the coastal regions of the Cape Province and in the Transvaal. *P. cinnamomi* has been recorded on 63 species of field-grown proteas from eight indigenous and two Australian genera (Von Broembsen and Brits, 1985).

Phytophthora root rot is a limiting factor in the production of certain kinds of cut-flower proteas in South Africa, especially *Leucospermum* and *Leucadendron* spp. (Brits and Von Broembsen, 1978; Von Broembsen, 1979; Von Broembsen and Brits, 1985). Losses incurred include reduced cut-flower profits, increased production costs for fungicide treatments and re-establishment, and the decreased value of Phytophthora-infested land for susceptible crops. Disease losses of *Leucospermum* and *Leucadendron* spp. under cultivation have discouraged their horticultural production as a financially attractive alterna-

tive to picking from the wild. In addition, attempts to establish commercial production of *Serruria* and *Banksia* spp. have been hampered by losses. Phytophthora root rot is also a problem in protea nurseries (Brits and Von Broembsen, 1978; Von Broembsen, 1984a).

This paper reviews research on the control of Phytophthora root rot of proteas in South Africa. It also evaluates what progress has been made toward adequate control of disease and discusses future approaches to research.

2. Current knowledge of control methods

The primary means of controlling Phytophthora root rot of cut-flower proteas in South Africa are:
- exclusion,
- cultural practices,
- chemical control, and
- plant resistance.

2.1 Exclusion

Exclusion entails primarily the use of Phytophthora-free propagation material, irrigation water and field sites, and the prevention of subsequent infestation of plantings. Production of Phytophthora-free propagation material has been described previously in detail (Brits and Von Broembsen, 1978; Von Broembsen, 1981) and will not be dealt with further here.

The endemicity of *Phytophthora cinnamomi* to mountain fynbos vegetation of the southwestern Cape Province (Von Broembsen and Kruger, 1985) and its widespread occurrence in the region's river systems (Von Broembsen, 1984b) greatly increase the difficulty of exclusion. An often unforeseen problem is soil infestation resulting from the use of land cleared of fynbos vegetation or from spread of the fungus from nearby fynbos vegetation. Irrigation water can be de-contaminated by filtration to 5 microns or by chlorination (Von Broembsen, 1984b), but this is costly for field use. Storing irrigation water vor 3-4 weeks in farm dams greatly reduces but does not completely eliminate the fungus. The fungus can also be introduced from infested areas to disease-free plantings through surface run-off or soil carried on equipment. Methods of preventing introduction to natural and cultivated areas by these and other means have previously been presented (Brits and Von Broembsen, 1978).

2.2 Cultural practices

Cultural practices which reduce or avoid conditions favourable for disease play an important role in the control of Phytophthora root rot of proteas (Brits and Von Broembsen, 1978). Severe root rot is often associated with poor drainage (Von Broembsen and Brits, 1985). Low-lying or poorly draining sites should therefore be avoided. Drainage can sometimes be improved through the installation of underground drainage systems or plants can be grown on

ridges to achieve better drainage. Regular removal and destruction of plants that have died of root rot reduces build-up of inoculum. Highly susceptible proteas should not be planted to field sites with a previous history of root rot.

The use of non-competitive cover crops or natural fynbos as ground cover to minimize soil disturbance and promote the activity of beneficial soil micro-organisms has been recommended as a control method (Brits and Von Broembsen, 1978). Recent studies of the factors affecting sporulation of *P. cinnamomi* at cultivated and fynbos field sites (Von Broembsen and Van der Merwe, unpublished) indicate that ground cover has important effects in reducing sporulation of the fungus. Soil moisture and temperature fluctuations are moderated by ground cover. The temperature/moisture requirements for sporulaton occur more frequently and for longer periods in bare cultivated soils. Furthermore, sporulation often takes place following rain during mid-summer to early autumn (January to March) in bare cultivated soil but not in soil with ground cover. This not only indicates the importance of ground cover but also highlights the need to understand more about how irrigation practices influence sporulation. Research on the effects of type and amount of ground cover on sporulation is underway with a view to selecting the best cover crops and cover cropping methods to reduce root rot.

2.3 Chemical control

Development of fungicide treatments for controlling Phytophthora root rot in field plantings has been largely unsuccessful in South Africa. Effective timing of fungicide application has been hindered by the lack of information on the disease cycle under local conditions. Field studies of the seasonal sporulation of *P. cinnamomi* in cultivated protea fields (Von Broembsen and Van der Merwe, unpublished) show that sporulation occurs mainly in October through December and in April. Testing of fungicide application schedules which protect proteas during these periods should lead to improved control. However, proteas are a minor crop in South Africa and there is, consequently, little financial incentive for chemical companies to develop field application methods. The lack of standard production practices for this newly developing agricultural crop further complicates the task of developing field application techniques.

Most of our research on fungicide control (unpublished) has been carried out on the commercially important and highly susceptible pincushions (*Leucospermum* spp.). Although metalaxyl gives reasonably good field control of root rot, it is unacceptably phytotoxic to pincushions at the rates required for control under local field conditions. Fosetyl-Al is less effective than metalaxyl, but it is also much less phytotoxic to pincushions and less expensive. Some phytotoxicity is experienced if fosetyl-Al is used at transplantation time when plant growth is temporarily slowed down, but these effects are later overcome. Fosetyl-Al can be used as a protective treatment for pincushions. Isolated spots of disease in pincushion plantings can be contained by disinfesting

planting sites with vapam and treating the remaining plants with fosetyl-Al. Once root rot has become established in a planting, fosetyl-Al can be used to reduce losses. However, this is not cost efficient in many situations.

2.4 Plant resistance

There is considerable field resistance in the genus *Protea* (Brits and von Broembsen, 1979; Von Broembsen, 1979; Von Broembsen and Brits, 1985). Several important commercial *Protea* spp. (*P. cynaroides*, *P. neriifolia*, *P. repens*, and *P. compacta*) display strong mature-plant resistance. These species are successfully used to replant Phytophthora-infested lands. However, two commercially important species, *Protea magnifica* and *P. grandiceps*, are somewhat more susceptible and field losses can occur. *P. cinnamomi* infects seedlings of many *Protea* spp. (Von Broembsen, 1984a; Von Broembsen and Brits, 1985). Losses of even the more field resistant species sometimes occur in the nursery or during field establishment if infected plants are used. It is therefore important that evaluation of resistance in breeding programs for *Protea* spp. does not relay too heavily on data from seedlings or juvenile plants.

The important commercial genera, *Leucospermum* and *Leucadendron* are highly susceptible both as juveniles and as mature field plants (Brits and Von Broembsen, 1978; Von Broembsen, 1979; Von Broembsen, 1984a; Von Broembsen and Brits, 1985). There appears to be only limited field resistance or tolerance available within these genera for resistance breeding. This suggests that evaluation of resistance in breeding programs should be based mainly on field evaluations. In pot trial inoculations of various kinds of proteas, the time elapsed before death occurred was, however, a useful indicator of field resistance or tolerance (Von Broembsen and Brits, 1985).

Production of cut flowers from *Banksia* spp. has met with serious Phytophthora root rot problems in south Africa. Resistance breeding for this highly susceptible genus is underway in Western Australia (Dixon et al., 1984). Only one species of the genus *Serruria*, *S. florida*, is commercially cultivated. It is highly susceptible both in the seedling and mature plant stages (Von Broembsen and Brits, 1985). There is little field information for other indigenous gnera with commercial potential such as *Aulax*, *Mimetes*, and *Paranomus*, but seedlings of representative species are moderately to highly susceptible (Von Broembsen and Brits, 1985).

Over the past few years we have been evaluating resistance within the genus *Leucospermum* using more than twenty selected pincushion species and hybrids (unpublished). Pot trials using one-yr-old plants inoculated with zoospores have shown that all these lines are susceptible to infection by *P. cinnamomi*, but that some lines are more tolerant to infection and subsequent disease development. Shoot cuttings from these lines have also been

inoculated using methods similar to those of Jeffers et al. (1981) and Dixon et al. (1984) to determine if a shoot assay can be used to screen for tolerance. Problems with the reliability of these inoculation techniques have been encountered with detached shoots of *Leucospermum* spp. Preliminary results at field sites with high inoculum levels and soil conditions conducive to root rot indicate that an *L. reflexum* selection is the most tolerant line tested and that certain selections or hybrids of *L. cuneiforme* and *L. conocarpodendron* also have some tolerance. However, the tolerance shown at field sites with more moderate inoculum levels and soil conditions not favouring disease appears to be much greater for most of the breeding lines. This indicates the importance of considering the field conditions under which tolerance is evaluated.

3. Future research on control

Apart from improvements in chemical control, future advances in control are most likely to come from the manipulation of cultural practices to reduce disease and the exploitation of the resistance available within the Proteaceae by plant breeding.

The use of cultural practices to reduce disease is a challenging prospect. Knowledge of factors influencing the disease cycle of the fungus could be used to predict how the cycle might be interrupted or inhibited by specific cultural practices. For instance, the poor survival of *P. cinnamomi* in soil outside living roots (Marks et al., 1975; Shea, 1975) suggests that the use of fallow to reduce or eliminate the fungus from infested soils should be explored. Another approach would be to investigate what limits disease in natural ecosystems such as the fynbos. *P. cinnamomi* occurs naturally in the fynbos in the presence of highly susceptible hosts without causing significant disease (Von Broembsen and Kruger, 1984). Comparison of factors affecting disease at such sites with those at cultivated sites may indicate factors that could be promoted by specific cultural practices. The ground cover research discussed above is an example of this approach.

It is also important to examine how present cultural practices influence root rot. What are the effects of irrigation practices on disease? Can disease be reduced by controlling irrigation frequency and intensity? Do soil cultivation practices or the use of plastic mulches influence disease? Does the form or method of nutrient application affect disease? Important control methods may lie in the answers to these questions.

Plant resistance is the ultimate means of control, but it requires considerable research and testing to develop resistant cultivars for commercial use. Resistance and tolerance within commercially important, susceptible genera such as *Leucospermum* and *Leucadendron* need to be fully evaluated under defined conditions of disease pressure in the field. Inoculations of seedlings and cuttings can give useful indications of field resistance if inoculum dosages and the time after inoculation until death occurs are considered. Shoot assays are likely to be

more useful to compare reactions within other genera of the Proteaceae with more resistance than L e u c o s p e r m u m. Breeding programs should also include species with little apparent commercial potential. Even limited tolerance in highly susceptible genera could be useful, especially when combined with other control methods. Such tolerance should be incorporated into breeding programs to determine if useful additive genetic variation for tolerance is available.

Resistant rootstocks have been successfully used against P h y t o p h t h o r a spp. on other crops and are an important potential control method. However more research on grafting is needed to evaluate this possibility. If sufficiently resistant material in highly susceptible genera cannot be found for development of resistant rootstocks, the possibility of intergeneric grafting to resistant material should be tested. Other modern breeding methods such as the use of polyploids or mutagens may even be used for protea breeding in the future.

Plant resistance is the most promising means of achieving control of Phytophthora root rot. With the breeding of proteas only in its infancy, many opportunities exist for plant breeders to incorporate disease resistance into breeding programs.

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INSECTS - A HAZARD TO THE PROTEA INDUSTRY

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Abstract

A crop which is cultivated in its natural habitat is attacked by a wide spectrum of insects. The insects on Proteaceae can be divided into three groups according to the damage they cause: (a) flower visitors, some of which cause serious phytosanitary problems (b) leaf feeders and leaf miners (c) borers, including both stem and seed borers. Natural fynbos which borders on cultivated proteas creates problems with the control of these pests since it serves as a source of re-infestation. To control this wide spectrum of pests an integrated pest control programme must be developed. Such a programme should include chemical and biological control, as well as correct cultivation methods. The use of insecticides should play a subordinate role. A thorough knowledge of the biology and ecology of the different pests and the effect of the pests on these plants are important requirements for this programme. Without an efficient pest control programme proteas cannot be cultivated successfully in their natural habitat.

1. Introduction

Plants belonging to the family Proteaceae are grown on a commercial scale in South Africa in their natural environment. Advantages are that climatic and soil conditions are suitable, but the great disadvantage is that indigenous pests are also present. These can be very abundant, as in the case of Proteaceae, since the insects had a chance to adapt to the plant over a long period of time. In contrast, a plant growing outside its natural environment can be expected to have a narrower spectrum of pests of which only a few may be dominant. These consist of a few insects from the natural fauna that could adapt to the "foreign" plant and those that normally feed on the plant and succeeded in following the plant to its new habitat.

In an undisturbed natural environment a dynamic yet delicate balance exists between the host plant, the insects that feed on it, and natural enemies of the herbivores. The balance between the components of the food chain is influenced in the short term by environmental factors such as the climate, and in the long term by co-evolutionary processes. This usually ensures that the numbers never increase to exceptionally high levels nor do they decrease to very low levels. Plants as a group are therefore never without

damage, but the damage is seldom so severe as to cause them to die on a large scale.

Not all insects associated with the Proteaceae are pests: in certain instances the association between the Proteaceae and insects is mutualistic : These pollen and nectar feeders obtain food and shelter from the plant, but they also pollinate the plant (Coetzee & Giliomee, 1985). A most interesting mutualistic relationship, known as myrmecochory, exists between certain ant species and some of the Proteaceae (Slingsby & Bond, 1981). The seeds contain elaiosomes which attracts ants that carry the seeds to the safety of their nests.

In this paper attention will be given to past research on the type of damage caused to Proteaceae by insects, problems related to control measures, and the implementation of an integrated pest control programme.

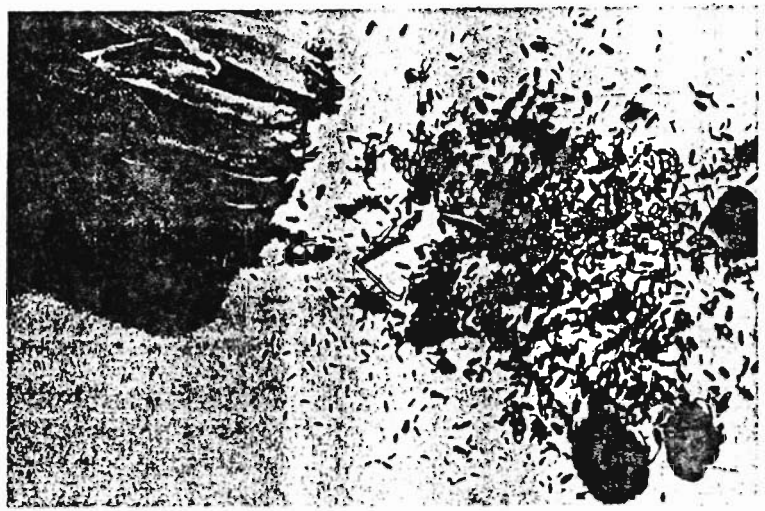

Figure 1. Flower insects collected in ten P. neriifolia inflorescences

2.1 Current state of research on protea insects

The first article on the insects of the Proteaceae was published by Tooke (1944). It delt with the borer, Sphenoptera sinuosa (Castelnau & Gory) which attacks the silver tree, Leucadendron argenteum (L.) R.Br. Gess (1968) drew attention to the large number of insects found on proteas. A number of articles dealing with the destructive effects of insects on different protea species then followed (Myburgh et al. 1973; Myburgh et al. 1974; Myburgh & Rust, 1975a; Myburgh & Rust, 1975 b). A comprehensive study of the insects associated with Protea repens (L.)L. was undertaken by Coetzee (1984). Based on these studies, the pests of proteas can be divided into three main groups: (a) flower visitors (figure 1), (b) leaf feeders (figure 2a) and leaf miners (figure 2b) and (c) borers (figure 3a & 3b) which include stem and seed-borers.

A faunal list for the Proteaceae was compiled from these publications and other unpublished data and includes 233 species (Coetzee & Rust, unpublished). This list is incomplete, mainly because the identity of many of the insects is still unknown, and several of these will probably be described as new species. In order to facilitate the identification of protea insects, a reference collection of over 3 000 insect specimens has been compiled, mainly by D. J. Rust. The first entry dates back to 1959. The collection is still being enlarged and as many of the insects as possible are being identified. The collection is housed at Stellenbosch in the Entomology Section of the Horticultural Research Institute.

It is obvious from the above that research on protea insects is still in its infancy, but a firm foundation has been laid with the collection and identification of large numbers of protea insects. An assessment has been made of the destruction caused by certain species and of possible control measures. However knowledge of the biology and ecology of most species is lacking.

2.2 Damage and control of protea insects

Insects and mites which occur mainly in the inflorescences of the genus Protea consist of a great variety of species (figure 1). In the inflorescences of P. repens, 45 insect species have been found (Coetzee & Giliomee, 1985). Some of these play an important role in pollination, but give rise to phytosanitary problems. In order to comply with the strict export regulations, no insects may be present in the inflorescences, and therefore all flowers must be treated with a chemical insect spray before they are packed.

Leaf feeders destroy approximately 10% of the leaf surface area of P. repens in its natural habitat (Coetzee, 1984). This level can be tolerated by the plant, but is unacceptable to the grower, as it is cosmetically unacceptable to have damaged leaves (figure 2a & b) on the flower stem of marketed inflorescences.

The borers cause destruction of the growing points (figure 3a), flower buds (figure 3b) and seed. Nine economically important borers are found on proteas. They have an adverse effect on both flower and seed production (Coetzee, 1984). Although it is possible to control borers with chemical sprays, it is both difficult and costly; therefore sanitation has been the most acceptable method of control in protea plantings.

Figure 2a. P. cynaroides with leaf damage caused by leaf feeders.

Figure 2b. Leaf miner damage caused by Eucosma sp. on the leaves of P. neriifolia.

2.3 Pest control problems of cultivated Proteaceae

A number of factors make it difficult to cultivate Proteaceae in their natural habitat. Not the least of these is the fact that all the natural pests of proteas are present. The problem of controlling protea pests in commercial plantings is aggravated by the fact that such plantings are usually adjacent to areas where the same and closely related plants grow naturally. Normally insect numbers are able to recover quickly after a spray application as spraying usually affects the natural enemies as much or more than the pest insects themselves. It also lessens competition between the various species of insects. As there is in the case of proteas, a source of re-infestation in the immediate surroundings pest numbers can recover even more rapidly.

When Proteaceae are cultivated commercially in plantings, the extent of damage normally caused by a specific insect species or complex of insect species is not acceptable to the producer. It is expected that the number of insect pests will increase to higher levels in commercial plantings than in the undisturbed natural environment, since plants of the same kind are grown in a dense monoculture. In this situation there is no shortage of suitable food for pest species, which could possibly be a limiting factor in the increase of natural insect populations. As a result insects need not unnecessarily expend energy searching for food or places to lay eggs, allowing more energy to be channelled into reproduction.

The selection of new cultivars can result in a change in the flowering period. This can adversely affect certain insects which attack the flowers but on the other hand it might be an advantage to others. This was the case with the infestation of flowers of P. repens by Euderes lineicollis. The infestation was much lighter on the Stellenbosch mountain where the inflorescences flowered earlier than those in Jonkershoek (Coetzee, 1984). On the other hand P. repens cultivar Guerna, which flowers in summer, is attacked by the larvae of the protea butterfly Capys alphaeus, which is not a problem on winter flowering P. repens.

Figure 3a. C. ammopleura borers in the stem of P. neriifolia causing the growth point to wilt.

Figure 3b. C. ammopleura feeding in the involucral receptacle of P. repens.

2.4 Problems regarding the application of integrated pest control (IPC) to proteas

It has already been noted that there are three main insect pest groups of proteas: flower visitors, leaf-feeders and miners, and borers. Any pest control programme will have to take into consideration the differences between these types of pests.

A prerequisite for the compilation of an IPC programme is a thorough knowledge of the biology and ecology of the relevant pests and their natural enemies. Biological control, which usually plays an important role in IPC programmes, seems to have limited possibilities in the case of protea pests, as the harmful insects reach pest status in the presence of the full complex of natural enemies.

The regular and large scale use of insecticides in commercial

orchards must be seen as a short-term approach, because it will give rise to resistance, secondary pests and cause the poisoning of many harmless organisms. Efforts should therefore be made to develop an IPC programme in which the use of insecticides plays a subordinate role. Such a programme will be more acceptable ecologically, but will stand no chance of acceptance by the producer unless it is effective, economical and reliable.

The plant phenology also has an effect on the IPC programme. The growth pattern of individual cultivated protea plants is irregular and can differ from plant to plant. This complicates the development of an IPC programme as there is continually new growth which must be protected from insect attacks.

Finally, there is the problem of determining economic injury levels, i.e. the level that pest numbers can attain before economic damage is done. This is influenced by a complex of factors, such as the effect the insects have on the plants, the value of the crop, and the cost of control measures. Furthermore, since chemical treatment in an IPC programme is based on insect numbers, simple, yet reliable monitoring systems will be required for the major pests.

3. Conclusion

There is little hope for cultivating proteas commercially in their natural habitat unless successful insect control measures can be developed. For this reason an IPC programme is of the utmost importance.

Research is therefore planned to develop an IPC programme. The aim will be to obtain: (i) a faunal list of insects associated with the most important economic protea species; (ii) a list of insects which should be regarded as important economic pests; (iii) information on the life cycles of the most important pest species through biological studies and (iv) the possible correlation between the distribution of plant pathogens and insects. Control programmes are drawn up for exclusive use in planted orchards, since pest control is practically impossible where proteas grow naturally. A great deal of attention is also being given to the control of insects which occur in the flowers after they have been harvested.

From the above it is clear why there has been, and will be a great demand for efficient and acceptable control measures against protea pests. Therefore knowledge is required of the identity, biology, ecology and damage caused by the different pests and of the control strategies which should be followed.

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POPULATION ECOLOGY OF WESTERN AUSTRALIAN BANKSIA SPECIES : IMPLICATIONS FOR THE WILDFLOWER INDUSTRY

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Summary

The harvesting of blooms and cones of B a n k s i a species from natural stands comprises an important component of the Western Australian wildflower industry. Therefore the management of banksia populations in the wild should enjoy a high priority. Our research on the population ecology of Western Australian banksias in relation to fire has important implications for the industry. The intensity of flower and cone harvesting should be constrained by the seed bank dynamics, variation of cone and follicle production and seed viability of individual species. Fire regime effects may have a profound affect on the recruitment of banksias. The possibility that certain horticulturally valuable species might be driven to extinction as a result of inappropriate fire management, cannot be ruled out. The industry should therefore actively support research on the management and conservation of banksia populations in the wild.

1. Introduction

Of the 73 described species of B a n k s i a, 58 grow in the fire-prone shrublands and woodlands of southwestern Australia (George, 1981). B a n k s i a flowers and fruits are an important component of the export wild flower industry in Western Australia (Hopper 1983; Lamont 1983). Only 72 ha was under cultivation in 1982 for the production of B a n k s i a flowers; most flowers are cut under license from natural stands and it seems likely that this practice will persist for many years to come (Watkins 1983). Therefore a predictive knowledge of the management of banksias in the wild is essential for the growth and success of the Western Australian wildflower industry.

Fire is central to the management of vegetation in which banksias are conspicuous (Gill and Groves, 1981). A major research challenge is the identification of the critical limits of species to various components of the fire regime (particularly fire frequency and season of burn) so that the extinctions of horticulturally valuable species can be avoided. In this respect it is essential to have a knowledge of the location and size of viable

seedbanks, together with an understanding of the factors which contribute to the production and attrition of seed (Cowling et al. 1985, Lamont 1985). It must be remembered that by harvesting flowers, the wildflower industry is responsible for lowering the reproductive potential of species.

This paper reviews data on the reproductive and population ecology of four B a n k s i a species which are relevant to management practices for the maintenance of their populations in the wild. The four species, along with their modes of regeneration and seed storage characteristics are (George, 1981): B. a t t e n u a t a (resprouter, serotinous), B. l e p t o p h y l l a (non-sprouter, serotinous), B. m e n z i e s i i (resprouter, weakly serotinous) and B. p r i o n o t e s (non-sprouter, weakly serotinous). Serotiny refers to canopy storage of seed. The four species represent just about the full spectrum of regeneration types associated with B a n k s i a in southwestern Australia (cf. George, 1981). The studies were undertaken at Mount Adams, 300 km north of Perth, where all four species co-occurred in scrub-heath (for details see Cowling et al., 1985). We will, where appropriate, make reference to relevant data from other banksias growing on the sandplain scrub-heath north of Perth.

2. Seed banks

2.1. Canopy-stored seed

All banksias have massive woody infructescences (cones) in which are embedded none to many follicles (fruits) each containing two or less seed (George, 1981). For many species seed are held in the cones for many years and only released after fire or plant death (serotiny); in other species seed are released spontaneously (Lamont and Cowling, 1984). There is no evidence of a soil-stored seedbank (Cowling et al., 1985). The degree of serotiny can vary enormously within a species, depending on climate and other factors (Cowling and Lamont, 1985). The degree of serotiny of a species can be easily assessed by determining the proportion of empty follicles on older cones. B. l e p t o p h y l l a and B. a t t e n u a t a are strongly serotinous whereas B. m e n z i e s i i and B. p r i o n o t e s are weakly serotinous and largely dependent on the current years crop for recruitment (table 1). For serotinous species in general, it will be possible in any year to harvest intensively flowers and the current years cone crop without seriously reducing recruitment potential. For weakly- or non-serotinous species sufficient blooms and cones should not be harvested to ensure that the size of the seedbank is always large enough to ensure adequate recruitment after a fire.

2.2. Cone and follicle production

There are large differences in cone and follicle production among species (table 2) and also large year-to-year variations in reproductive output (figure 1). Generally, however, sprouting species (e.g. B. a t t e n u a t a and B. m e n z i e s i i) have the lowest follicle set (the percentage of flowers which develop into follicles). Low follicle set is compensated for by the high post-fire sprouting success of these species (Cowling and Lamont, unpublished data).

The low and highly variable follicle production (figure 1) is cause for concern in terms of flower and cone harvesting. Populations should be harvested on at least a three year rotation in order to ensure that one good year of follicle production replenishes seed reserves. Careful monitoring is required in order to prevent overexploitation. The causes of low follicle set in banksias are complex and probably related to resource limitations (Abbott, 1985; Lamont et al., 1985) which are beyond the scope of management.

2.3. Seed germination and viability

Almost all banksia seed show no innate dormancy and the seed of most southwestern Australian banksias will germinate readily at 15-20°C (table 3). The germination success of B. m e n z i e s i i was low, possibly due to fungal infection. The relatively low temperature requirement for germination of banksia seed confers a drought-avoiding dormancy; seed will only germinate with the onset of cooler (and wetter) winter weather. Furthermore, banksia growers should not attempt to germinate seed outdoors during the hotter months since not only is germination success low at high temperatures (table 3) but there is evidence that high summer soil temperatures reduce seed viability.

There was a decline in the germination success of seed from older cones of banksias, although this was least marked for B. l e p t o p h y l l a (table 4). Therefore the existence of a large cone crop with firm seed should not be taken as a justification for intensive and sustained annual harvesting; seed viability will decline with increasing age and this will reduce recruitment potential.

3. Seed release

Banksias possess a complex mechanism for seed release. Most Australian banksia growers are familiar with the problems of extracting seed from cones. Experiments have shown that when burnt cones were periodically immersed in water and then allowed to dry, seed release increased many-fold compared to untreated controls (figure 2). In each

Whelan, R.J. and Main, A.R., 1979. Insect grazing and post-fire succession in a South-west Australian woodland. Aust. J. Ecol. 4:387-398.

Table 1 - Percentage contribution of firm seed to total canopy-stored firm seed crop of four B a n k s i a species. 15 plants of each species were assessed. Data from Cowling et al. (1985).

Cone age (yr)	1	2	3	4	5	6	7	8	9	10	11	12
B.leptophylla		20			2			44			33	
B.attenuata	18	14	14	9	11	19	7	5	2	1	0	
B.menziesii	73	18	2	0	5	1	1	0				
B.prionotes	61	15	6	3	1	6	2	4	0	2		

Table 2 - Cone and follicle production by four B a n k s i a species. Values are means ± standard errors. 15 plants of each species were assessed. Data from Cowling et al. (1985).

	No. cones per plant	No. follicles per cone	Follicle set
B.attenuata	25.4 ± 3.5	3.3 ± 1.2	0.1 ± 0.1
B.leptophylla	52.3 ± 5.6	25.2 ± 15.8	4.7 ± 3.0
B.menziesii	15.4 ± 4.0	2.9 ± 1.6	0.3 ± 0.2
B. prionotes	7.9 ± 1.7	32.2 ± 5.8	2.4 ± 0.6

Table 3 - Germination of seeds of B a n k s i a species at different temperatures. Mean % germination of three replicates of 15 seeds each after 30 d. Cowling and Lamont, unpublished data.

Species	Temp.(°C) 10	15	20	25	30
B. a t t e n u a t a	0	70	50	0	0
B. h o o k e r a n a	0	100	100	27	0
B. l a n a t a	0	87	83	7	0
B. l e p t o p h y l l a	0	93	77	0	0
B. m e n z i e s i i	0	13	3	0	0
B. p r i o n o t e s	0	80	77	20	0

Table 4 - Germination of different aged seeds of B a n k s i a species at 15°C. Mean % germination of three replicates of 15 seeds each after 30 d. Data from Cowling et al. (1985).

Species	Age class (yr) 1-3	4-6	7-9	9-12
B. a t t e n u a t a	75	60	51	-
B. l e p t o p h y l l a	100	100	100	64
B. m e n z i e s i i	11	8	7	-
B. p r i o n o t e s	76	42	40	-

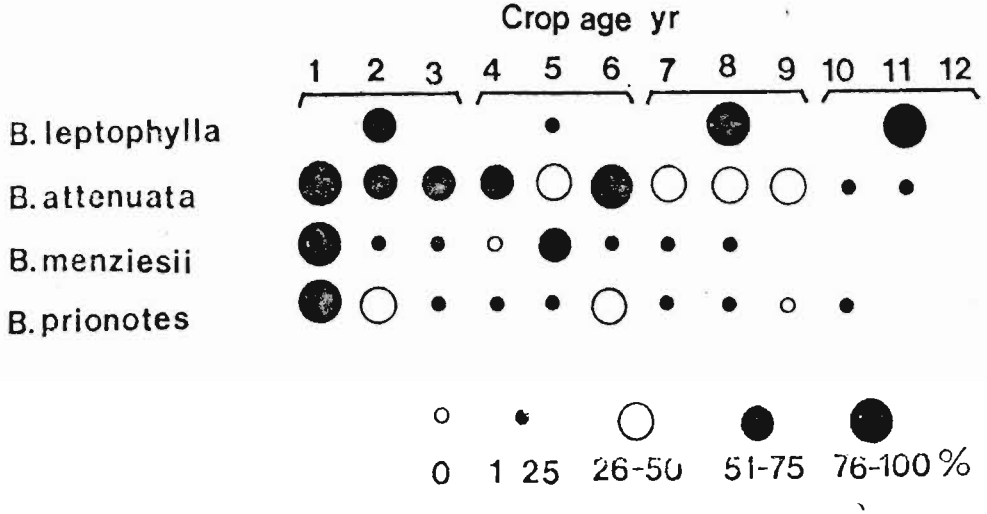

Fig. 1 - Follicle production by four Ba n k s i a species. The results are expresssed as percentages of the best year's production. From Cowling et al. (1985)

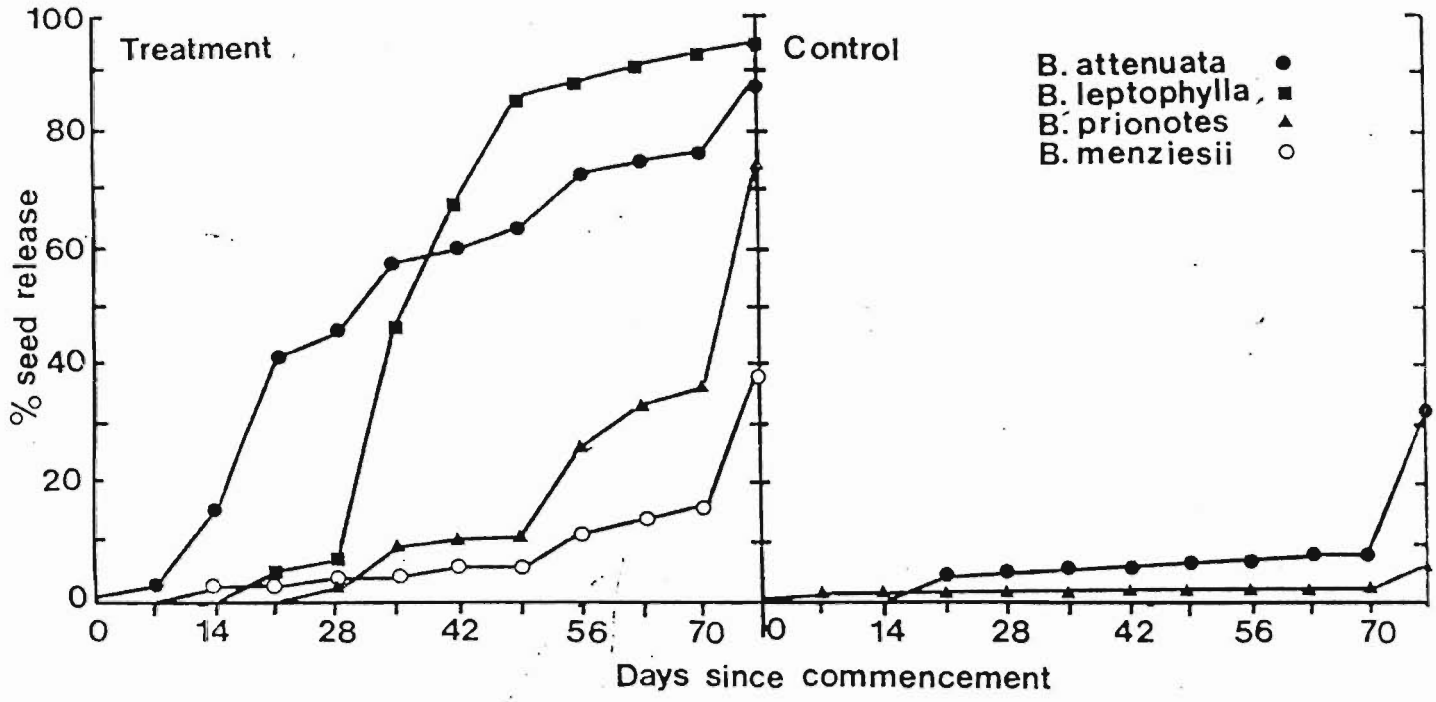

Fig. 2 - Means of percentage of seed released per cone from burnt cones submitted to wet-dry cycles and untreated controls. Values for B. l e p t o p h y l l a and B. m e n z i e s i i were effectively zero in the control treatments and so have been omitted from the graph. From Cowling and Lamont (1985b).

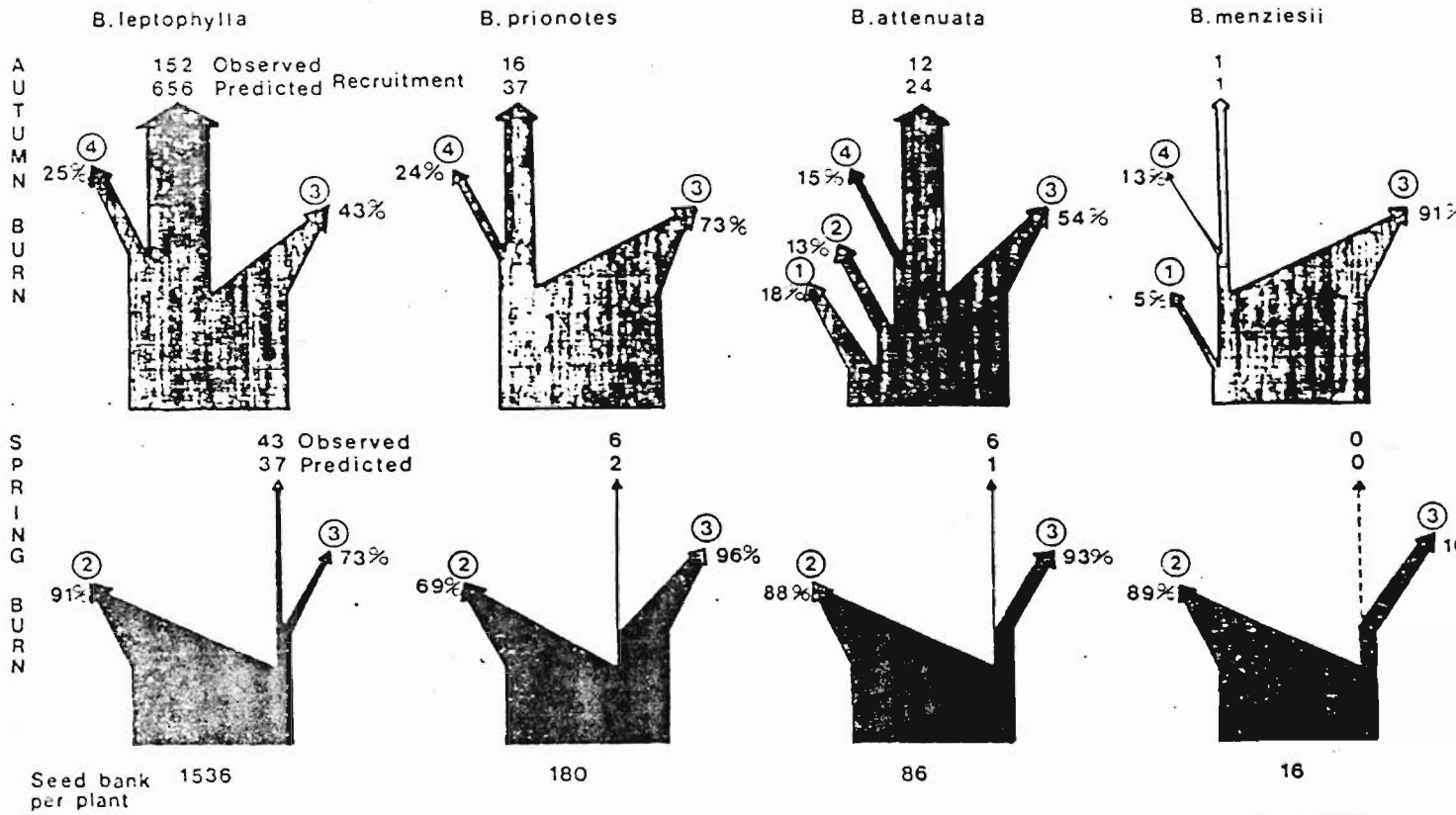

Fig. 3 - Seed and seedling attrition and predicted and observed recruitment of four B a n k s i a species after autumn (May 1983) and spring (Sep 1983) burns at Mount Adams. Recruitment observed in Sep 1983 after autumn burn and in Aug 1984 after spring burn. 1 = predispersal but post-fire seed predation by cockatoos; 2 = postdispersal seed predation; 3 = seed not germinating; 4 = seedling mortality (measured up to time of recruitment observation). Cowling and Lamont (unpublisned data).

PATHOLOGICAL PRO[illegible] ASSOCIATED WITH PROPAGATION MATERIAL IN PROTEA NURSERIES IN SOUTH AFRICA

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Summary

Preliminary surveys were made of indigenous Proteaceae in nurseries and botanic gardens in the South-western Cape to determine to what extent pathological problems are associated with propagation material. Diseased material collected from nursery beds and mistbeds indicate that the most significant local nursery diseases are caused by soil and seed-borne fungi. Monitoring of seed, seedling and cutting diseases has shown that pre- and post-emergence damping-off and seedling blights, are the most prevalent in nursery beds, particularly on the genus *Protea*. Dieback of cuttings in mistbeds, caused by a range of organisms including *Colletotrichum gloeosporioides* is widespread, and species of *Leucospermum*, *Leucadendron*, *Serruria* and *Protea* are susceptible to cutting dieback. Organisms frequently isolated from all sources of propagation material included *Fusarium* spp.; *Rhizoctonia solani*; *Phytophthora cinnamomi* and *Botryosphaeria* spp. Provisional control recommendations are given for specific propagation diseases. Seed treatments found to be effective in controlling damping-off diseases are also discussed.

1. Introduction

Proteaceae form a dominant element of the unique Cape fynbos and are probably one of the most intensively researched groups of the fynbos plants. Pioneering in cultivation of these plants led to the development of an economically important indigenous cut-flower industry. South Africa, the land of origin of most cultivated proteas, is faced with many problems, as native pathogens subsist on protea communities growing in their natural habitat and consequently exert continuous pressure on the cultivated plant. A horticultural approach, together with improved breeding and selection programes, is an essential part of successful commercial protea production. This move towards intensive cultivation placed increased demands on the nursery. Diseases and the threat they pose in protea nurseries have become a major concern.

Studies on a seed-borne disease of *Protea compacta* R. Br. (Benič and Knox-Davies, 1983) highlighted the need for further investigation on seedling and other propagation diseases. Surveys were made of disease problems in protea nurseries and a list of the dominant fungi associated with diseased material was compiled.

Control recommendations formulated from existing and accepted nursery disease control practices are discussed for specific seedling and cutting disease problems.

2. Pathological problems associated with propagation material

Diseased material collected from nursery beds and mistbeds at Kirstenbosch, Betty's Bay, Assagaaibos, Protea Heights and Tygerhoek Research Farm indicate that the most significant local nursery diseases are caused by soil and/or seed-borne fungi.

2.1. Nursery bed problems

Pre- and post-emergence damping-off and seedling blight diseases were the most prevalent nursery bed problems, particularly on the genus *Protea*.

2.1.1. Damping-off diseases of seedlings in seedbeds

Colletotrichum gloeosporioides, the causal organism of damping-off of *P. compacta* (Benič and Knox-Davies, 1983) was the dominant organism isolated from infected seedlings of several other species of the genus *Protea* (Table 1). Typical symptoms developing on infected seedlings were pre- and post-emergence damping-off, necrosis of cotyledons and leaf and stem necrosis. Cankers typically formed around the base of leaves, extended down the stem and girdled the stem. Fungi isolated less commonly from damping-off seedlings included a *Fusarium* sp.; *Rhizoctonia solani*; *Phytophthora cinnamomi* and a *Pythium* sp. Inoculations of young *P. compacta* and *Protea cynaroides* (L.) L. seedlings, with these fungi resulted in the development of a range of typical damping-off symptoms. Symptoms caused by the different fungi were similar and often indistinguishable from one another. Acervuli usually developed on the cankered stems of seedlings inoculated with *C. gleoesporiodes*. Seedlings inoculated with *R. solani* also developed symptoms on the cotyledons. This is often a symptom associated with seed-borne diseases; however, it is not yet known whether this organism is seed-borne. Repeated experiments using seed of the same species but taken from different seed lots to check for the presence of these fungi, did not always give consistent results. Disease occurrence and severity of the infection varied from one seed sample to another. In some cases no infection occurred. Inconsistency of results made it difficult to determine which damping-off infections were caused by seed-borne fungi and which resulted due to seed being contaminated by soil-borne fungi in planting media. Certain fungi regularly developed on potato-dextrose agar from seed of several different species of Proteaceae but were not isolated from damped-off seedlings. These include *Phomopsis* sp., *Phoma* spp., *Botryosphaeria dothidea*, *Alternaria* spp., *Stemphylium* spp., *Curvularia* sp., and a *Pestalotia* sp. During this survey damping-off symptoms were not encountered on *Leucospermum* or *Leucadendron* spp.

2.1.2. Seedling blight on young plants

Seedling blight symptoms ranged from severe dieback of terminal shoots and leaves to minor necrosis of leaves. The age that plants became infected varied. *C. gloeosporioides* was frequently isolated from dying back, girdled shoots on young plants. A number of *Protea* spp. were susceptible to *Colletotrichum* dieback. Greenhalgh (1981) reported *Colletotrichum* dieback to be an economically important disease of many species of the genus *Protea* in Australia. The importance of *Colletotrichum gloeosporioides* as a pathogen in protea nurseries in South Africa was clearly shown in the present survey. This fungus is also known to cause anthracnose of mature *P. compacta* (Benič and Knox-Davies, 1983). Mature *Serruria florida* and some additional *Protea* spp. are also susceptible to this organism (Table 1). So far *C. gloeosporioides* has not been isolated from seedlings, young plants or mature plants of *Leucospermum* or *Leucadendron* spp., suggesting that they are resistant.

Other fungi were also isolated from plants with blight symptoms similar to those caused by *C. gloeosporioides*. A *Fusarium* sp., was occasionally isolated from plants showing blight but no root symptoms. *Botryosphaeria dothidea*, a fungus found to be a secondary invader of the canker and dieback disease of mature *P. compacta* (Benič and Knox-Davies, 1983) was sometimes isolated together with *C. gloeosporioides*. This fungus was also isolated alone from young *P. compacta*; *Protea grandiceps* Tratt.; and *Leucadendron spissifolium* (Salisb. ex J. Knight) I.J. Williams plants showing symptoms of canker and dieback.

2.1.3. Root and collar rot

Phytophthora cinnamomi was isolated from the roots of young *Leucadendron* spp., especially *L. xanthoconnus* (Kuntze) K. Schum.; *L. salignum* Bergius; *L. cordifolium* and *Orothamnus zeyheri* Pappe ex Hook. f. Symptoms were similar to those on older / mature plants i.e., yellowing of upper parts of plants; arrested growth and the death of some shoots in the collar region. Blackening and girdling of the lower part of the stem was common. In the survey *P. cinnamomi* often appeared in patches amongst densely packed nursery stock, usually killing all plants in the affected area. *Leucadendron agrenteum* (L.) R. Br. was particularly susceptible to *P. cinnamomi* and resulted in death and loss of large numbers of plants. *P. cinnamomi* was isolated from young *P. cynaroides* plants with symptoms of dieback from the tip of the stem and necrotic areas of leaves. Typical root symptoms were not apparent and roots appeared healthy. *P. cinnamomi* was isolated from many plants (Benič, unpublished data). *P. cinnamomi* occurs commonly in nurseries in the South-western Cape (Von Broembsen, 1984). It was also isolated from typical root and collar rot symptoms on *P. cynaroides*. *P. cynaroides* has been known to be

fairly resistent to this fungus (Von Broembsen, 1984); however, results have shown that young P. c y n a r o i d e s plants are susceptible to root rot caused by P. c i n n a m o m i (Benić, unpublished data and Von Broembsen). F u s a r i u m o x y s p o r u m was often associated with diseased roots of young plants, particularly on P r o t e a m a g n i f i c a Link and many of the L e u c a d e n d r o n spp. M a c r o p h o m i n a p h a s e o l i n a was isolated from a group of drought stressed plants. Plants were slightly yellowed and generally lacking vigour.

2.2. Mistbed problems

Vegetative propagation by rooting cuttings in mistbeds is a widely used technique for the propagation of many members of the Proteaceae. Cuttings are highly stressed plant tissue and are therefore more subject to invasion by disease organisms than are rooted plants. These resulting diseases may kill cuttings and cause severe losses during propagation or in later stages of plant growth. Such losses were observed during this survey.

2.2.1. Cutting dieback

Cutting dieback was caused by a wide range of fungi. C. g l o e o s p o r i o i d e s was consistantly isolated from diseased P r o t e a r e p e n s (L.) L., hybrid P. c o m p a c t a x P r o t e a n e r i i f o l i a R. Br. and S e r r u r i a f l o r i d a (Thunb.) Salisb. ex J. Knight cuttings. Cankers developed from cut tips and extended up into the stem, girdling the stem as it progressed. Necrosis of leaves and in severe cases, defoliation followed. This infection resulted in the loss of up to seventy percent of the cuttings. R. s o l a n i was isolated from P. r e p e n s and many of the hybrid L e u c o s p e r m u m cultivars. It caused many losses in the nursery. Basal stem necrosis and defoliation were the most common symptoms observed. Preliminary pathogenicity tests with these two fungi, produced symptoms similar to those on naturally infected cutting material. Symptoms appeared within ten to twelve days after inoculation. B. d o t h i d e a, F u s a r i u m sp., P h o m o p s i s sp., S c l e r o t i n i a sp., and a P e s t a l o t i a, were sometimes isolated from diseased cuttings. Basal and tip dieback and necrosis of leaves were typical symptoms. P e s t a l o t i a- infected cuttings developed acervuli on the necrotic leaves. These fungi were occasionally isolated together from the same cutting. Most of the hybrid L e u c o s p e r m u m cultivars were susceptible to infection. B o t r y t i s c i n e r e a was repeatedly isolated from a group of S. f l o r i d a cuttings. These cuttings were taken from mother plants in an orchard in which many of the plants showed severe symptoms of shoot and flower blight from which B. c i n e r e a was isolated. This indicates that the B o t r y t i s inoculum was initially brought into the mistbed on infected cutting material collected from the mother plant. Irregularity of disease outbreaks in the mistbed have made it difficult to determine which species of Proteaceae are susceptible to cutting dieback. Factors such as overwatering of cuttings, soggy planting media, wounding and drought stress due to cuttings drying out, all seem to favour infection. P. c i n n a m o m i was found to be a further problem in the mistbed, causing dieback and root rot of rooted and rooting cuttings. Blackened basal stem lesions extended from cut surfaces up into the stem. This was often accompanied by girdling and reddening of the stem above the crown lesion in rooted cuttings. Many of the L. c o r d i f o l i u m hybrids were highly susceptible to root rot.

2.2.2. Scab and blight in the mistbed

Symptoms of scab were observed on isolated groups of cuttings in mistbeds. The disease is characterised by corky leaf lesions; more extensive stem lesions and stem twisting (Benić and Knox-Davies, 1983). The disease resulted when cutting material was collected from scab-infected mother plants brought into the mistbed. The causal fungus (E l s i n o e sp.) can survive on scab lesions as resting mycelium, stromatic tissue, chlamydospores and microsclerotia inside the host tissue (Benić and Knox-Davies, 1983). Latent infections occur on new growth flushes and when cuttings are taken, these infections are not noticed on the plant material, since no distinct symptoms are visible (Benić, unpublished data). Free moisture and cool temperatures enhance disease expression. New growth on the cutting is highly susceptible to scab infection. L e u c o s p e r m u m and L e u c a d e n d r o n spp. and S e r r u r i a f l o r i d a are susceptible to scab (Benić, unpublished data).

D r e s c h l e r a d e m a t i o i d e a, the causal organism of blight of L e u c o s p e r m u m spp. (Von Broembsen, 1985), was isolated from cuttings showing typical symptoms of blight. Bright red cankers developed from the tip of cuttings and extended along the stem, sometimes collapsing in the region of the canker. Leaf lesions were yellow-brown; irregularly shaped with distinct outer margins. Hybrid L e u c o s p e r m u m cultivars were most susceptible to this organism.

2.3. Disease control

2.3.1. Provisional recommendations for the control of C o l l e t o t r i c h u m g l o e o s p o r i o i d e s in the nursery

C. g l o e o s p o r i o i d e s can be associated with diseased seed, seedlings, young plants or cuttings. Control of this organism in the nursery is therefore important. Previous work with P. c o m p a c t a showed that a hot water treatment at 50°C for 30 minutes, followed by a thiram dusting was the most effective seed treatment for controlling damping-off caused by C. g l o e o s p o r i o i d e s (Benić and Knox-Davies, 1983). Further work with seed treatments has shown that a hot water treatment at 50°C for 30 minutes, followed by a benomyl dusting was equally effective, in controlling the disease (Benić, unpublished data). Treated seedlings rarely damped-off in seedbeds; however, untreated control plants of susceptible species damped-off continually, resulting in major losses of seedlings. Nursery losses of P. c o m p a c t a; P r o t e a

longifolia Andrews; Protea obtusifolia Buek ex Meissner and Protea nana (Bergius) Thunb. were 90%; 95%; 95% and 100% respectively, from severely infected seed samples (Benič, unpublished data). After treatment, seedling survival in treated plants was above ninety percent. Infection by C. gloeosporioides has been shown to vary from one seed sample to another and from one season to the next (Benič, unpublished data). The two seed treatments given above, have been tested on several of the Protea spp. found to be susceptible to C. gloeosporioides and are presently being used as an effective control for seedling damping-off caused by seed-borne organisms. All seed should be treated with thiram or benomyl dust if no facilities are available for hot water treatment. Soil drenches with thiram have been used on severely affected untreated seedlings to reduce disease severity.

Colletotrichum dieback on young plants can be reduced with regular sprays of effective fungicides. Maughan and Greenhalgh (1983) evaluated certain fungicides for the control of Colletotrichum dieback of protea seedlings. Difolitan was recommended (1981) as an effective fungicide for reducing severity of Colletotrichum dieback. Similar experiments with selected fungicides showed that the use of difolitan reduced the occurrence of seedling blight in protea nurseries (Benič, unpublished data).

A preliminary recommendation for the control of cutting dieback caused by C. gloeosporioides in mistbeds is a pre-plant fungicide dip of cuttings. Care should be taken that material collected from mother plants is clean and disease-free. Cuttings should then be dipped into a solution of the fungicide (difolitan; captan or benomyl). A combination of difolitan together with benomyl can also be used. After planting, cuttings can be sprayed regularly with difolitan or difolitan combined with benomyl.

2.3.2. Control of cutting dieback, scab and blight in mistbeds

Pre-planting dipping of cuttings followed by regular sprays with effective fungicides (see above) can help to prevent cutting disease from developing in mistbeds. Difolitan, captan and benomyl have been used to spray cutting material in mistbeds. Difolitan is particularly effective for the control of scab and certain cutting dieback diseases. Ipriodine is effective against Dreschlera (Greenhalgh, 1981; Von Broembsen, 1985). Mother plants can be sprayed before cuttings are taken to keep them free of disease during the last growing season. It is critically important that cuttings are taken from disease-free mother plants. This survey has shown that scab, Dreschlera blight and cutting dieback caused by Botrytis, resulted when infections were brought into the mistbed on the infected cutting material. Distribution of such infected cuttings could therefore result in spread and outbreaks of these diseases.

2.3.3. Control of root and soil-borne organisms in the nursery

Root and soil-borne diseases can become a serious problem if they become established in the nursery. It is always more effective to prevent these diseases than to treat them. Control can be accomplished by planting disease-free propagating material in a pathogen-free soil medium, irrigating with pathogen-free water and maintaining a program of sanitation in the nursery to prevent recontamination (Von Broembsen, 1981). In protea nurseries, control of P. cinnamomi is extremely important since planting out of infected material can lead to mass infestation in the commercial orchard. Several measures should be adopted to control and prevent Phytophthora disease outbreaks in the nursery. The most important of these are briefly listed:-

- All soil and planting media should be sterilized or pasteurized.
- Containerised plants should not be introduced from other nurseries.
- Infected and dying plants and their containers should be removed and burnt.
- Flow of surface run-off water into the nursery area should be prevented.
- Contact between containers and underlying soil should be prevented by covering nursery area with stone chips and placing containers on slotted benches.
- Traffic into and within the nursery should be controlled.
- Weeds and all plant debris should be removed from the nursery.
- Susceptible species should not be grouped together but should rather be spread out in the nursery.

3. Concluding remarks

This paper has shown that disease problems occur on all forms of propagation material in protea nurseries in South Africa. Production of disease-free nursery stock is necessary to prevent spread of disease. Seed should be treated to prevent seed-borne diseases from entering the nursery and to minimize local and international dispersal of these diseases. Transfer of seed-borne diseases is particularly important for Protea spp. Control of diseases of rooted cuttings has become more important with the development of cultivars which require vegetative reproduction. Since these cultivars are distributed to nurseries throughout South Africa, distribution of infected material could result in large scale quarantine problems and the introduction of disease to one production area from another.

Much research is required before these complex pathological problems and their solutions are fully understood in Proteaceae nurseries. A study of this nature is extremely involved since one is working with so many different host plants within the family Proteaceae. Each genus can be regarded as a separate group, with certain of the disease organisms being host specific while others show no specificity. Intensive studies and surveys are being continued.

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Table 1 - Susceptibility of commercially-cultivated species of Proteaceae to Colletotrichum gloeosporioides

Species	Type of host material: Seedling	Young Plant	Cutting	Mature Plant
Protea				
compacta R. Br.	xxx	xxx	xxx	xxx
cynaroides (L.) L.	x	-	-	-
eximia (Salisb. ex J. Knight) Fourc.	xx	x	-	xx
grandiceps Tratt.	xx	x	-	-
lacticolor Salisb.	xx	x	-	xx
laurifolia Thunb.	xx	x	-	x
lepidocarpodendron (L.)L.	xx	x	-	x
longifolia Andrews	xxx	xxx	-	xxx
magnifica Link	xxx	-	-	-
mundii Klotzsch	x	x	-	x
nana (Bergius) Thunb.	xxx	xx	-	xxx
neriifolia R. Br.	xx	x	-	x
obtusifolia Buek ex Meissner	xxx	xx	-	x
pudens Rourke	xxx	xx	-	xx
repens (L.)L..	x	x	xxx	-
scolymocephala (L.) Reicherd	xx	x	-	xxx
susannae E. Phillips	xx	x	-	x
Serruria florida (Thunb.) Salisb. ex J. Knight	-	xx	xx	xxx

xxx highly susceptible
xx moderately susceptible
x susceptible
- no observations recorded

EXTENSION OF HARVESTING PERIOD IN LEUCOSPERMUM BY MEANS OF MANUAL AND CHEMICAL PRUNING METHODS

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Abstract

Cut flower harvesting period in Leucospermum can be delayed by deactivation of primary inflorescence buds, but late treatment can cause loss of yield through poor resumption of secondary bud development. Primary inflorescence buds of 5-year old plants of three normally and two late flowering Leucospermum cultivars were sprayed with ethephon 250 mg l^{-1} in 1984 on August 1 or debudded by hand on August 14. Although the time of harvest was later, the length of the actual harvesting period was reduced in all treated plants. The 50% harvesting dates in ethephon treated and hand debudded plants coincided, confirming an approximately 14 day longer resumption time of bud development in the former. Treatments delayed 50% harvesting dates in normally flowering (Flamespike, Yellow bird, T77 10 07) and late cultivars, (Vlam, Caroline) by an average of 37 and 20 days respectively, thus extending the harvesting period of controls by 67% in normally and 9% in late flowering cultivars. Mean yield loss as a result of ethephon treatment and hand debudding was 11 and 3% respectively, tending to involve flowering stems of poorer quality. It was concluded that all 5 cultivars may safely be hand debudded and cvs. Flamespike, T77 10 07 and Vlam be treated with ethephon, up to August 1.

1. Introduction

The short natural flowering period of Leucospermum R.Br. plants causes a major cut flower marketing problem (Brits, Jacobs & Vogts, 1983).

A number of axillary capitula develop distally on Leucospermum flowering branches (Rourke, 1972) up to the stage where floret primordia are discernible (Malan, unpublished data). These young capitula are termed inflorescence buds. The uppermost inflorescence bud in Leucospermum cordifolium, and other species with large inflorescences, normally develop into a marketable primary inflorescence (Brits, 1977).

Cut flower harvesting period in pincushions can be delayed by deactivation of the primary inflorescence buds. Both hand debudding and spraying plants with ethephon (e.g. "ethrel") are effective

treatments (Brits, 1977: Jacobs & Honeyborne, 1978). Secondary inflorescence buds on branches sprayed with ethephon resume development approximately 14 days later than on hand debudded plants (Brits, unpublished data).

Late treatment (August onwards) can cause loss of yield through poor resumption of secondary bud development (Brits, 1977; Jacobs & Honeyborne, 1978). Yield loss increases progressively with later treatments. Cut flower quality can also decrease. Cultivars reacting favourably to treatment will therefore have to be selected (Brits, 1977).

This work was undertaken to study the effects of late treatment on harvest distribution and yield loss in normally and late flowering cultivars.

2. Materials and methods

Five-year old plants of 3 normally and 2 late flowering L e u c o s p e r m u m cultivars were given a full cover spray with ethephon at a concentration of 250 mg l^{-1} on August 1, 1984, or primary inflorescence buds were removed by hand on August 14.

Four replications of 3 to 5 plants were used in a randomised block design. The number of flowering branches cut per week, exceeding 30cm in length, was recorded.

3. Results

The results are summarized in Figure 1. Flowering time in untreated normally and late flowering cultivars commenced at approximately the same time. The principal difference between normally and late flowering cultivars was a naturally extended flowering period in the latter.

Ethephon spraying and hand debudding had much the same effect on harvesting dates. Coniciding harvesting graphs confirm an approximately 14 day later resumption time of bud development in ethephon sprayed than in hand debudded plants. Length of secondary inflorescence development and harvesting periods were reduced in all treated plants, due to higher seasonal development temperature (Jacobs & Honeyborne, 1979), but the actual harvesting times were nevertheless notably later.

The 50% harvesting dates in treated plants were delayed by an average of 37 and 20 days in normally and late flowering cultivars, respectively. Harvesting period of controls when combined with treatments was extended by 67 and 9% on average, in normally and late flowering cultivars, respectively.

Average yield loss relative to controls was 11 and 3% as a result of ethephon treatment and hand debudding, respectively. Yield loss

was due to non-resumption of inflorescence bud development, mostly on weaker, thinner and shorter flowering branches. Flower quality in treated plants was apparently slightly poorer, but still acceptable for marketing.

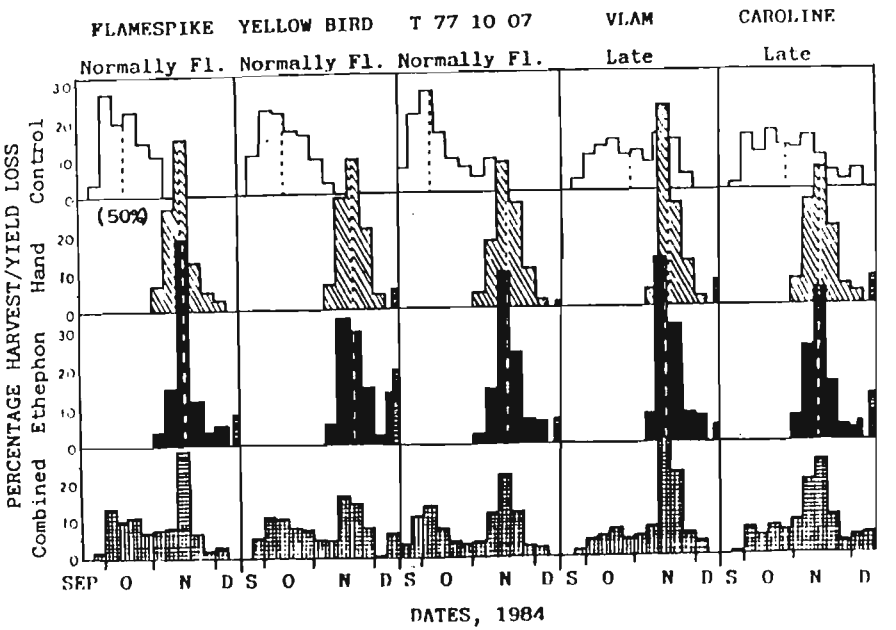

Figure 1 Distribution of percentage harvest, and yield loss (▨) of 5 L e u c o s p e r m u m cultivars after hand debudding or spraying with ethephon; and harvesting pattern with combined non-treated and ethephon sprayed plants.

4. Conclusions

Both manual and chemical pruning can be used as a practicalmeans of extending the harvesting period of pincushions.

All 5 cultivars may safely be hand debudded and cultivars Flamespike, T77 10 07 and Vlam may be sprayed with ethephon up to August 1.

Peaks in the combined graph indicate that a number of sequential treatments of different plantings will improve the overall harvest distribution even more - e.g. fortnightly from June 15 to August 1 (4 treatments).

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FAUNAL LIST OF PROTEA REPENS

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Abstract

Protea repens is structurally a complex plant and can therefore provide a diversity of niches for insects to exploit. The plant can be divided into three main niches: (a) flower heads housing flower visitors and pollen and nectar feeders, (b) leaves housing leaf feeders and/or visitors and (c) seed heads and stems housing the borers. Insects create major phytosanitary problems for marketing P. repens cut flowers. Leaf damage is caused by 32 species of leaf feeders. This group includes the leaf miners, which are responsible for most of the leaf damage. The ten borer species found in seed heads have a significant effect on the reproduction of the plant.

Introduction

Protea repens (L.)L is one of the economically most important cut flowers which is both grown in cultivation and harvested in its natural environment. Heavy insect infestations in natural stands cause great pressure on adjacent cultivated stands. To produce a high quality flower it is important to control the insect pests of these plants. It is therefore necessary to have an in-depth knowledge of the natural insect fauna of P. repens. The plant can be divided into three main niches: (a) flower heads, (b) leaves and (c) seed heads and stems.

The object of this study was to determine which phytophagous insects occur in the three main niches of P. repens under natural conditions.

Materials and methods

A census of the phytophagous insects of winter-flowering P. repens, growing in its natural environment, was made over a period of two years. Using methods described previously (Coetzee and Giliomee 1985) we collected flower head visitors during the flowering period at 29 of the many areas in which P. repens occurs. Arboreal insects were collected by means of the beating method. Seed heads and stems were collected in the Stellenbosch area at three-weekly intervals. The seed heads and stems were dissected after collection and examined for insects and insect damage.

Table 1 Insects which visited the flower heads of winter flowering P. repens (L.)L. in the natural environment, during the flowering stage

COLEOPTERA
Halticidae
- Chirodica calcoptera Germ.
- Chirodica wollastoni Baly
- Chirodica sp. (Ac.HRP.639)
- Chirodica sp. (Ac.HRP.640)
- Chirodica sp. (Ac.HRP.641)
- Ac. HRP. 642

Nitidulidae
- Pria cinerascens Er.
- Carpophilus hemipteris (L.)
- Carpophilus binotatus Murr
- Carpophilus dimidiatus F.
- Carpophilus sp. (Ac.HRP.647)
- Meligethes rimulosus Reitt.
- Meligethes viridulus Reitt.
- Soronia marmorata Grouw

Cucujidae
- Phyconomus tricolor Woll
- Phyconomus pallidus Woll
- Phyconomus sp (Ac. HRP.653)

Staphylinidae
- Atheta sp. (Ac.HRP.654)
- Phloeonomus sp. (Ac.HRP.655)

Melolonthidae
- Diaplochelus longipes F.

Histeridae
- Platysoma capense Wied.

Anthicidae
- Formicomus coeruleus Thumb.

Mordellidae
- Anaspis sp. (Ac.HRP.658)

Meloidae
- Lytta nitidula F.

Scarabaeidae
- Genuchus hottentottus F.

Cryptophagidae
- Micrambe tenuicornis (Grouw)

Cetoniidae
- Trichostetha fascicularis F.

Curculionidae
- Ceutorhynchus sp. (Ac.HRP.664)
- Ceutorhynchus sp. (Ac.HRP.665)
- Ceutorhynchus sp. (Ac.HRP.666)
- Sibinia sp. (Ac.HRP.667)

HYMENOPTERA
Formicidae
- Iridomyrmex humilis (Mayr.)
- Technomyrmex albipes (F. Smith)
- Acantholepis capensis (Mayr.)
- Anoplolepis custodiens (F. Smith)
- Camponotus niveosetosus (Mayr.)
- Camponotus rufoglaucus (Jerdon)
- Monomorium sp. (Ac.HRP.674)
- Myrmicaria sp. (Ac.HRP.675)

Apidae
- Apis mellifera L.

Colletidae
- Hylaeus unmarginatus Alfken

Vespidae
- Ac.HRP.679

THYSANOPTERA
Aeolothripidae
- Homothrips sp. (Ac.HRP.680)

DIPTERA
Drosophilidae
- Ac. HRP.681

Leaf damage is caused by 32 species of leaf feeders (Table 2) which include ten sap-sucking species, 19 chewers and three leaf miners. Leaf miners are responsible for most of the damage to leaves. The method developed by Fuentes et al. (1980) was used to estimate the proportion of the surface area leaf damage. Based on this formula on average just over 10% of the leaf surface area was damaged by insects.

Table 2 Insects in association with the leaves of P. repens (L.)L in its natural environment.

COLEOPTERA
Curculionidae
- Euderes lineicollis (Weid.)
- Eremnus sp. 1 (Ac.HRP.664)
- Eremnus atratus Sparrman
- Eremnus sp. near parcus Boheman
- Eremnus sp. 3 (Ac.HRP.667)
- Tanyrhynchus affaber Boheman

Buprestidae
- Sphenoptera sp. A
- Sphenoptera sp. B

Phalacridae
- Olibrus aerotus Champ
- Olibrus natalensis Champ
- Olibrus sp. (Ac.HRP.674)

Halticidae
- Podagrica sp. (Ac.HRP.674)

Lamprosomatidae
- Oomorphus sp. (Ac.HRP.675)

Galerucidae
- Pseudorupilla sp.(Ac.HRP.676)

ORTHOPTERA
Gryllidae
- (Ac.HRP.677)

Tettigoniidae
(Ac.HRP.678)

HEMIPTERA
Pentatomidae
- Antestiopsis variegata Thunberg
- Orthoschizops lineaticeps Stal
- Ac.HRP.681

Lygaeidae
- Poeanthus nr. velox Bergroth
- Caprhiobia similus (Scudd.)
- Nysius sp. (Ac.HRP.684)

Coreidae
- Ac.HRP.685

Cixiidae (Fulgoroidea)
- Ac.HRP.686

Coccidae
- Ac.HRP.1067

Psyllidae
- Psylla sp. (Ac.HRP.559)

LEPIDOPTERA
Geometridae
- Ac.HRP.689a
- Ac.HRP.689b

Pyralidae
- Bostra conspicualis Warren

Microlepidoptera
Phyllocnistidae
- Phyllocnistis sp. (Ac.HRP.75)
- Ac.HRP.1068
- Ac.HRP.1066

COLLEMBOLA
- (Ac.HRP.839)

PSOCOPTERA
- (Ac.HRP.758)

Ten different larvae (borers) (Table 3) are associated with P. repens, from the commencement of flower head development, up to the seed head stage. Three other insect species and five ant species were also collected. The larvae of three Coleoptera species, i.e. Genuchus hottentottus, Sphenoptera sp. A. and Euderes lineicollis and two Lepidoptera species, i.e. Argyroploce sp. and Tinea sp., were responsible for all the damage to seeds in the seed head. Almost 85% of the stored seed reserve of P. repens would be destroyed by insects after two years (Coetzee & Giliomee, in preparation.)

Table 3 Insects found in the seed heads of *P. repens* (L.)L. in its natural environment.

COLEOPTERA
Scarabaeidae
Genuchus hottentottus F.
Buprestidae
Sphenoptera sp. A
Sphenoptera sp. B
Curculionidae
Euderes lineicollis Weid.

LEPIDOPTERA
Olithreutidae
Argyroploce sp. Ac.HRP.380
Tineidae
Tinea sp. Ac.HRP.349
Oecophoridae
Cryptolechia ammopleura Meyerick
Pyralidae
Bostra conspicualis Warren
Lycaenidae
Capys alphaeus (Cramer)

DIPTERA
Cecidomyiidae
Resseliella proteae Gagné

HEMIPTERA
Lygaeidae
Oxycarenus maculatus Stal
Machiademus diploterus Stal

HOMOPTERA
Pseudococcidae
Ac.HRP.1069

HYMENOPTERA
Formicidae
Crematogaster liengmei Forel
Crematogaster peringueyi Emery
Camponotus werthi Forel
Meranoplus peringueyi Emery
Iridomyrmex humilis Mayr.

No borers were found in the growth points of stems. Two borers i.e. *Cryptolechia ammopleura* and *Sphenoptera* sp. B, were found in the involucral receptacles of flower and seed heads. These borers were occasionally found in stems. *P. repens* is structurally very complex - such architectonically complex plants will, according to Lawton (1983), provide a diversity of favourable niches and enemy-free areas for insects. This hypothesis could partly explain why *P. repens* accommodates so many insect species.

All flower visitors are regarded as economically important pests, since their mere presence in exported flowers is unacceptable. The most important leaf insects are the leaf miners. They cause unsightly leaf damage which is unacceptable on cut flowers. Borers destroy the seed bank but are not otherwise important economically. However, the borer *Cryptolechia ammopleura* not only destroys the flower heads, but can also create phytosanitary problems in cut flowers and must therefore be regarded as an economic pest.

Information on the life cycles of insects on *P. repens* is needed to develop a pest control programme for cultivated plants. The present faunal list will be used in conjunction with information from studies of the seasonal occurrence of the most important pests affecting *P. repens*, to draw up a provisional control program.

Acknowledgements

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Summary

Only two mite species associated with Proteaceae can be regarded as of economic importance in South Africa, namely Proctolaelaps vandenbergi, the itch mite and Aceria proteae, the witches' broom mite. The itch mite does not affect the plant adversely since it feeds on pollen and nectar, but it causes significant phytosanitary problems in cut flowers as well as skin irritation to humans. Aceria proteae is found on numerous proteas and is probably the vector which conveys the agent causing witches' broom.

1. Introduction

Twelve mite species (Acari) have been collected on plants of the family Proteaceae (Table 1). Two species, namely Proctolaelaps vandenbergi Ryke and Aceria proteae Meyer, can be regarded as economically important pests. P. vandenbergi (Ascidae) is found in the flower head of the genus Protea. The nymphs and adult stages feed on pollen and nectar. P. vandenbergi causes no damage to the plant, but irritates the human skin and also causes significant phytosanitary problems in cut flower.

Table 1 List of mites (Acari) found on Proteaceae

Aceria proteae (Eriophyidae)
Proctolaelaps vandenbergi (Ascidae)
Oligonychus coffeae (Tetianychidae)
Oligonychus proteae (Tetianychidae)
Agistemus africanus (Stigmaeidae)
Aculus sp. (Eriophyidae)
Thyreophagus sp. (Acaridae)
Paralorryia sp. (Tydeidae)
Typhlodromus (Onthoseius) saevus (Phytoseiidae)
Histiostoma sp. (Anoetidae)
Nioxognium sp. (Celaenopsidae)
Pyemotes ventricosus (Pyemotidae)

A. proteae (Eriophyidae) is microscopically small and is found under the bracts in dormant leaf buds and in flower buds (unopened inflorescences). It also occurs in highly proliferated outgrowths known as witches' brooms. On account of the presence of A. proteae in witches' broom outgrowths, Rust and Myburgh (1971) claim that there must be a connection between the mites and the abnormal growth.

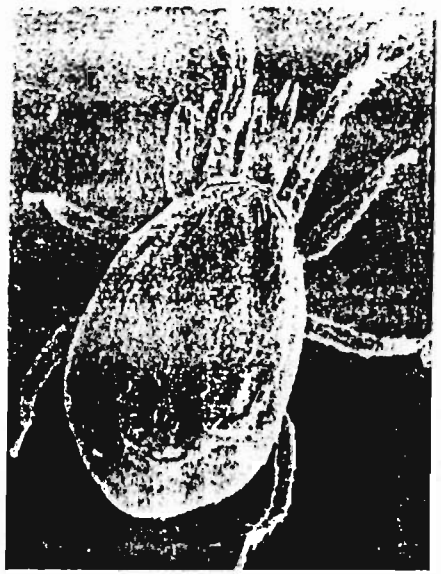

Figure 1 Electronmicrograph of P. vandenbergi

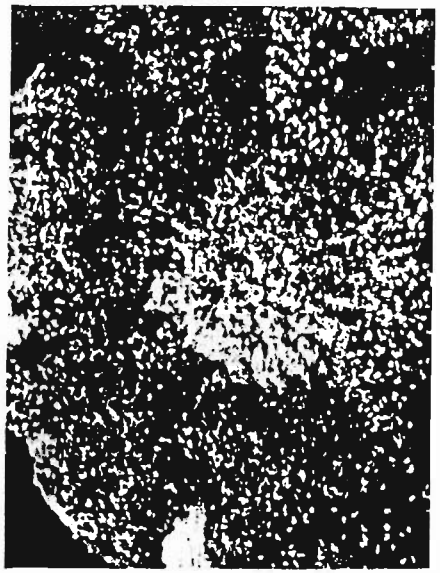

Figure 2 Flower head of P. neriifolia infested with P. vandenbergi.

2.1 Proctolaelaps vandenbergi Ryke

The itch mite Proctolaelaps vandenbergi (Figure 1) occurs in great numbers in especially the bearded proteas (Figure 2), but they also occur in the flower heads of other species such as P. repens. Great numbers of eggs, nymphs and adults might be present on the flower heads at the picking stage. Myburgh et al. (1973) have recorded more than 6 000 mites on one flower head of P. laurifolia. When flowers are cooled during the post-harvest treatment, the mites move to the centre of the flower head. On subsequent exposure of the flowers to room temperature, the mites crawl out to the surface. From there they can easily be transferred to the human skin, and cause a severe irritation. The adult mites are oval, and greyish white in colour. They can be clearly seen with the naked eye.

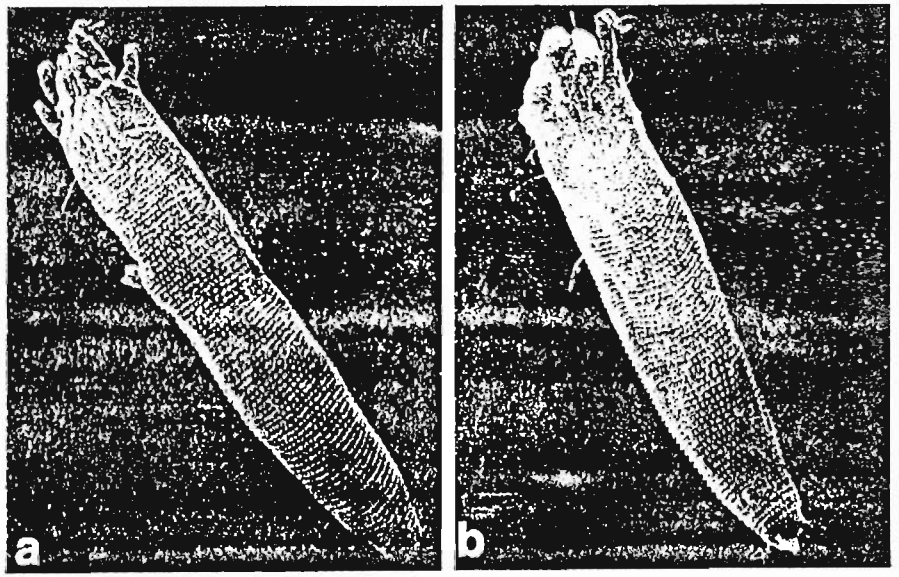

Figure 3 Electronmicrographs of Aceria proteae; (a)dorsal; (b) ventral.

2.2 Aceria proteae Meyer

Aceria proteae is one of the most important mites of Proteaceae, because it is associated with witches' broom. Meyer (1981) has described the mites on plants belonging to the genus Protea.

Aceria proteae has an elongated wormlike body. The female is 211-268 um long and 43 um wide, and is invisible to the naked eye or through a hand lens. The dorsal shield (Figure 3a) is sub-semicircular. Seventy five rings with microtubercules occur on the thanosome and the telesome consists of about seven rings (Meyer 1981). The ventral coverflap (Figure 3b) that covers the female genitals has 10 longitudinal ribs. These eriophyoid mites have only three pairs of legs. A. proteae is mainly distributed by wind, but spread by infested plant material is an important means of distribution. There is no proof that witches' broom can spread by means of seed.

Seedlings infested with witches' broom (Figure 4) grow poorly, resulting in stunted plants except for the proliferations. Such seedlings will never become viable plants. When adult plants are infested with witches' broom, their normal growth is affected and flower production is low. Witches' brooms also serve as a suitable hiding place for insects.

Figure 5 Witches' broom on seedling of P. cynaroides.

Figure 4 Witches' broom growth on adult P. cynaroides plants.

There is no proof that A. proteae is the vector of the organism causing witches' broom, but it can be accepted that a connection between the abnormal growth (Figure 5) and the mite exists. This abnormal growth has been observed in 16 Protea spp.(Table 2). Although the mites have been collected on P. repens, witches' broom has never been reported on this species. Eriophyoid mites were also collected on Leucospermum and Mimetes, but it could not be established whether they belonged to the same species. It is not clear whether witches' broom can spread from one Protea sp. to another.

Table 2 Protea spp. on which Witches' broom has been recorded.

P. nitida	P. compacta
P. cynaroides	P. lepidocarpodendron
P. caffra	P. scorzonerifolia
P. neriifolia	P. burchellii
P. laurifolia	P. punctata
P. eximia	P. glabra
P. sulphurea	P. cryophila
P. magnifica	P. scolymocephala

Conclusion

Itch mites can not be practically controlled in the field. Control will therefore have to be achieved through harvesting of flowers at the correct stage of opening and through post-harvest treatment of flowers. The insecticide dichlorvos gives effective post-harvest control of itch mites.

Eriophyoid mites can be chemically controlled, but there is no specific pesticide registered against A. proteae in South Africa. Although chemical control will restrict the distribution of the mites, it has no effect on existing witches' brooms. Sanitation is the only practical control measure against witches' broom. It is therefore important that only mite-free cuttings be used for vegetative propagation and that all plants with witches' broom symptoms should be immediately removed from plantings and destroyed.

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We would like to thank Mr P van der Merwe of the Electronmicroscopy section of the Fruit and Fruit Technology Research Institute, Stellenbosch, for his assistance in the use of the electronmicroscope.

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THE EFFECT OF CONTAINER MEDIA ON THE GROWTH AND ESTABLISHMENT OF *LEUCADENDRON* "SAFARI SUNSET"

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Abstract

Plants were propagated in container mixes based on peat or bark with 10% of mineral soil and compared with those grown in a mineral soil mix used by nurseryman. Responses to a regular supplementary liquid fertilizer were also measured. Performance in containers was followed for six months before planting in the field after which growth and yield responses were measured for two seasons. Media based on peat or bark gave an advantage which was maintained over the first season after planting. The propagation advantage gained from the supplementary fertilizer was subsequently lost.

Introduction

Proteaceous plants have been regarded as difficult container subjects with rates and types of base fertilizers, particularly phosphorus (P) and nitrogen (N) in soilless mixtures, being cited as the greatest source of difficulties (Thomas, 1974). Long term slow release nutrient sources markedly reduced P toxicity as did the use of loam in mixtures based on peat or wood wastes (Nichols, Jones and Beardsell, 1979). Nevertheless some New Zealand nurserymen still reported that field establishment was unsatisfactory when plants were grown in media containing high proportions of peat (Harre, 1981 personal communication).

Three propagation media were compared under three levels of supplementary nutrition. Two of these were based on peat (90%) or bark (90%) with a 10% mineral soil addition. Plants were selected from all media and two supplementary nutrition levels for a field trial and the performance followed for two growing seasons.

Methods and Materials

Details of the prepared peat or bark based media are given in table 1. These were compared with a medium prepared by a commercial nurseryman. It consisted of silt and pumice in undefined proportions and with nutrients added at undisclosed rates. Supplementary fertilizer at two rates (table 1) was compared with no supplement; this was commenced about 3 months after potting. This supplement was given weekly at 50 ml per 0.7 l container.

Plants were propagated from seven node cuttings, potted into the media on 22/10/81 and placed on an outdoor capillary bed (White, 1981).

For the field study plants were selected randomly from the three media treatments which received either a nil fertilizer supplement or the I rate. These were incorporated into an eight replication randomised block experiment on Levin silt loam, a yellow brown loam, with a high P retention characteristic. Available P on the site was approximately 20 ppm. Proteoid root development was assessed at planting by scoring for the presence of structures on the compost surface in contact with the container. The following five point scale was used;

1 = non visible, 2 = 1 visible, 3 = 3 visible, 4 = up to 6 visible, 5 = more than 6 visible.

Growth in the field was assessed by stem width measured with callipers (calliper) and by a count of shoots 'longer than' 100 mm both flowering and non-flowering.

Results and Discussion

Leucadendron 'Safari Sunset' grew well in both the peat and bark based media (figure 1), the performance in these being better than in the commercial mixture. The growth in the peat based medium was significantly improved by supplementary fertilizer at rate I. Similarly the growth in the commercial mixture was substantially improved by supplementary fertilizer but even so plants in this medium did not achieve the size of those in the media based on bark or peat. Plant and compost analyses in April 1982 showed lower tissue N values for plants receiving no supplement compared with the I rate but little difference in N between plants in the media was apparent. Compost analyses however revealed low N and K levels in both the peat based and commercial mixtures suggesting that the responses noted resulted from the supply of these nutrients.

Proteoid root development (table 2) was less pronounced where supplementary fertilizer had been given but media showed no significant differences in this feature.

The marked growth effects generated by the media during propagation were sustained after planting. Plants raised in either the peat or bark based medium produced significantly more growth than those produced in the commercial mix (table 3). The benefits conferred by supplementary fertilizer were not sustained however and by the end of the first growing season had dissipated. Tissue samples taken in May 1983 showed significantly higher P levels in plants grown in peat (but not the bark mix) compared with the commercial mix. The plants grown in the peat mix subsequently produced significantly higher numbers of flower stems than both bark and the commercial mix even though the total numbers of shoots produced did not differ between the peat and bark based mixtures (figure 2). In the second season there were no significant differences in flowering stem production but the number of non-flowering stems was significantly less for commercial mixture compared with both the peat and bark based mixtures. Plants from all treatments established well. None showed chlorotic symptoms and none died during the two season experiment.

This work has shown that proteaceous plants such as *Leucadendron* "Safari Sunset" benefit from being produced in media with a balanced addition of fertilizers. These benefits were enhanced with supplements of N and K. Furthermore, the advantages conferred by production in properly formulated media were sustained after planting out and led to increased growth and yield in the first season. No disadvantages of using peat or bark as a main bulk ingredient were revealed. The differences in proteoid root development which resulted from the supplementary fertilizer did not appear to affect growth, yield or establishment of the plant in any other way.

The difficulties ascribed to the use of peat in propagation mixtures by New Zealand nurserymen might be attributed to factors such as disease (von Broembsen, 1979), excessive phosphorus (Thomas, 1974) or to plant management either in the container or at the planting site rather than the use of peat per se in well formulated, hygienic mixes.

Acknowledgements

We acknowledge the help of I. Ravenwood, W. Borst for technical assistance, A. Byett for biometric analyses and I. Plunkett for biometric design.

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TABLE 1 - Composition of peat and bark based media and supplementary fertilizer.

Ingredient	Peat	Bark
Hauraki peat	90% (Vol.)	nil
Pinus radiata bark	nil	90%
Levin silt loam (8 ppm avail. P)	10%	10%
dolomitic lime	4.0 g/ℓ	2.0 g/ℓ
Sierrablen 8-9 mth (19-2.6-8.3 + Fe)	2.0 "	2.0 "
ammonium sulphate	0.56 "	0.79 "
potassium sulphate	0.3 "	0.3 "
trace elements (Woods, 1966)	yes	yes

Supplementary fertilizer

Rate	N (ppm)	K (ppm)	NH_4 : NO_3
I	100	83	1 : 1.8
II	200	166	1 : 1.8

TABLE 2 - Effect of propagation treatments on proteoid root score (1-5) at planting (3-6-82)

Medium				Supplement		
Peat	Bark	Comm.	MSD 5%	nil	I	MSD 5%
1.63	1.71	1.59	0.466	1.83	1.44	0.381

TABLE 3 - Carry-over effect of the propagation treatments on main stem* calliper (mm) after planting.

Date	Medium				Supplement		
	Peat	Bark	Comm.	MSD 5%	nil	I	MSD 5%
4 Oct 82	5.9	6.0	4.6	0.42	5.2	5.8	0.34
11 Jan 83	9.5	9.5	7.1	0.72	8.3	9.0	0.59
13 Apr 83	16.2	16.1	12.9	1.12	15.2	14.9	1.37

* Measured 50 mm below the primary shoot.

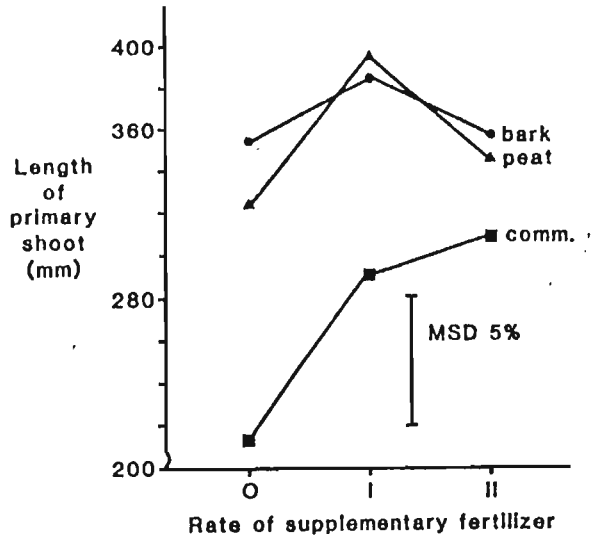

Figure 1:

The effect of supplementary weekly fertilizer and three container media on the shoot growth of Leucadendron "Safari Sunset"

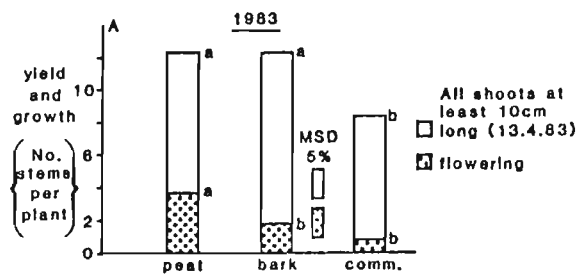

Figure 2:

The carry-over effects of propagation mixes on the production of shoots and flowering stems of Leucadendron "Safari Sunset" after planting in the field.

THE PRODUCTION OF AUSTRALIA'S MAJOR PROTEACEAE AS FLORIST CROPS

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Introduction

Within the 45 genera of Proteaceae native to Australia, a number of species of Banksia, Dryandra, Grevillea, Isopogon and Telopea are suited for commercial cut flower production. With this genetic diversity a systematic approach should be used by plant breeders and growers to determine which species or variants of proteaceous flowers and foliage to select and cultivate. This paper examines those factors and selection criteria which influence those species which are grown as commercial crops. Examples of each genus are highlighted as to their suitability for cut flower production.

Selection Criteria

The species described are considered as major florist crops because of the (1) flowering qualities, ie conspicuous flowers, good color and form with long, strong stems, (2) keeping quality (3) number of flower stems produced (4) market trends and (5) in relation to species of the same genus. Foliage species are considered for (1) interesting form and shape (2) long lasting and (3) pleasing colors, especially used with other flowers. Since the production of these species in cultivation is relatively new, some of the natural forms possess flowering attributes which readily lend themselves directly as florist crops.

The ten species described have been charted based on the flowering characteristics, growth factors important for field production, and key economic factors in relation to their productivity as florist crops. A detailed study of each species and their natural habitat will assist in the successful growing of these plants.

Field Production

After investigation of market trends and species ecology, site selection is determined by the type of soil and climatic factors, especially rainfall, temperature and latitude. Soils with good drainage and low available nutrients are required. Summer rainfall and humidity are detrimental for some species. During dry periods, young plants should be irrigated, preferably by drip systems to keep water from the foliage and reduce disease occurence.

Field layout in Australia is commonly in single rows with spacing depending on the spread of each species. Weeds are

controlled by spraying or provision for sod between rows. For most species propagation is by seed, sown in autumn or spring, otherwise cuttings are best taken from leafy semihardwood shoots.

Telopea speciosissima (Waratah) has been planted more extensively than any other Proteaceae native to Australia. Worrall estimates that 50 hectares have been planted in Australia. This planting continues to increase, with an increase of 15-20 hectares per year. Nursery stock that is two or three years old in containers is usually planted out in autumn.

Most of the acreage planted with Waratah in Australia has been in Victoria. The best quality commercial blooms in Australia have been produced from this state. Due to the short flowering season of each area and the large number of blooms that will be produced, care is necessary in controlling the market in terms of price, quality and continued supply while in season.

In New South Wales, Telopea speciosissima exhibits considerable variation in flower form and color, vigor, and leaf shape. The rare white Waratah is not vigorous but flower size is ideal. Most of the Waratahs in New South Wales are harvested from the bush, where fire significantly affects bloom production. Usually three or four years after fire flowering returns to normal.

Most of the production of Banksia inflorescences is from Western Australia, mainly due to favorable soil and climatic conditions. Most of the cultivated stock has been propagated from seed. The flowering periods of some Banksia may change as certain species are brought into cultivation from the wild. Pruning should be light because those species with no lignotuber are usually killed by fire and regenerate from seed. The stems taken with flowers remove enough wood to allow remaining dormant buds on leafy stems to shoot.

Banksia hookeriana has ideal plant size and shape coupled with good production of inflorescences. The size and color of Banksia coccinea warrants increased planting of this species. Flower form and color also vary, with an orange form having growth habit and vigor similar to the red form. Banksia coccinea is susceptible to Phytophthora cinnamomi as are other Banksia species. Some species such as Banksia ashbyi and Banksia ericifolia flower well but side branches tend to grow around each inflorescence.

Although most of the Dryandra and Isopogon species are from Western Australia, selected species are being grown in other Australian states. Isopogon tend to have shorter vase life but many are useful as foliage. Grevillea have not been grown in large quantities for cut foliage. In the field selected Grevillea can be planted as windbreaks.

The stage of picking is the main factor affecting the vase life of Australian Proteaceae. Normally inflorescences should be picked when 5 - 10% of the individual flowers are open. Picking should be done during cool periods and blooms placed in shade or cooled as soon as possible. The blooms must be packed dry to reduce fungal infection.

Retail florists continue to demand Australian Proteaceae for a variety of floral decorations. This includes large arrangements, table decorations, posies, bouquets and wreaths. Banksia and Dryandra are used for many dried arrangements. Size (not necessarily large) and quality of blooms will bring premium prices.

The market for flowers in Australia has indicated significant demand for selected Australian Proteaceae. With the upsurge of production of other proteaceous flowers, the market will increase for Australian species. This expansion will be considerable compared to roses, carnations, chrysanthemums and orchids.

In the systematic approach of species selection, the following criteria have and will continue to be important in the crop production of Australian Proteaceae. These are: (1) flowercolor and size (2) vase life (3) length of flowering season (4) stem length and (5) disease susceptibility. In this regard both plant breeders and flower growers have the same vested interests which ultimately lead to better cut flower production.

Acknowledgements

The author wishes to thank flower growers in New South Wales, Victoria, South Australia and Western Australia for their information on culture and production estimates. Retail florists in Sydney were helpful in discussion of the current flowermarket. Jolyon Burnett at the University of Sydney kindly provided two photographs of Waratah. Assistance was given by the NSW Department of Technical and Further Education in the production of this paper.

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FLORAL CHARACTERISTICS

NAME OF SPECIES	VASE LIFE (DAYS) A	STEM LENGTH RANGE (CM)	INFLORESCENCE COLOR(S)	INFLORESCENCE DIAMETER (CM)	OTHER NOTES
TELOPEA SPECIOSISSIMA	13	30-100	DEEP RED, PALE PINK AND WHITE	10-16	WIDELY RECOGNIZED HEAVY STEMS
BANKSIA COCCINEA	15	30-90	SCARLET OR PALE RED WITH GRAY, ORANGE	8-10	INFLORESCENCE 3-6 CM LONG
BANKSIA ERICIFOLIA	14	20-50	ORANGE RED TO YELLOW TO BROWN	3-6	FOLIAGE, SPIKES 7-22 CM LONG, SIMILAR TO B. SPINULO
BANKSIA ASHBYI	14	30-80	BRIGHT ORANGE	6-8	DRIES WELL
BANKSIA HOOKERIANA	15	15-30	ORANGE TO LIGHT ORANGE	8-10	SIMILAR TO B. BURDETTII
DRYANDRA FORMOSA	17	30-60	YELLOW AND BROWN	4-8	USED AS FOLIAGE
DRYANDRA QUERCIFOLIA	15	20-30	YELLOW AND BRONZE	2-6	FOLIAGE IS STIFF WITH DIVIDED LEAVES
GREVILLEA LONGISTYLA	13	30-90	RED, PINK AND WHITE	2-5	FOLIAGE HAS SOFT APPEARANCE
GREVILLEA 'POORINDA PETER'	20	30-80	ROSY PINK	2-3	FOLIAGE, TOOTHBRUSH INFLORESCENCES
ISOPOGON CUNEATUS	9	20-45	ROSY PURPLE	2-4	SPOON SHAPED LEAVES

A = AT 20°C IN DISTILLED WATER

GROWTH CHARACTERISTICS

NAME OF SPECIES	ORIGIN	SOIL REQUIREMENTS	HEIGHT (M)	SPREAD (M)	CULTURAL NOTES
TELOPEA SPECIOSISSIMA	VARIOUS PARTS OF EASTERN N.S.W.	WARM WELL DRAINED SAND, LOW PHOSPHOROUS	2-3	1-2.5	NEEDS SEVERE PRUNING AFTER FLOWERING, BORER
BANKSIA COCCINEA	SOUTHWEST W.A.	DEEP WHITE OR GREY SAND	2-6	2-3	NO LIGNOTOBER, ERECT, FAST GROWING, HARD TO FLOWER
BANKSIA ERICIFOLIA	CENTRAL AND NORTH COAST N.S.W.	SANDY LOAM OR SHALLOW SAND OVER SANDSTONE	2.5-5	2-4	NO LIGNOTUBER, WIDELY CULTIVATED, DENSE OR OPEN
BANKSIA ASHBYI	CENTRAL COASTAL W.A.	WARM DEEP RED SAND	4-8	2-3	NO LIGNOTUBER, OPEN, DWARF FORMS, DRY AIR
BANKSIA HOOKERIANA	ENAEBBA AREA OF W.A.	DEEP YELLOW OR WHITE SAND	2-3	2-3	NO LIGNOTUBER, LIGHT PRUNI BUSHY, FROST SENSITIVE
DRYANDRA FORMOSA	SOUTHWEST W.A.	SHALLOW POOR OR CLAY SOIL, SANDY, DRAINAGE	2-5	2-3	DENSE OR OPEN HABIT
DRYANDRA QUERCIFOLIA	SOUTHWEST W.A.	SAME AS DRYANDRA FORMOSA	1-2	2-2.5	REQUIRES LITTLE PRUNING
GREVILLEA LONGISTYLA	EASTERN QUEENSLAND	SANDY, WELL DRAINED OR SOME GRAVEL	2-4	1.5-2.5	FAST GROWING, WILL TAKE HEAVY PRUNING
GREVILLEA 'POORINDA PETER'	GIPPSLAND VICTORIA	SAND, LOAM OR SOME HEAVY SOIL	2-4	3-4	FAST GROWING, SPREADING OPEN SHRUB
ISOPOGON CUNEATUS					

ECONOMIC FACTORS

NAME OF SPECIES	VALUE PER STEM NSW A	FIRST FLOWER IN YEARS	NO. FULL AVE. PROD. YEARS B	FLOWERING PERIOD C	MARKETING NOTES
TELOPEA SPECIOSISSIMA	1.00-2.00	3-4	60-250 (8)	SEPT-NOV	SHORT FLOWERING PER
BANKSIA COCCINEA	.50-1.10	3	25-30 (5)	JUNE-JAN	SUPERIOR BLOOMS REQUIRES SELECTION
BANKSIA ERICIFOLIA	.40-1.00	3-4	30-40 (6)	APRIL-AUG	MANY COLOR FORMS
BANKSIA ASHBYI	.50-1.10	3-4	6-8 (7)	MAY-AUG	EXCELLENT COLOR
BANKSIA HOOKERIANA	.50-1.10	3-4	8-12 (7)	APRIL-OCT	GOOD FLOWER PRODUCER
DRYANDRA FORMOSA	.35-1.00	2	40 (4)	AUG-NOV	SOLD AS SINGLES OR BUNCHES
DRYANDRA QUERCIFOLIA	.15-.25	2	30 (4)	MAY-OCT	DECORATIVE FLOWERS
GREVILLEA LONGISTYLA	.10-.15	2	65 (6)	SEPT-NOV	SMALL PRODUCTION
GREVILLEA 'POORINDA PETER'	.10-.15	1	60 (5)	AUG-DEC	HYBRID VIGOR
ISOPOGON CUNEATUS	.15-.20	2-3	20-100 (4)	AUG-OCT	IDEAL MEDIUM SIZE FLOWER

A = WHOLESALE, SA B = PER PLANT C = IN AUSTRALIA

SUSCEPTIBILITY TO PHYTOPHTHORA AND NUTRITION OF BANKSIA SPECIES

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Australia has the greatest number of Proteaceae, possessing some 800 species, of which 500 are endemic to Western Australia. Banksia is one of the most well-known genera in Australia. Only one of the 73 species of Banksia occurs naturally outside Australia. 58 species are endemic to south-western Australia (George, 1981).

The vigorous root-rot and stem collar pathogen Phytophthora cinnamomi causes extensive death in some Australian Eucalyptus forests. It is particularly pathogenic to the proteaceous understorey, which includes Banksia species as a major component.

Considerable controversy and discussion surround the question of the geographic origin of Phytophthora cinnamomi. While there are some indications of resistance in a range of species having developed in NE Australia (Pratt & Heather, 1973), the large number of susceptible hosts in Western Australia (WA) indicates that the fungus was introduced, probably within the past 60 - 70 years. Proteaceous hosts include the genera Banksia, Conospermum, Dryandra, Grevillea, Hakea, Isopogon, Lambertia, Persoonia and Petrophile.

Two major areas in WA are affected by P. cinnamomi: the jarrah (Eucalyptus marginata) - banksia forest, and the heath-land of the south coast. (Figure 1)

E. marginata is highly susceptible to P. cinnamomi, yet is the most valuable timber component of the forest. Banksia grandis, a major understorey tree, is even more susceptible than jarrah, and is used by foresters as an indicator species to map P. cinnamomi spread. Death is characterised by 'dieback' from the crowns, often suddenly in Banksia. Large tracts of the forest are quarantined to halt the spread of P. cinnamomi.

While proteaceous species are one major component of forest understorey, in the heath-lands of the south-coast they are dominant and account for up to 60% of total species.

Although P. cinnamomi is an important pathogen in Australia and elsewhere (Zentmyer, 1980) the mechanisms by which damage is caused to host plants are not well understood. Little is known of the interactions between P. cinnamomi and inorganic mineral nutrition.

Soils for avocado cultivation (P. cinnamomi-suppresive) are characterized by high ammonium-N (Broadbent & Baker, 1974), while Marks et al (1972) found that fertilization increased the

susceptibility of eucalypts to P. cinnamomi. The effects of N appear variable and depend on pH, organic matter, host plant and the availability of other nutrients.

Phosphorous and calcium are both deficient in many WA soils. Disease responds variably to supply of these nutrients (Schmitthenner & Canaday, 1983). In New Zealand (Newhook & Podger, 1972) correction of P deficiency has checked the spread of P. cinnamomi and this affect persisted for sixteen years, with treated trees making excelllent growth. In WA, supply of Ca (as $CaCO_3$) suppresssed P. cinnamomi root rot in jarrah (Boughton et al, 1978). The soils used for avocado cultivation in which P. cinnamomi is naturaly suppressed (Broadbent & Baker 1974) had high Ca. Ca is important in cell wall formation, and might play a role in reducing infection by P. cinnamomi (Graham, 1983).

Studies have been undertaken to determine whether levels of N, P & Ca affect susceptibility of Banksia species to P. cinnamomi. Preliminary work is with B. grandis, where very high levels of colonization are observed.

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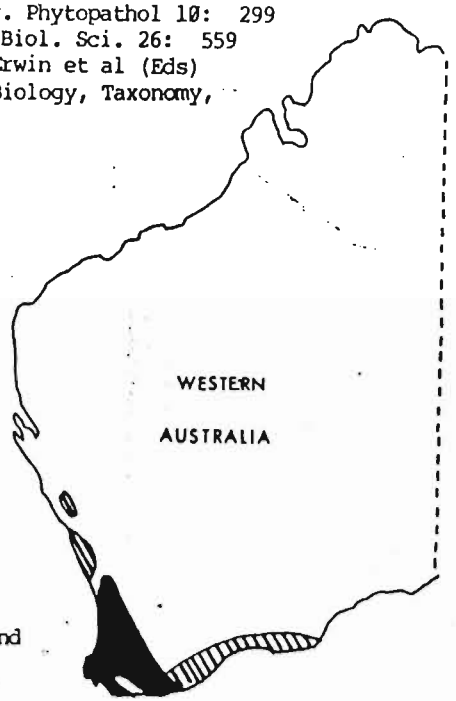

Fig 1: Western Australia: Forest (dark) & heath (hatched) land under threat from Phytophtohora cinnamomi.

POST-HARVEST STUDIES WITH NSW WARATAH

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Abstract

The NSW waratah (T e l o p e a s p e c i o s i s s i m a) is of increasing importance as a cut flower in New Zealand. Experiments studying its post-harvest handling have shown that refrigeration after harvest is critical for achieving satisfactory performance in the vase. Flowers harvested at an immature stage had longer vase life than mature flowers and treatment with floral preservatives did not give consistent results.

Introduction

The striking scarlet bloom of the NSW waratah has been developed as a cut flower in New Zealand. Little however has been published on post-harvest methods (Worrall 1983), and this information is of critical importance for the successful transport and marketing of the crop. Problems encountered by shippers included browning of the bracts, nectar spillage in the packed boxes, nectar moulding during transit and flowerhe decay.

The value of some post-harvest techniques i.e. refrigeration, stage c maturity at harvest and floral preservatives was investigated. The aim v to improve flower quality to consumers.

Methods

1. Flower maturity at harvest:

Eleven blooms from clone no. 6 (Levin HRC clonal collection) were harvested to cover a wide range of maturity. They were conditioned in water for 3 h, packed in film lined fibreboard boxes, and held at 18°C for 90 h to simulate tranport to market. The stems were recut and placed in vases of distilled water and held at 20°C ± 2°C and 70-80% RH with 12 illumination ($2w/m^2$ cool white and daylight florescent). Vase life and flower opening were assessed.

The end of vase life was determined as the stage when the flowers showed discernible deterioration, with noticeable wilting and blueing of the florets.

2. Effect of refrigeration:

To establish the effect of refrigeration during the first four days after harvest, flowers of four clones (no. 6, 25, 8 and 11) were conditioned in water for 3 h, packed in film lined fibreboard boxes and held at 2°C for varying lengths of time. For the balance of the period, they were held at 18°C. After the treatment period the stems

Culture vessels were 200 ml glass jars (figure 1a) closed with vented translucent polypropylene screw lids. The culture room was heated to 25°C ± 2°C and the shelves were illuminated for 16 hours daily at 2400 lux with cool white fluorescent tubes.

Studies were conducted on the response to BA, IBA and GA_3 concentrations during shoot proliferation and elongation as well as root development and exflasking procedures.

Results and Discussion

1. Growth Regulators and Proliferation:

Shoot numbers, but not shoot size, increased when BA concentration was increased from zero to 2.0 mg/l in the absence of GA_3; however there was a corresponding decrease in shoot quality (figure 2) characterised by the formation of many fasciated shoots on the half basal elongation medium. At the lowest BA rate (0.3 mg/l) the number of visible shoots and size, (figure 3) as well as their quality, improved with the addition of GA_3 at 1.0 or 3.0 mg/l. The addition of GA_3 overcame the earlier requirement for a separate elongation medium prior to exflasking. A rate of GA_3 less than 3.0 mg/l may be optimal since this concentration produced excessive stem elongation. At 1.0 or 2.0 mg/l BA and GA_3 at 2.0 mg/l, shoot elongation was suppressed.

The proliferation medium which provided the best compromise of growth regulators consisted of 0.05 mg/l IBA, 0.3 mg/l BA and 2.0 mg/l GA_3. This medium produced adequate multiplication (figure 1b) of consistantly higher quality shoots without the requirement for a separate elongation phase on a different medium. While IBA was included, studies on its effect on shoot multiplication could not demonstrate any consistant advantage in its use.

2. Rooting and Exflasking:

IBA concentrations of 3.0 and 10.0 mg/l added to the half basal medium were suitable in initiating roots in culture. Root elongation occurred after transfer of these shoots to hormone free basal medium. Excessive callus tissue developed on shoots from the highest IBA rate. Root development in vitro was also induced after two weeks following basal end dips of 1000 mg/l IBA and then re-setting shoots onto half basal medium. Up to 90% of shoots initiated roots out of culture under enclosed mist after a basal dip of 250 or 500 mg/l IBA.

Exflasking either rooted or non-rooted shoots into standard greenhouse open mist facilities resulted in rapid collapse and death. The use of an enclosed polythene tent along with mist gave good survival and growth (figure 4a). A nutrient free fine pumice medium was used for shoot support. This allowed rapid root growth and the formation of proteoid root structures (figure 4b). After 6 weeks, once new leaf growth had occurred, humidity was gradually reduced by opening the tent in small stages over many days.

Plants were potted into a mix of 50% pumice and 50% pine bark and peat with added nutrients.

3. Other Proteaceous genera:

Both L e u c a d e n d r o n f l o r i d i u m and L e u c o s p e r m u m c o r d i f o l i u m were established in culture using the same procedures and medium as for T e l o p e a but additional surface sterilisation was necessary to obtain contaminant free cultures.

After five months L. c o r d i f o l i u m had produced 5 cm long shoots with well-developed leaves. Following subculturing into nodal segments and placement onto the T e l o p e a proliferation medium, further shoot development occurred with some achieving lengths of 4 cm within 10 weeks.

While axillary buds of L. f l o r i d i u m expanded and produced small shoots in 5 months these subsequently died.

Figure 1 - Shoot development from single node explant (A). In vitro shoot proliferation (B).

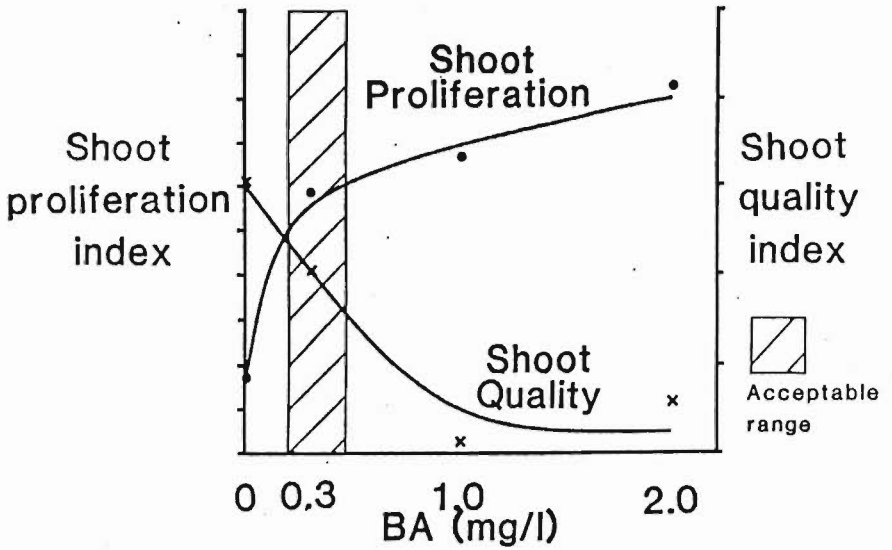

Figure 2 - Effect of BA on shoot proliferation and quality.

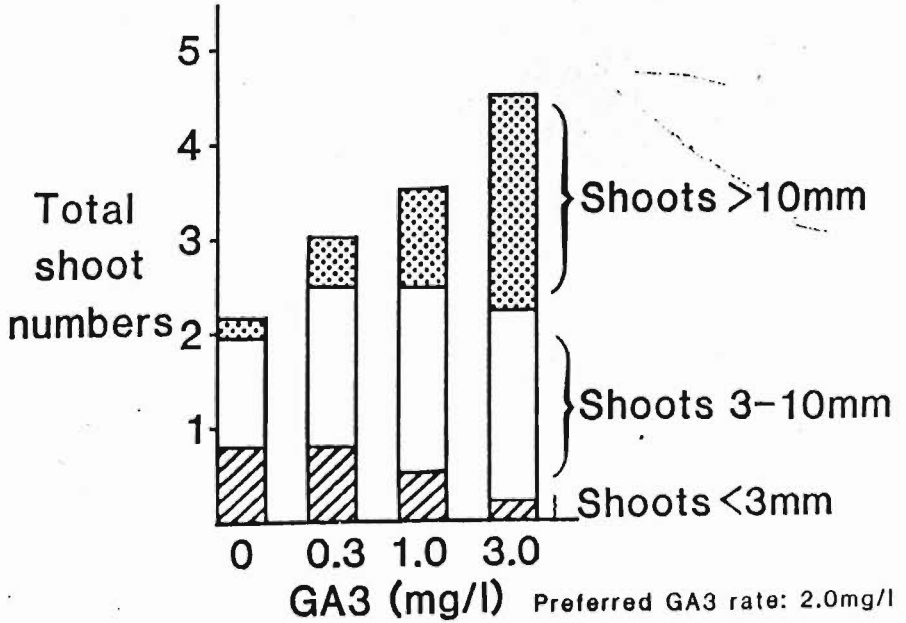

Figure 3 - Effect of GA_3 on shoot size and numbers with 0.05 mg/l IBA and 0.3 mg/l BA

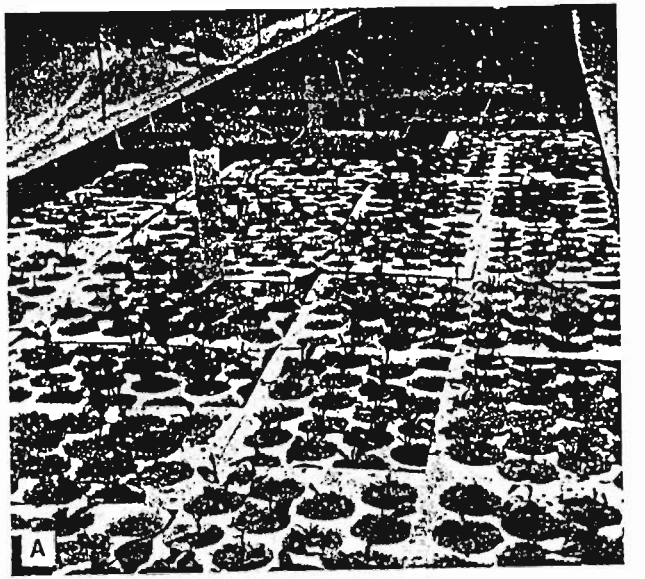

Figure 4 - Rooting under an enclosed misting environment (A).
Eight week old rooted shoot with proteoid structures (B).

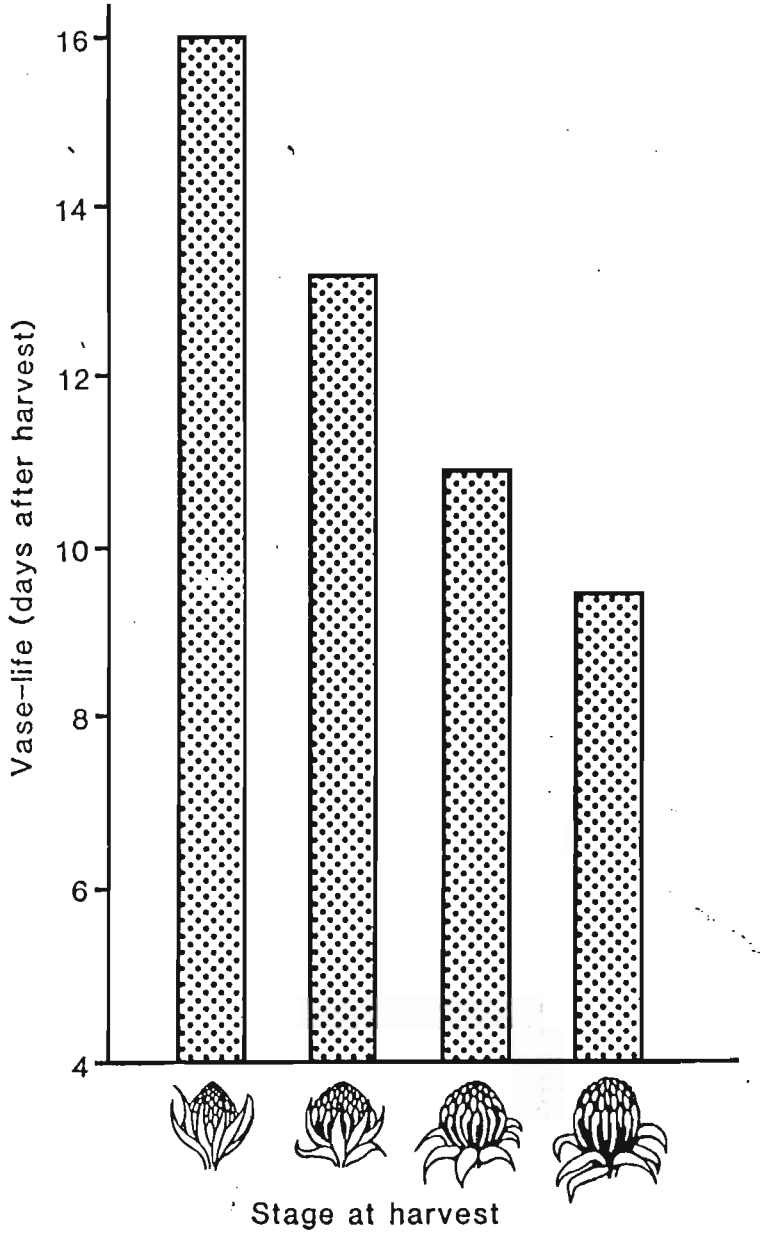

Figure 1: Effects of harvest maturity on vaselife of NSW waratah blooms.

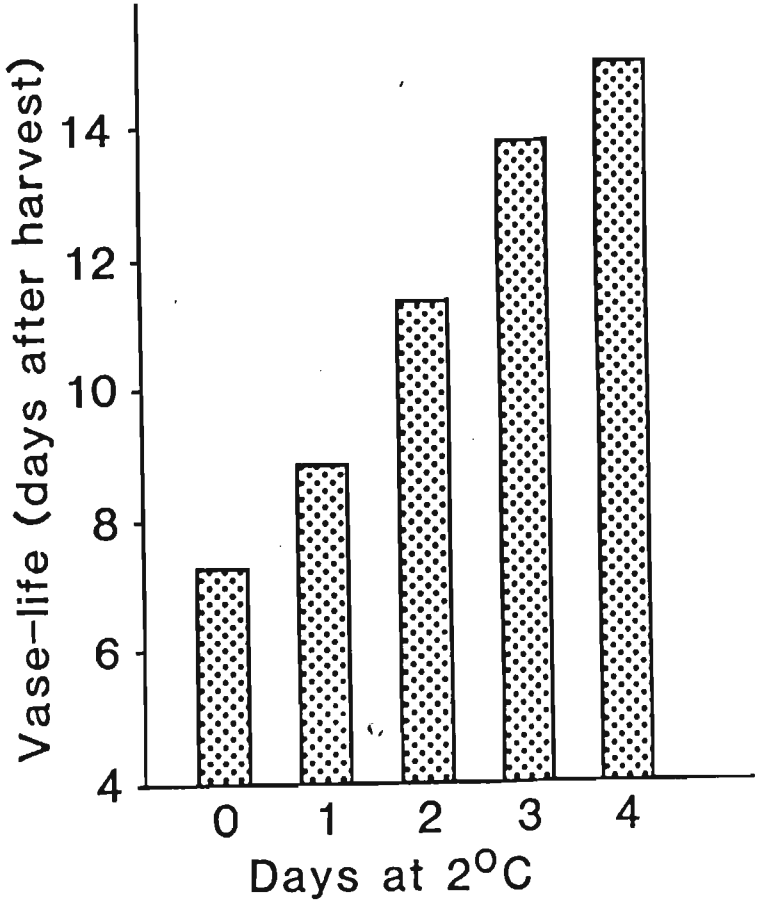

Figure 2: Effects of temperature during the first four days after harvest on vaselife of NSW waratah flowers. The flowers were held at 2°C for part of the period and at 18°C for the balance.

FLOWERING PATTERNS IN CAPE PROTEACEAE

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Abstract

Post-fire regeneration levels of Cape Proteaceae depend on the size of pre-fire seed stores. Based on seed maturation data, mainly for Leucadendron species, the most favourable season of burn is suggested for 9 sub-divisions of the fynbos biome. These suggestions conflict in part with suggestions based on climatic models.

Introduction

The welfare of the Cape Proteaceae depends on management burning operations being restricted to the most favourable periods. Bond (1980) and Bond, Vlok and Viviers (1984) have shown that post-fire regeneration levels are not static and can result in differences in seedling to parent ratios, of several orders of magnitude.

There are many factors which managers must consider when deciding whether an area of fynbos must be burned. This is because many factors determine whether post-fire regeneration levels of Cape Proteaceae will be adequate to maintain populations after fires at different times. For example, a management fire in vegetation which is too old (senescent) or too young (immature) will deplete, or even eliminate, certain populations of the Proteaceae.

Another important factor in determining regeneration levels of the Proteaceae after fires during different seasons of the year is the relative contribution of the latest years seed crop, to the total seed store. A fire just after the latest years seed crop has matured will result in the maximum number of seeds being available for regeneration. In contrast, if a fire consumes developing seeds or causes developing seeds to be released, then regeneration levels will be depressed because these immature seeds will not contribute to the total seed store (for details see Midgley 1985a).

The present study was initiated to determine which months of the year will be the most favourable for burning to obtain optimum Proteaceae regeneration, for different areas of the fynbos biome. As will be demonstrated, there is a considerable difference in flowering times between closely related species from different geographic areas. Also, there is considerable synchrony in flowering and seed maturation periods in each geographic area. Leucadendron (79 extant species in the fynbos area), was chosen for this study because; species are widespread and the reproductive phenology is well known (Williams 1972). Protea species are very variable in regards to the development time of seeds Vogts (1982).

The only other work aimed at prescribing optimal burning times for different geographic areas of the fynbos is by van Wilgen (1984) who used a climate model. A comparison between the burning seasons suggested for management, based on seed maturation phenology (this study) and that from the above climate model, indicates some differences.

Methods

Using the information provided by Williams (1972) in a detailed monograph on Leucadendron, all species have been allocated to;
1) 9 geographic districts (Map 1)
2) seed maturation times (month).

Some species occur in several geographic areas. The seed maturation time was taken as the first month if Williams (l.c.) indicated that seed maturation or flowering was spread over more than one month. Therefore, these times are conservative and represent a minimum date for seed maturity.

Results and Discussion

Table 1. The geographic trend of flowering phenology of closely related Leucadendron species (each pair is from the same sub-section).

West	flowering month	East	flowering month
1)dubium	8	galpinii	11
2) platyspermum	9	nobile	12
3) argenteum	9	dregei	11
4) macowanii	6	conicum	11
5) uliginosum (Outenikwa mts.)	11	loeriense (Eastern mts.)	12

Table 1 indicates that flowering time is mainly spring-summer in the east and winter-spring in the west, as was noted by Williams (1972). The important implication of this is, that the seed maturity period is also earlier westward; late summer in the west and late autumn in the east. Therefore fires should also take place later in the year in the east.

Table 2. Seed maturation times for the different geographic areas

	number of species that mature seeds during listed months										
geographic areas	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul
Cedarberg	1	3	7	6	4						
Westcoast		1	4	3	7						
Peninsula		2		2	2	1					
Central	1	1	5	5	8						
Bredasdorp	1	1	4	7	4		3				
Langeberg		2	2	2	1	1	2				
Outenikwa			2	2	1	1	2				
Swartberg		1	2	4	2	1	3				
East			2	1	1		1	2	1		

Table 2 suggests that the best time to burn in the north-west is from February (late summer) onward and for the more eastern areas from April (late autumn) onwards because by these times most species have matured the latest years seed crop. These suggestions are supported in part, when considering the phenology of other fynbos Proteaceae (Midgley 1985a).

Table 3. Proposals for burning prescriptions in the fynbos.

Geographic areas	Optimum burning time	
	This study	van Wilgen (361 : 1984)
Cedarberg	February-May	Nov-January
Peninsula	February-May	Jan-March
Central	February-May	Jan-march
Bredasdorp	April-June	Dec-February
Langeberg	April-June	Dec-February
Outenikwas	April-June	June-August
Swartberg	Ma;y-July	Nov-January
East	May-July	Dec-February

Table 3 indicates that there is conflict between the suggested season of burn from this study and the study by van Wilgen (1984). We suggest that the Cedarberg is not burned before February whereas van Wilgen (l.c.) suggests burning from November onwards. Arid areas, such as this, are particularly sensitive to season of burn. Thjis is because serotinous species are largely absent from these areas (Midgley 1985b) and also because summer drought mortality is higher in these areas (Midgley 1985c). In mesic areas adequate rainfall ameliorates summer drought conditions and an abundance of serotinous species confers more flexibility as regards burning times.

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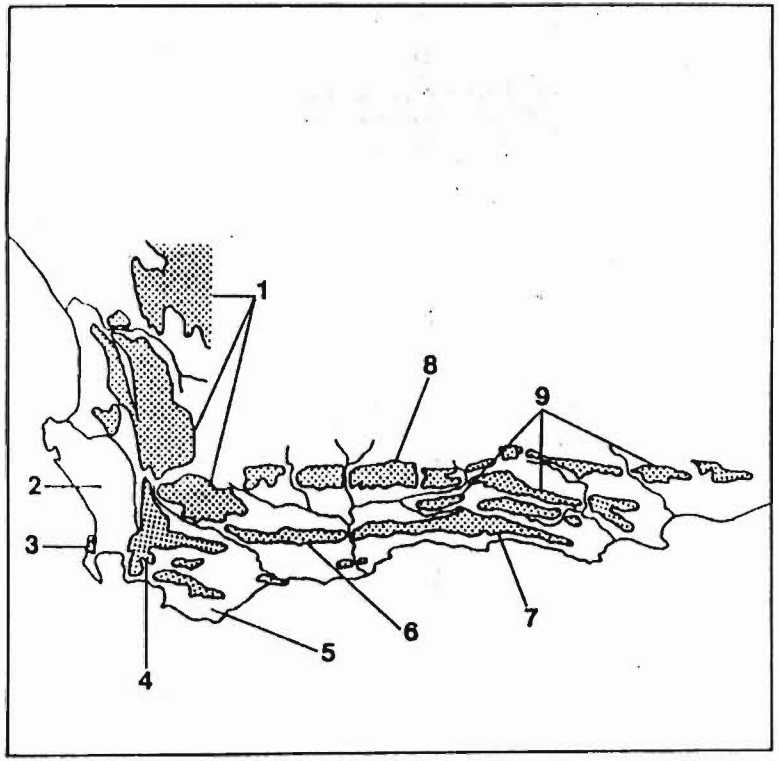
Please see map on following page.



CORRECT TERMINOLOGY FOR PROTEA INFLORESCENCES

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The situation is frequently encountered in the literature that an inconsistent terminology is used when reference is made to the Protea inflorescence. Terms such as flowers, flower heads, inflorescences, inner flower bracts, outer flower bracts, peduncles, stems etc are commonly and indiscriminately used.

The following terminology for the inflorescence and sub-parts of the inflorescence of the Genus Protea is recommended:

- The inflorescence is called a flower head and is borne at the end of a flowering branch (Fig 1).
- Each flower head consists of many florets (individual flowers) crowded on the involucral receptacle and surrounded by the involucral bracts (Fig 2).
- The involucral bracts are grouped into series, e g Protea magnifica having 9-10 rows; P. neriifolia having 11 rows and P. grandiceps having 8 rows.
- The bracts of the lower (outer) rows are shorter and scaly and are called scaly bracts whereas the bracts of the inner rows are longer and showy and are called the inner or coloured bracts (Fig 3).
- Individual florets are sessile on the receptacle and have four perianth segments which consist of 3 adaxial fused segments and 1 abaxial free segment.

Suggestions recommending various inflorescence parts of the other genera of the family Proteaceae will be welcomed by the author.

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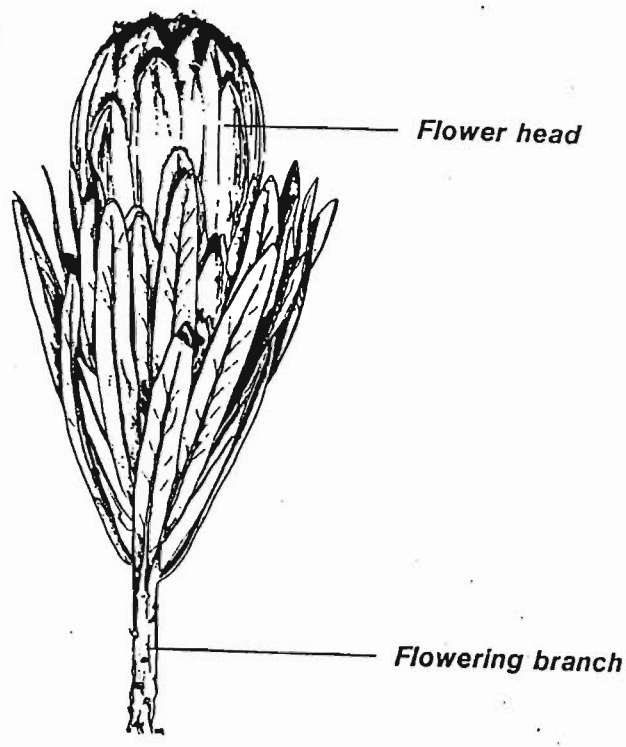

Figure 1 Inflorescence of Protea nerlifolia

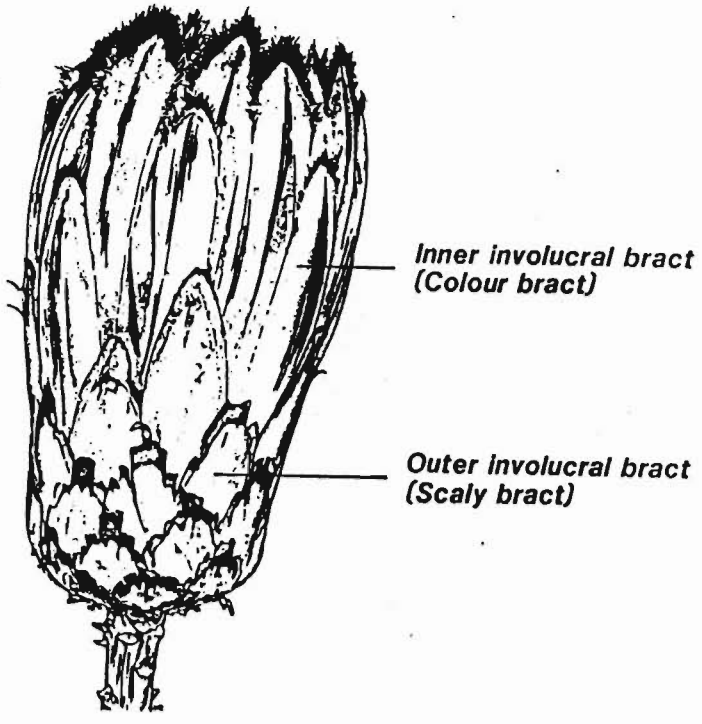

Figure 2 Flower head to show colour (inner) and scaly (outer) involucral bracts

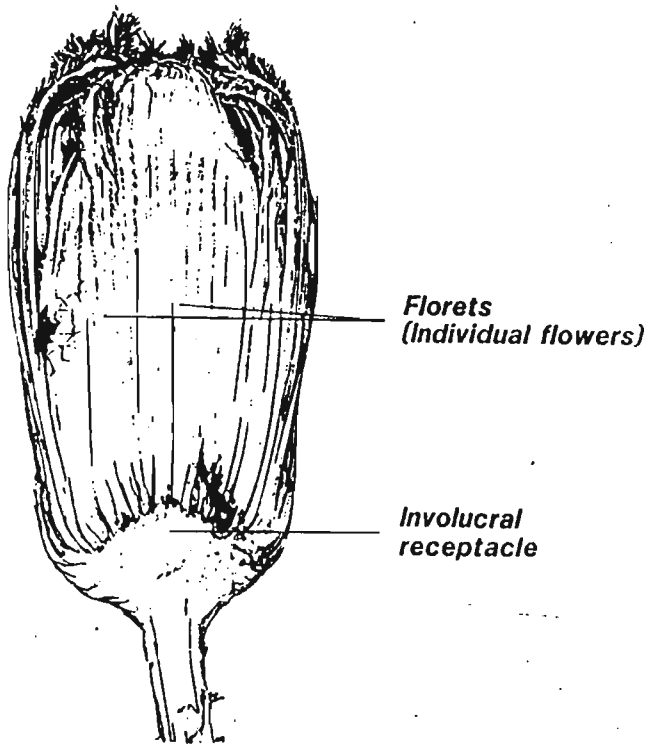

Figure 3 Flower head to show individual flowers on involucral receptacle

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Abstract

The New South Wales waratah is a woody proteaceous plant cultivated for cut flowers. Seed-raised plants vary in cut flower quality characteristics. A micropropagation method was developed to rapidly increase the number of plants of forms selected for cut flowers.

After establishment in culture, single node explants initiated shoots on a modified MS medium. Shoots proliferated on a basal medium supplemented with IBA, BA and GA_3, a six-fold increase being achieved in six weeks.

Rooting was achieved both in, and out of culture. Precise control of temperature and humidity was essential for survival and the subsequent growth of the plantlets.

The applicability of these techniques to L e u c o s p e r m u m and L e u c a d e n d r o n has been assessed.

Introduction

In New Zealand T e l o p e a s p e c i o s i s s i m a is cultivated for cut flowers. A selection programme was initiated because seed raised plants show considerable variation in flower colour and form, post-harvest quality and plant habit. In vitro techniques of vegetative propagation were investigated so that improved forms could be rapidly increased in number from a limited base stock.

Methods

Vegetative shoots taken from both field and greenhouse grown plants provided the material to initiate cultures. Single node segments, with petiole removed, were surface sterilised by dipping in ethanol for a few seconds, washing in a 0.6% Sodium hypochlorite solution for 20 minutes and rinsing in sterile distilled water. The 'basal' medium comprised of Murashige and Skoog (MS) minerals, 0.4 mg/l thiamine-HCl, 100 mg/l myo-inositol, 30 g/l sucrose and 7.5 g/l agar. A 'half basal' medium which had only the MS macroelement salts reduced was used for proliferation and elongation. Media was adjusted to pH 5.7 before autoclaving. The growth regulators used were indole-3-butyric acid (IBA), 6-benzyl-aminopurine (BA) and gibberellic acid (GA_3), the latter being filter sterilised.

Explants were established and developed shoots after two months (figure 1a) on a modified basal medium which contained 0.05 mg/l IBA, 0.3 mg/l BA and 0.1 mg/l GA_3.