PROTEAS

THE PROPAGATION AND PRODUCTION OF PROTEACEAE

by

JACK HARRE

Printed by
FISHER PRINTING & STATIONERY LTD.
Feilding, New Zealand.

FOREWORD

Jack Harré has over twenty years experience in growing and observing plants of the Proteaceae family in New Zealand.

He has also seen them growing wild in South Africa as well as with some success and some failures under cultivation in New Zealand, Australia, California, Hawaii and South Africa. He has had many discussions with other growers and scientists.

His intention in this book is to present readers with the accumulated results of his practical experience, trials, observations and thoughts and; "put the joy of growing Proteaceae within the reach of many more people".

It is aimed primarily at beginners and those who are not achieving success in propagating, growing and marketing Proteaceae, especially Proteas, Leucospermums and Leucadendrons.

Jack Harré is an enthusiast, with a fresh, common-sense approach to the subject. He takes nothing for granted, and questions each aspect critically.

Some of his conclusions may be controversial, but most growers should benefit from his advice and from a similar analysis of their individual properties, plant selections, propagation and production techniques.

JOY AMOS,
Northcote,
New Zealand.
17 October 1988

PREFACE

It is now some eight years since I set about compiling and writing this book. At that time Proteaceae was just emerging as a new and exciting cut flower crop in many parts of the Western World and as a grower with some 20 years experience, I became involved in the commercial build-up associated with the "discovery of the Protea".

It was obvious right from the beginning that there was a great need for a book on the basics of Protea growing, not only for the use of the home gardener and the commercial cut flower grower, but also within the nursery trade whose job it is to produce the plants that are used in our gardens and commercial plantations.

When I started making notes and doing preliminary layouts for this book in 1980, it became obvious that my knowledge of the complexities of propagating, cultivating and production of flowers was insufficient to do full justice to the subject. To increase my knowledge and skills I set about a programme of research, observations and travel that has absorbed some 4000 hours over these past eight years not counting the time spent in travelling and visiting Protea growers throughout New Zealand and other countries.

The sections dealing with propagation and plant production within this book contain a condensed summary of the information gathered during thirty years of growing Proteaceae plants as a commercial nursery crop and the results of the past eight years of research in our nursery and observations made in a number of Protea growing areas. Some of the information given on commercial production and flower handling is derived from personal experience but to some degree it is accumulated facts and knowledge gained by observation and discussion with cut flower growers in many places throughout the world. Many people have given me their time and shared their knowledge. I thank them here for their contribution to this book.

This book is intended for the use of those involved in the practicalities of Proteaceae growing through out the world. It does not attempt to be, nor is it intended to be a scientific document. Its contents have been compiled and written from practical experience and self motivated research. Although it deals specifically with the South African varieties, the Australian Telopea has been included because of its importance as an international cut flower.

In covering such a wide range of subjects that are dealt with in the following sections, there is a great risk of being, "A Jack of all trades and a master of none". I am well aware of this and have endeavoured to keep within the bounds of factual information. The exception to this is in Section 17 "Facts and Fancies", where in some areas I have indulged in a certain amount of conjecture and supposition.

In the next 10 years the spread of Proteaceae under cultivation will increase greatly in both quantity and in a wider range of varieties. This will be assisted by implementing the information on their care and cultural needs that is continually being gathered and dispersed to growers. It will put the joy of growing Proteaceae within the reach of many more people in many new places around the world. It is hoped that this book will help in the spread of these plants to many parts of the globe.

This book is designed as a base of information on Proteaceae and will need upgrading every few years as we develop our cut flower crops and improve the techniques in propagation and production. To this end there are three Appendixes attached to this publication. These contain the findings of trials completed during or since the writing of this text. It is intended to publish additional appendixes as further trials are completed or information becomes available and make them available as a supplement to this book.

In writing this book I have assumed that the reader has little knowledge of Proteaceae growing and more advanced growers may find it a little tedious in places. Nor may experienced growers necessarily agree with some of the statements made. There is always room for improvement and if anyone can show me and others better and more reliable ways of "Protea Growing" I will be more than happy.

Jack Harré

R.D. 7

Feilding, New Zealand

HOW TO USE THIS BOOK

To facilitate easy referencing to any particular subject, the text is arranged in Sections numbered 1 to 18 with each Section dealing with a particular phase of development or handling technique.

Within each Section are a number of Files each of which is pre-fixed with two numbers and a Heading in CAPITALS.

The first number identifies the Section.
The second number identifies the File number.
The Heading in CAPITALS identifies the subject it deals with.

Example:- 3:7 JUDGING MATURITY AND HARVESTING CUTTINGS.
is: — Section 3, File 7,
Deals with — Judging the maturity of cutting material and the harvesting of it.

Within the text of the files are references to information in other files. This information is related to the subject of the file that is being read.

These references are identified as : - [ref.*:*]. with the numbers referring to a particular file.

Example:- You are reading Section 8 which deals with:-
GROWING THE PLANTS ON.
In file 8:16 SOIL BORNE FUNGI CONTROL. you will read quote —
"in the section on fungi and pest control [ref.9:10 & 9:11]." — unquote.

This [ref.9:10 & 9:11] is directing you to Section 9 File 10 & 11 for full information on the control of soil borne fungi.

It is important in the growing of Proteaceae that the handling of them from propagation to the final harvesting of the crop be considered in its entirety. With this genus of plants, what happens to them in one phase will have carry through implications to all latter phases of their development. Because of this, this book should be read in its entirety as it deals with each phase of the plants development in its natural sequence.

SPECIAL SYMBOLS USED IN THIS BOOK

As a means of simple reference and to enable readers to make their own calculations and assessment of three very important aspects of climate, LIGHT, TEMPERATURE/HUMIDITY and FROST there are three non standard symbols used through out this book.

These are:-

l/lu	referring to LIGHT. See 2:2 for particulars.
th/c	referring to TEMPERATURE/HUMIDITY. See 9:1 for particulars.
f/f	referring to FROST FACTOR. See 10:6 for particulars.

CONTENTS

SECTION ONE

Proteas In Nature

1:1 OVERVIEW

For the home gardener and commercial grower, the cultivation and growing of South African Proteaceae is an occupation which will be a never-ending challenge. With some varieties success will come easily but with others there will be difficulties and with some varieties in some locations it will be almost impossible to succeed. Unlike most other plants that are in cultivation throughout the world, Proteaceae are still at a stage in which they are introduced to their adopted location directly from the wild, ie. the seed is collected from natural stands. Almost all other ornamental genera have been through many generations of cultivation "in captivity" and are selections of the originals that have been chosen because they are suited to a particular climate location.
Proteaceae are reaching a stage where selections have been made because they are suited to a particular climate or use (cut flower landscape) and then vegetatively propagated. They are however a long way from the refinements that roses, carnations, camellias, rhododendrons or hibiscus have reached. Because of this an understanding of these plants physical make up, which in nature is matched to the soil type and climate under which they survive will help growers to greater successes or alternatively an understanding of their failures.

This family of plants is so diverse and complex in its makeup that it may be likened to the human race with its varied cultural and climatic requirements. Individuals' life span may also be likened to that of our own with the baby seedlings looking so fragile, yet like infants having an incredibly strong hold on life. In the childhood phase of development they may catch every malady going, yet with treatment usually recover. As teenagers they grow rapidly and flop around all over the place and if they survive this period they will become adults to bloom and enrich their surroundings until the decline of old age sets in.

To understand and be successful with these plants always remember that they are as varied in their makeup as Proteus the mythical God they were named after. As he did, they may show themselves in many moods and forms.

In the past 25 years these plants have been grown more and more in "captivity" and today some varieties are quite common in a number of locations outside their homeland of South Africa. The species and varieties that have become established under cultivation are not great when compared to the total inventory of South African Proteaceae, but they are quite an achievement for those who grow them.

1:2 THE ENVIRONMENT

In their homeland of South Africa, Proteaceae have adapted themselves to survive and thrive in areas which are inhospitable to other genera of plants. In many instances they and their supporting associate plants (Ericas, Reeds, etc,) are the only plants able to survive in that particular location and even if others were introduced they would fail. Many of the varieties, especially the rarer "gems" live in environmental locations where the particular soil type, rainfall, light intensity, air movement and seasonal temperature variations are finely balanced. It is when we are trying to match these environments in cultivation that we run into difficulties. It is almost impossible to match them all in one location. The best we can do is to know and understand what these environmental factors are and try to match them in our cultivation techniques.

In their natural environment the fertility of the soil is usually very low and this is matched by low pH levels (as low as 3) with exceptions being in the few places where certain varieties such as Protea obtusifolia and some variants of repens are found in the limestone outcrops. The ground structure is usually porous and well drained though not necessarily particularly dry, except on the surface during the dry season. The ground texture is such that plants are able to get a firm grip and not be unduly rocked by the wind which is a constant companion. The amount and seasonal pattern of rainfall varies greatly from one location to another with total annual aggregates varying from 300 to 2000mm. (12 to 80 inches).

These are the main conditions in which, over the ages, Proteaceae species have adapted themselves to grow and reproduce. Added to these is the fine tuning that each variant of each variety has gone through during its evolution to adapt to its own particular local environment which at times may be confined to one hectare (two acres) or less in many thousands of hectares.

These special conditions include: facing into the sun (north), facing away from the sun (south), the land lying flat, sloping steeply, sloping gently, altitude (above 500 metres, below 500 metres), (1500 feet), annual total rainfall and the seasonal pattern of its distribution, soil structure (rocky and dry rocky and moist, sandy and dry sandy and moist), air movement (strong winds moderate breezes), dry air, moist air, hot air, cold air, does it freeze, if so, to what degree.

Finally the most important point of all to those growing Proteaceae outside their natural environment is the cloud sheet. The seasonal pattern, intensity and moisture content of the cloud sheet and of upper atmosphere that prevails where they grow in nature has influenced each individual species and variety to adapt to their own particular local radiation levels.

South African Proteaceae are what I term rhythm plants. Many of them are adapted to grow in a climate that has wide variables between seasons in temperatures, rainfall, air movement and light intensity. When we take these varieties and grow them in appreciably different climates to which they are adapted, they can be most unforgiving. The two conditions to which they take

greatest exception are heavy rains or irrigation during the season when they are resting (their natural dry season), and exposure to light levels that are well in excess of those they are accustomed to. Whether or not the sun's rays are being broken up by atmospheric conditions has a strong influence on the success or failure of cultivation of Proteaceae in "captivity" and is dealt with in the following sections.

With Proteaceae whether they are growing in nature or in cultivation, the two principal factors governing the plants health are; a well developed healthy root system and a foliage type that has the physical capabilities to cope with the light factor of the chosen growing site. If either roots or foliage are under stress and not in accord with the plantation site, the plant will not flourish as it should and may fail to survive for more than a year or two.

An understanding of the regeneration cycle and functions of the root and foliage systems will help propagators and growers to understand these plants' many likes and dislikes. Such an understanding of their base requirements should make it possible to propagate, establish and grow the more common varieties to greater levels of achievement and perhaps make it possible to establish those gems that have hitherto proven so elusive.

1:3 THE REGENERATION CYCLE

Almost all species and varieties of South African Proteaceae regenerate following fire. Without fire there is no way for new generations of many varieties to establish in the veld. This is true of much of the veld flora, from the reeds and grasses, the Leucadendrons, Leucospermums and Proteas, and many others of the multitude of plants present. It is unusual to find fresh seedlings of many of the Proteaceae family more than two years after fire unless the ground has been broken in some way.

The periods between spontaneous fires can be up to fifteen to twenty years apart. By that time the surviving plants of all species and varieties are woody and tired with short annual growths and progressively sparse flowering and seed sets. Research on seed survival and viability shows that in the veld situation, both viability and survival of seed, falls off rapidly when the seed heads and cones are over three years old. By that time rodents and insects have eaten most of the seed or caused it to fall on the ground to perish, or it has become non-viable through natural ageing. This means that at the time of any fire, provided it is more than five or six years since the previous one, there is a three year supply of seed to be released on to the freshly burned land. It is when man interferes with the natural sequence of fire that the veld is in danger.

Following fire, which destroys all predators (both insect and animal) as well as all fungi, at least above the ground surface, there is a pattern of regeneration which is natures way of re-establishing this finely balanced flora. In the few days immediately following the fire there is a great release of seed from the cones and seed heads which were left scorched but mostly undamaged above the level of the fire. The first growths of Proteaceae to appear through the soils surface are the shoots from plants with a lignotuber such as Protea cynaroides. Leucadendron salignum, Leucospermum cuneiforme and Mimetes cucullatus. Depending on the time of year and the rainfall pattern, but usually in the autumn, these are joined by the bulbs. reeds and grasses. Closely following are the local varieties of Leucadendron and Erica seedlings with the initial population of these often exceeding 50 to the square foot.

The growths of lignotubers and these first seedlings can be regarded as the pioneers of regeneration and for the first two to three years they will dominate the veld's developing vegetation. Protea and Leucospermum seed germinate when conditions are suitable for their survival and this is normally not until there has been a substantial drop in the average temperature which coincides with the onset of winter. Research has shown that this low temperature period is necessary to initiate the germination in some varieties, especially those that are known to have a built-in dormancy period such as some Leucospermums. and Ld. argenteum.

The young seedling Proteas and Leucospermums usually remain at not more than half the height of their companions of reeds. grasses and Leucadendrons which in those first two summers usually reached 45 to 60cm. Many varieties of Proteas and Leucospermums are extremely sensitive to long hours of bright sunlight for the first two to three years of their life and they are happy to stay within the dappled shade created by the pioneer plants. Exceptions to this are those varieties with glaucous foliage such as Pr. eximia. nitida. laurifolia. These reach through the canopy of the pioneer plants more rapidly (usually towards the end of the second summer) whereas varieties with green leaves such as Pr. neriifolia, nana, some repens variants. Lsp. cordifolium and many others take a further one to two years before they begin to reach through the pioneer canopy and establish their dominance.

The glaucous (blue) leaved varieties of Proteaceae are able to withstand considerably higher light intensity than those with green leaves and in nature there are few Proteas with green leaves growing on any slopes facing north. On these north slopes the sunlight is of higher intensity and has a greater daily aggregate of radiation than on the south facing slopes. It is interesting to note that almost without exception, seedling and cutting grown Leucadendrons have a covering of minute downy hairs on their leaves for the first two or three years of their life. On most varieties they disappear with maturity but can be seen on older plants that favour growing on north facing slopes such as the particular form of Ld. uliginosum found growing on the inland north facing slopes of the Robinson Pass. These hairs are the Leucadendron's way of screening bright sunlight from their leaf surface.

In the ashes following fire, the germination of seedlings and initial survival rate is very high. This is probably due to the fact that most fungal spores are destroyed by the fire coupled to the lack of competition both above and below the ground from other than their own kind. Germination is almost certainly assisted by a balance of nutrient and trace elements in the ashes and the presence of

micro-organisms in the soil which are generated in the decomposing litter of the previous generation. It is probable that micro organisms play a much greater roll in the life cycle of Proteaceae than has been previously thought. This is dealt with in Section 17:3.

1:4 THE ROOTS

Plants of the genus Proteaceae are unique in that they have two separate root systems, each of which has a specific well defined function.

The primary roots are those that anchor the plant firmly in the ground. They are capable of penetrating to a depth of at least two metres and under certain circumstances four metres through the substrata to become the moisture seekers and supporting life lines during dry conditions. These roots can be observed in the banks along the roadsides in South Africa where they have been exposed during construction or by slips. In these banks, areas of moisture can be observed in the substrata and it is into these levels that the roots are reaching. The roots are not massive but tend to be fine and arranged in clusters at the various moisture levels.

The second system is called proteoid roots and these are of a highly specialised nature. They form at or just below ground surface level and their function is to absorb the nutrients released from decaying litter (humus). They form during the rainy season and in most varieties reach their maximum efficiency towards the end of that period which coincides with the maximum level of nutrient in the humus. They resemble hairy sponges, and acting in that manner, are capable of taking up and temporarily storing food. It is also possible they may play some part in the more rapid break-down of litter to humus by fostering high levels of micro organisms in the soils surrounding them.

Following the process of absorbing nutrient which will then promote the next growth cycle of branches, leaves and flowers, these proteoid roots die, to be replaced by a new system the following rainy period. Their development each year or cycle, (they may form twice per year) is controlled by the seasonal pattern of the rainy period. If the rains are late they also will be late in development. Where plants are growing in unusually high levels of fertility such as in cultivation these roots will not be as evident in their development. Proteoid roots are invariably at or just below the surface of the ground and this makes them particularly vulnerable to damage by cultivation and chemical misuse. The dangers of these to the plants' well-being is dealt with in the following sections.

A lack of understanding by growers and nurserymen of the function of proteoid roots is often the cause of problems with Proteaceae. They are not moisture seekers; they are feeders and play little part in sustaining the plant with moisture. A plant, no matter whether it be in a container or in the ground, could have a mass of proteoid roots yet die of dehydration in quite moist conditions if it had not developed a primary root system. This is one of the great problems associated with soil-less mediums in the production of Proteaceae and is dealt with in 8:5 to 8:7.

It can be seen from the foregoing that if Proteaceae plants in cultivation have been encouraged to develop a well balanced dual root system, they are well equipped to supply moisture to the plant during dry periods as well as having the ability to absorb and store a sometimes very limited supply of food. Both primary and proteoid roots are tailored to operate efficiently in relatively dry conditions and will deteriorate rapidly in other than these conditions. This is the reason why good drainage is essential at all times.

1:5 THE FOLIAGE

In nature, the types and texture of leaves are tailored to match each variety's particular location. Plants of the same variety from different locations sometimes have quite different leaf texture and colour. They can vary significantly in natural stands only a few kilometers apart depending on the aspect and cloud-bank conditions that prevail where they are established. When plants are grown from seed, as in nature, variations within a variety are known as "variants". These are quite common among varieties we know in our gardens and commercial crops, eg. Pr. neriifolia, cynaroides, magnifica, grandiceps etc. with each variant being confined to its own particular location and micro-climate.

In horticulture, when we take an outstanding seedling of a variant, name it, then propagate it vegetatively, it becomes a "cultivar" or "clone". Each variant and clone has its own particular characteristics in leaf colour, texture, the way the leaves are set on the plant, the physical make-up etc., that enables it to live in its own particular location. To casual observation these differences are not greatly apparent and it is not until we remove variants from their natural surroundings and grow them in "captivity" that we find they have differing behaviour patterns. The two most noticeable of these are their resistance or susceptibility to fungal diseases and acceptance or intolerance to the prevailing light levels in the adopted growing site.

It is this variable physical make-up of Proteaceae variety variants, that we have hitherto imagined to be all the same, that explains the inconsistent results with some varieties in some locations when we grow them in our gardens and plantations. In the past they have all been regarded as being a "variety" by growers and nurserymen, ie. a plant has been a neriifolia, a cynaroides, a magnifica etc. This is technically correct, but in practice, plants grown from seed of a variety that has been harvested from different locations may produce plants that will have vastly differing tolerances to light, air movement, soil type, rainfall — the seasons it flowers and minimum temperatures even although they are all neriifolia, cynaroides etc. P. magnifica is a good example of how highly variable a variety can be in nature with each variant being finely tuned to its own particular mountain range or even an area within a mountain range. When trans-located to another area, even in South Africa, it often fails to adapt to its new location and performs poorly.

In 1984 I collected seed from five different stands of Pr. neriifolia in South Africa, three of which were within 10km. of each other. The plants that grew from this seed were later planted out for observations on their adaptability to climate in two locations about 300km apart in New Zealand. There have been marked differences in their reactions in each location with those in one location giving one result and those in the other a different one. The principal variable has been in their susceptibility to fungal infection and to a lesser degree reaction to light levels. If you have planted Pr. magnifica or other varieties in the past and not had the anticipated success with them, there is a possibility that you have not planted the right variant for your location. This is dealt with in detail in Section 10.

It can be seen from the foregoing that Proteaceae are highly variable not only between species but also within each species, variety and variant. These variables are carried through to the propagation, production and in the case of cut flowers to the handling of the crop. The successes and failures of growing these plants and producing flowers for either home use or as a commercial cut flower crop are to a large degree controlled by two factors. These are the selection of the right variety/clone for a given climate and the grower's understanding of the genus and their skill in applying that knowledge to cultivating the crop. The following sections outline to the best of my ability a summary of the knowledge that I have so far acquired in the propagation, cultivation and production of Proteaceae.

There is still a lot of scope for study and research in the area of the genus regeneration cycle in nature and its application to commercial production. Points of particular interest which are or will be looked at in future are continued studies on their sensitivity to light and its further application in propagation: the composition of the ashes following fire in the veld and the effects that those ashes have in the pre- and post- germination period on breaking seed dormancy and later on the seedlings and whether it has possible application in vegetative propagation. Other points include the influence of the decomposing roots of the previous generation on soil aeration and moisture retention and the effects of the fire in sterilizing the soil surface. It is also highly probable that certain beneficial micro-organisms are present in nature that have considerable influence on plant health, growth rate and disease resistance. If this is so, can they be applied to cultivation in "captivity"?

The answers to these points and many others lie in the future and will be discovered by those who grow and live with the genus Proteaceae.

SECTION TWO

The Theory of Propagation and Provision of Environment

2:1 OVERVIEW

In horticulture there are a number of ways of carrying out vegetative propagation. The most common means are by cuttings, grafting, budding and more recently by tissue culture. So far tissue culture has met with little success, other than with Telopea, and even here, success has been limited. The most widely used method of vegetatively propagating Proteaceae is by cuttings and this book deals only with that method.

Some Proteaceae are difficult subjects to root from cuttings. The difficult varieties demand very specific environmental conditions before they will produce roots and some of these are so demanding that they are seldom met under normal nursery conditions. So far I have found nothing impossible to root but some are so slow or difficult that they are not a viable commercial proposition to increase in this manner. In such instances these are better to be increased by seed or if it is important to retain a particular characteristic of a clone, by budding or grafting. I have had little experience of the latter two but it is possible and is carried out to a limited degree by some propagators.

To propagate any plant by vegetative means it is necessary to control:-

- light intensity
- water availability
- air movement.

These are the three factors that control the development of a plant or cutting and this section looks at the theory of why the environment in the propagation area must be controlled, and how to create the environment that will induce rooting.

2:2 LIGHT

The hours of sunlight and the control of the intensity of that sunlight will influence the percentage of cuttings that will root, the time it will take them to produce roots and often the vigour with which they do root. Once a cutting has been made and set, light has more influence on the results of propagating Proteaceae then anything else except the prevention of dehydration.

When I became aware of this I had to find some simple and accurate way of measuring the suns radiation and convert it to a light unit I could calculate and regulate with some degree of accuracy. My light units are calculated by measur-

ing the suns radiation in foot candles of light (ft c) and multiplying that by the number of hours it shines at that particular rate in a day. The light units derived by using this formula were given the name of "Jack's light units", abbreviated to j lu. Throughout this book where reference is made to j/lu it is referring to the accumulated daily aggregate of the sun's radiation calculated by this means. Where references are made to ft/c it is referring to the maximum allowable level of the sun's radiation measured as foot candles of light.

Whilst this is not a particularly scientific means of referring to the suns radiation it does serve the purpose in this instance and is a method whereby anyone who can ascertain what the prevailing foot candles are at a particular time of the day can then calculate with some accuracy how many j/lu are being generated in their nursery each day. If a light meter is not available which gives a ft c readout it is possible to calculate the light by using any SLR camera using the following procedure.

For an automatic camera:-
Set the ASA to 20
Set the iris aperture to f4
Sight the camera at a general view with 30% sky showing in the frame
9,000 ft/c will read 1/125 of a sec.
5,000 ft/c will read 1/30 to 1/60 of a sec.

For a manual camera:-
Set the ASA to 20
Set the shutter speed to 125
Sight the camera as for above and adjust the iris to give an OK reading
For 9,000 ft/c the iris ring will read f4
For 5,000 ft/c the iris ring will read f2.8

These methods are not entirely accurate but will give a workable assessment of the prevailing light.

The importance of light control cannot be over emphasised and propagators should make every effort to ascertain what levels of radiation prevail in their nursery. As a guide line to arriving at a reasonably accurate working formula of daily radiation, the maximum light that I have recorded in New Zealand with a few exceptions is 9,000 ft/c. On a clear day the first and last three hours of each day will average about half of this (4,500 ft/c). Therefore on a clear day at equinox, with twelve hours of total sunshine a day aggregate can be calculated as:

First 3 hours X 4,500	**=**	**13,500**
9am. to 3.pm 6 hours 9,000	**=**	**54,000**
Last 3 hours X 4,500	**=**	**13,000**
Total aggregate for the day	**=**	**71,000**

In mid summer on a clear day we record a maximum radiation of approximately 110,000 j/lu. in our nursery.

Big variations of radiation prevail from place to place. On the island of Maui I

have recorded 14,000 ft/c at 10 am. in midwinter. Readings at midsummer on the research station there have recorded light levels almost twice those that have been recorded in New Zealand. In Southern California midwinter light levels are about the same as New Zealand but by late February show increasing levels. Recordings in the Cape area of South Africa in the winter showed levels similar to New Zealand but were brighter in some inland areas. No readings have been taken in Australia but it is known that light levels are high in some areas.

Observations in a number of countries where Proteaceae are propagated, show that there is a constant relationship in every location of the effects that light intensity x hours of sunlight x temperature have on the percentages of cuttings that root or seedlings that survive.

Trials in New Zealand and observations in other countries where these plants are propagated and grown by cuttings and seed, covering a wide range of species and varieties, clearly show that a summer light intensity of 9,000 f/c with a day aggregate of 80,000 plus j/lu at daytime temperatures above 20°C. (70°F.) is fatal to many cuttings and detrimental to most seedlings especially if the relative humidity is below 50%. Below 15°C most varieties tolerance to light increases appreciably but with plants under two years old their tolerance seldom rises above a continuous daily aggregate of 80,000 j/lu.

2:3 LIGHT CONTROL.

To control the light level and daily aggregate of radiation under New Zealand conditions, 48% shade cloth can be used as a shield to bring the light intensity down to a level of 5,000 to 5,500 f/c. which will also reduce the day radiation aggregate at a pro rata rate. A further layer of 48% cloth will reduce the light level to 4000 f/c.

For many varieties a light level of 5,000 ft/c with a daily aggregate of 45,000 j/lu will give good results in rooting cuttings. It will be found however that this level will be insufficient for the grey and/or hairy leaf varieties of Protea and Leucospermums, and the glaucous-blue and hairy leaf forms of Leucadendron. Some of the varieties in this bracket are:- Pr. magnifica, pudens, stokoeii, Lsp. reflexum, some forms of cordifolium, conocarpodendron, Ld. argentum, discolour, nervosum, procerum, orientale. For these the light must be controlled to a maximum of 6,000 ft/c and a daily aggregate of 60,000 j/lu. with an absolute minimum of 4,500ft/c and a daily aggregate of 45,000 j/lu. Varieties in this bracket do not root well during prolonged cloudy periods or in the winter as it is difficult to provide them with sufficient daily aggregates of radiation.

Because of the variation in each variety's make-up and the necessity to provide differing conditions for the two types, it is not possible to provide the optimum conditions for all varieties under one control regime. To propagate both types successfully it will be necessary to provide two shade areas, one controlled to 5,000 ft/c. and 45,000 j/lu and the other to 6,000 ft/c and 60,000 j/lu. With this

it should be possible to propagate almost any Proteaceae. The practical application of these systems is dealt with under 6:3.

At light levels below 4000 f/c the initiation of rooting becomes very low in all varieties unless they are stimulated by bottom heat. There is a direct connection between the hours at which the light level is between 4000 f/c and 6000 f/c and the speed and vigour at which root initiation takes place. At 4,000 ft/c and below, it is almost impossible to maintain the minimum daily radiation aggregate of 35,000 j/lu. that is needed to stimulate rooting. The dangers of prolonged periods of low light, below 25,000 j/lu. are dealt with in 9:19.

In our nursery we had the experience for several years that cuttings of a number of varieties set in late December (mid summer) were rooting much more quickly than better material set in February. Initially this was thought to be the result of higher temperatures, but readings later showed that temperatures were consistently higher in the February/March period than the late December/January period. It was then noticed that there was a marked difference on the west side of the propagating area which was loosing the sun at midday in February/March because of the lower trajectory of the sun being blocked by an adjacent building. This was putting the cuttings in complete shade with a light factor of 2000 f/c for the afternoon (half of each day) which was resulting in those cuttings only receiving a daily aggregate of about 30,000 j/lu. The nett result of this was that the cuttings on this shaded side rooted much slower or not at all. This illustrates that it is desirable to arrange the propagation area so that it will expose the cuttings to as many hours as possible of light within the allowable range of 4000 to 6000 f/c.

When designing and building a propagation structure it is necessary to ascertain what the maximum ft/c and daily aggregate of radiation (j/lu) is for your area as the light control must be to the specific levels outlined and not just half of what is prevailing locally. In some places half of the local light would be too much while in others especially during the winter months it would be too little.

Under New Zealand conditions the first and last three hours of unshielded sunlight each day measure up to 6000 f/c which gives an average of about 4,500 ft/c. These times also coincide with the periods of the day when temperatures are usually within the range of 15°C to 20°C and in the mornings, humidity levels tend to be high (70% to 95%). It is therefore an advantage to arrange the structure so that for as many hours as possible of these two periods of each day, the sun is shining unshielded on the cuttings. This can be achieved by having a high level roof of shade cloth of 48% and leaving the sides open. The structure should run north/south and be no more than three times wider than it is high. This arrangement will give full sun for the first and last three hours each day and light levels of around 5000 to 6000 f/c for the middle of the day and should achieve the target of a maximum of 60,000 and an absolute minimum of 30,000 j/lu. In areas where light intensity and daily aggregates vary greatly from those in New Zealand or it is intended to propagate grey-leaved varieties the percentage grade of shade cloth may have to be varied and in very high light areas the side walls may have to be shielded.

What has been noted in the foregoing was identified by observation of light, temperature and humidity readings only and has not been done under controlled research conditions. The conclusions were reached before observations were made on plant sensitivity to light in the natural veld in South Africa. These veld observations support the earlier conclusions reached in nursery and field production phases. It is of interest to note that the light level of between 4000 and 6000 f/c that had been identified as being an acceptable level for cuttings and young seedlings is close to the average of the dappled sunlight recorded in one to four year old Proteaceae stands in South Africa on a sunny day.

2:4 WATER

The quality of the water that is available will influence what varieties and percentages of those varieties that will root. For real success it must be good quality, free from excessive salts and a stable low pH., preferably not above 5 or 5.5 maximum. PH. levels above this will limit the varieties that can be successfully rooted. While the cuttings are rooting they will be exposed to the water for a long period, and should it be incompatible to their needs, great difficulty can be experienced in getting them to survive and root. Water can be treated but such systems are expensive and usually need regular maintenance to keep them fully operational.

Before large scale propagation is attempted the quality of the water should be monitored for a period of several months. Water that is drawn from a well or stream may vary in pH. levels with the seasons, usually rising during long dry spells. Water from a stream is likely to carry unwanted fungal spoors such as Phytophthora cinnamomi and Rhizoctonia. If the stream runs through farmland it is probable that there will be sharp rises in phosphate and nitrogen levels at certain periods, especially following rain if phosphate has recently been applied to pastures or crops in the catchment area. Where high levels of carbon dioxide, calcium, iron etc. are present they will form as sediments which not only clog up sprinklers but also cause deposits to form on the leaves of the cuttings which then grow algae causing fungal problems.

Having experienced the difference between very bad and good water, I would recommend that every endeavour is made to have adequate supplies of good quality water available before attempting large scale vegetative propagation.

2:5 WATER CONTROL

The provision and control of a reliable water supply in the propagation area is another important element to success and is the only means of preventing the dehydration of the cuttings. In an outdoor situation, besides the water which is provided by natural rainfall, there are two ways that it can be provided. These are by overhead application (either by automated sprinkler control or by hand) or by a capillary system. Both have their uses and application under certain conditions and for particular reasons in vegetative propagation.

2:6 AUTOMATED OVERHEAD WATERING

An automated sprinkler system is one that has been designed to keep an intermittent supply of water on an area. With Proteaceae this does not necessarily mean a film of water on the leaves at all times but rather a supply matched to dehydration rates.

Types of automatic controllers vary from simple type sensors to an electronic or timing device. Whatever is used it should be able to "read" the days conditions and keep a regular supply of water available without drowning the cuttings and medium. In this, timing devices are somewhat inadequate as they are unable to read the current days conditions and are therefore reliant on how the operator sets the on/off frequency of watering. This is a problem if the day starts out hot and fine and it turns cold and wet or vice versa. Such devices are cheap and give little trouble, which can be an advantage over more sophisticated systems which can be temperamental.

With the electronic leaf system there are several methods used by different manufacturers. These systems can give problems with a build up on the sensors with minerals from the water or algae growths but are accurate and reliable if well maintained.

Another device is one that operates on a system of water evaporating off a mesh on a swing balance arm. As the water evaporates off the gauze mesh, a counterweight overcomes the inertia of the swing arm which trips a mercury switch. This activates a solenoid which turns on the water supply to the sprinklers thus wetting the mesh again. When the gauze is wet again its weight overcomes the inertia of the counterweight which trips the mercury switch to the off position thereby turning off the solenoid controlling the water to the sprinklers. It is a simple mechanism and can be made up in less than an hour in a workshop. Such a device is illustrated in figure 1. This is a very accurate means of water control but has one disadvantage in that it is sensitive to blustery winds and is not satisfactory under such conditions.

2:7 SPRINKLER AND SPRAY HEADS

The choice of these may be governed by the water pressure available and the amount of air movement within the propagation area. The use of misting heads, either fixed jet or revolving head have a serious drawback when being used outdoors. The fine mist produced can be blown off the beds thus letting the cuttings dry out along one side. The provision of wind baffles to control this problem usually results in too little air movement with resulting fungal problems.

In an outdoors situation the best and most reliable results will be obtained by using revolving head sprinklers which produce quite large droplets. Air movement has little effect on this droplet size and they will adequately wet the leaf surface rather than cause a fuzz of moisture on the tips of the cuttings as misting nozzles do. Provided the rooting medium has the necessary texture to drain

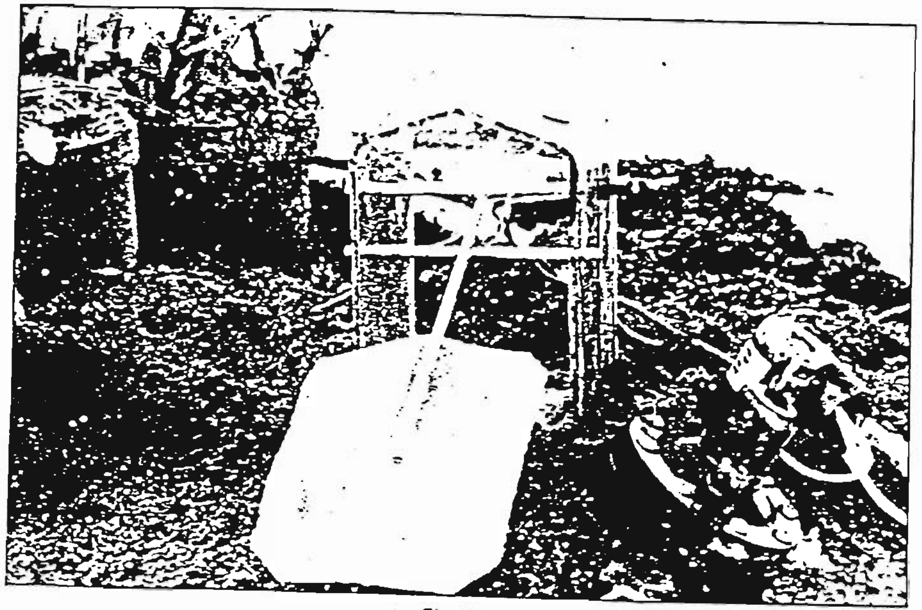


Fig. 1

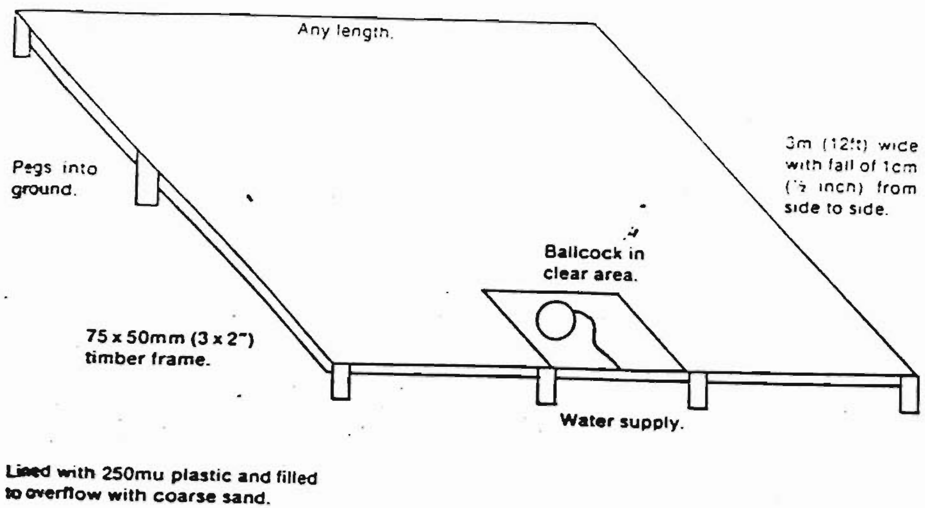


Fig. 2

properly, and attention is paid to providing the correct light levels in the propagation area for the varieties being rooted, large droplets and relatively high quantities of water will not harm cuttings from the time they are set until they start rooting. When they reach that point it will and at that time the amount and frequency of watering must be reduced preparatory to hardening-off.

2:8 STATIC LEVEL CAPILLARY BEDS

A static level capillary bed consists of a shallow "tank", 7.5cm. (3") deep. It may be made from heavy grade plastic sheet within a timber frame or more permanently from concrete. It may be of any dimension but it will be found that in very drying conditions, plants that are more than 6 metres (20ft.) from the reservoir may dry out. The "tank" is filled with coarse grade sand and has a small clear area to act as a reservoir. In this reservoir a ball-cock is installed and set to give a water level about 50mm. (1/4") below the surface of the bed. Figure 2 illustrates the basic design.

The principle is to provide a source of water below the plant which creates an atmosphere where the plant may collect some of its moisture requirements from the air as well as having a constant source of water that is drawn through to its root area by capillary action from the sun's warmth.

Such a system is very useful where a propagation or holding area is not constantly attended as mediums used in propagation are so free draining that they can dry out during half a hot windy day if they are not watered in some way. This system maintains their moisture requirements at a safe level.

The use of capillary beds is an excellent way of hardening off rooted cuttings or can be used in the latter stages of the rooting phase following root initiation under automatic watering. In use, the trays of tubes or medium with cuttings in them are placed on the bed. The bed may have overhead removable layers of shade-cloth which can be put on or removed as necessary. Once set up with the water and light adjusted to the correct levels, rooted cuttings or even those that have just initiated roots can be left unattended for weeks without attention.

It is possible to propagate most species of Proteaceae on a capillary bed without the use of an automated watering area if the operator is skilled in the use of shade and the timing of the operation. See section 6:6 for further information.

2:9 AIR MOVEMENT

A certain amount of air movement in the propagation area is an absolute necessity. Without it there will be problems with fungal infection and possible overheating of the cuttings during the rooting process. Some of these fungi can be serious and can cause the total loss of all material in a propagation area or a carry-through effect to later stages of the plant's life. The provision of gentle air movement especially near ground level will do much to alleviate the problem of fungal infection and keep the leaf surface temperature down.

By comparison too much wind will cause problems particularly with its effect of dehydrating cuttings either from the excessive movement of air around the leaves of the cuttings or through blowing the overhead watering away from the beds. Where wind is a problem some screening should be used especially on the windward side. Care should be taken that the beds are not shaded by the wind screens.

To provide air movement at or near ground level, especially in areas where there is little wind, the screening should stop about 100cm (4") from ground level so that it creates a draft. This small provision will prevent many problems. Some seasonal variations of control may have to be practised.

2:10 BOTTOM HEAT

The question of whether you are going to use bottom heat or not has to be considered. There are divided thoughts on this with some propagators using it and some not. In my early experiences with Proteaceae I eventually traced many problems to the use of bottom heat but this was in the days before we had such efficient chemicals for the control of soil borne fungi. There is no doubt that by providing bottom heat you are creating perfect conditions for the incidence of Phytophthora, Rhizoctonia, and Fusarium with moisture and temperatures at danger levels. The use of chemicals (Ridomil, Alliette, Terrazole, Ronilan) control these fungi but will not cure them and there is still a risk of infection with the conditions that bottom heat creates. These problems can remain latent in the plant for a considerable time and be carried over to the growing on phase or even in some instances to the final planting site in field or garden.

My preference is to use bottom heat on anything that is very slow at rooting and then for not more than two or three weeks. I never use it from when the cuttings are first set as research has shown that this is one of the reasons for heavy callousing and non-rooting of some varieties particularly in Proteas. This is the cuttings way of protecting itself from the heat. We do not like putting a freshly cut finger into hot water and neither does a cutting like a lot of heat on its fresh cuts.

The most efficient, economic and safe use of bottom heat is to set the cuttings and then stand them in a misting area without heat. After a period of three weeks for Leucospermums, Leucadendrons, Telopea and five to seven weeks for Proteas, place them on bottom heat. The results can be quite spectacular with roots often forming within two to three days on many varieties. A period of seven to ten days on heat is usually sufficient to give near 100% rooting. They should then be hardened off prior to tubing up. Never tube up directly off a heated bed as losses can be high.

Bottom heat may be provided by the use of heated water pipes under the benches or by electrical means. A new development in bottom heat is the carbon mat which is laid on the bench and plugged into an electrical outlet. These heat the whole area evenly whereas the old method of having wires running under the bench gives hot and cooler areas.

Where bottom heat is used it should be set at an absolute maximum of 25°C. Above this temperature will harm almost all varieties. Good results will be obtained with most varieties if temperatures are maintained around 22°C at the base of the cuttings. Care must be taken when heat is being used as the amount of water being applied by an automatic overhead watering system may not be sufficient to compensate for the extra evaporation caused by the added heat in the medium. Occasional hand watering may be needed to compensate for this moisture loss.

2:11 THE PROPAGATION AREA — SUMMARY

The propagation area can be anything from a simple screened frame to a fully automated glass-house complex. Proteaceae plants generally do not like environments created in a glass-house unless there is provision that encourages constant air movement. Even if they do survive and root satisfactorily they often give problems during establishment or even up to two years later when they have been rooted under these conditions particularly when excessive bottom heat has been used.

My choice is for a structure sited where there is some air movement at all times but away from the full force of the prevailing wind. It should run north/south and be in full sun, not influenced by large buildings or trees.

It should be of a dimension that is adequate without crowding and preferably not wider than three times its height. The roof should be covered with shade cloth of a grade that will give the correct light rating for the varieties being propagated. The sides do not usually need shade cloth except to control excessive air movement. The sun end may need shade cloth to control autumn-spring sunlight.

The windward side should have a solid wall of sufficient height to control the wind but should stop 100cm from ground level to provide air movement at ground level, it must not shade the area where cuttings have been set to root.

Within the propagation area there should be an automated sprinkler system engineered to keep a constant level of water available to the cuttings matched to dehydration rates. Sprinklers should overlap each other and perimeter margins by 30%. The provision of a capillary bed within the area will facilitate hardening off of cuttings but is not an absolute necessity.

A bed to supply controlled bottom heat can be provided but is not absolutely necessary.

High levels of success can be achieved with lesser facilities. In vegetative propagation good facilities are not a substitute for the skills of the operator but they can make life easier.

2:12 AUXILIARY EQUIPMENT

Besides the facilities incorporated within the propagation area there are certain other items needed to carry out vegetative propagation. These are simple

Fig. 3

Fig. 4

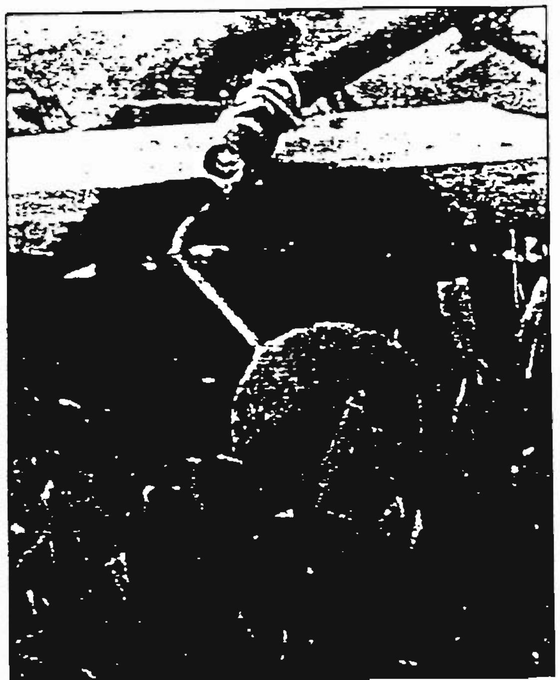


Fig. 5

Fig. 6

things that are found in most places where propagation is being carried out and include the following.

Propagating trays — needed to set cuttings in. They may be plastic or wood. If they are wood and have been treated with preservative make sure that they are well weathered. Leaching of wood preservative into the rooting medium will be fatal to all cuttings that come in contact with it. Polystyrene trays can be made by cutting down the trays used in the stone fruit industry. These trays are not suitable for use on heated beds as the polystyrene will insulate the cuttings from the heat source making the heat transfer inefficient. Plastic trays with a wide mesh bottom and used with a filter type liner give excellent results [ref. 5:4 for further information].

Propagating tubes — needed to set some varieties of cuttings in. It has been found that the 5cm dia. x 10cm deep is the most effective and economic size to use. The 5cm square liner does not give such good results.

Plant pots — needed to set some cuttings in. The 10cm 400 cc square pot has been found to be the most effective size. Avoid very deep pots as these give poor results compared to shallow ones.

Knives, secateurs, clippers should be kept clean and sharp. The final cut at the base of a cutting should always be made with a sharp knife as secateurs and clippers tend to bruise the plant tissue.

2:13 EXPENDABLE MATERIALS

In carrying out vegetative propagation there are a number of materials needed which are expendable. All are an integral part of the operation and will of necessity vary from place to place depending on availability. The following is an outline of what is needed, the possible sources and alternatives.

* *2:14 ROOTING MEDIUMS* *

The mediums in which cuttings are set can and do vary from country to country and even within countries. To some extent this is influenced by the materials that are available locally.

The composition and texture of the medium influences the rooting process and type of root produced. It is normal for coarse-grained mediums to cause the cuttings to produce strong but very brittle roots which break off easily (figure 3. Fine-grained mediums produce a more fibrous type but often results in a drop in percentages rooted (figure 4). An alert and successful propagator will determine which materials and which ratios give the best result for their particular conditions, type of material (soft or semi-hardwood), variety being propagated and season of the year.

There is one thing that any rooting mediums must have, particularly if being used in conjunction with automatic watering systems, and that is that it MUST BE FREE DRAINING. If it is not then there is little chance of real success. To test any medium, especially if it is to be used under automatic watering, it must be of a texture that it is impossible to flood it by hosing it down with the flow of water from a 12mm (1/2 inch) hose at 70 psi. If water is visible on the surface five seconds after the hose is removed, the medium is not satisfactory and more open grained material will have to be added.

The principal materials that will be used are:-

Sand, must be coarse, preferably with rounded grains as these stay "open" where as angular grains pack down hard.

Peat, must be a fibrous grade and not break down to a dust.

Pumice, must be coarse-grained. Some pumices carry high levels of phosphate and this should be checked out as it can cause serious problems.

Perlite, is a heat sterilized pumice. Use 400 industrial grade and check for phosphate as for pumice.

Scoria, lava, cinder, are volcanic materials all with similar characteristics. They are heavy forms of pumice and can be used instead of pumice or perlite.

Polystyrene regrind, waste polystyrene ground into angular particles of about 3mm. average diameter.

Other materials, can be used provided they are free draining and free of high levels of phosphate, pH. etc.

A typical medium for rooting Proteas and Leucodendrons would be 50/50 coarse river sand and perlite or pumice. To this may be added a further 10 to 15 parts of peat especially if water pH is above 5.5 or the variety is known to be very slow to root. Sand can vary in texture and grain size, and care must be taken that it is not derived from a limestone rock source and that it is truly coarse and does not pack down hard over a period of time when being constantly watered. If this does happen you will have to increase the perlite/pumice or use some other types of material such as scoria or decomposed granite. I do not favour adding peat above 15% maximum, for although it will "open up" a mix there is documented evidence showing that peat is responsible for many of the problems associated with Proteaceae plants in later life. This is dealt with in detail in the growing on section [8:5 to 8:7] and in Appendix One.

For Leucospermums I use 85 parts reground polystyrene and 15 parts peat. I have used 100% polystyrene with good ultimate results that have been a little slower than with the 15% peat but have experienced problems with the wind blowing the polystyrene out of the trays, leaving the cuttings in mid-air. With some clones of Leucospermums the 85/15 mix does tend to produce an initial course type of root that may break off easily. If this is a problem the mix can be changed to 65 polystyrene, 25 sand and 10 peat, which will produce more fibrous type of root but will usually result in a drop in percentage.

If polystyrene regrind is not available, use sand 30, perlite/pumice 60 and peat 10. This will give good results with strong roots but this mix can suffer from over watering under an automatic system. For this reason cuttings should be removed from the watered area as soon as roots initiate and be placed on a capillary bed to finish their rooting phase. (Figure 5)

If you are fortunate enough to have access to the river run pumice sands that are available in the north island of New Zealand, this can be used "as is" to root some varieties in. This is the near perfect material to propagate in with its porous texture and rounded grain formation which prevents it from packing down hard. For really good rooting and root type in all varieties, it gives best results with 10 to 15 % peat added. It is impossible to "flood" this material.

Whatever the propagator decides to use or is forced to use by the availability of local materials, remember that the medium must be free draining, preferably be a stable pH. of 5.0 to 5.5, must be capable of holding the cutting reasonable firmly (a cutting waving around in the breeze will never root), and it must be "open" enough to supply oxygen to the base of the cutting.

If you are unskilled in propagation or for any reason changing from your usual medium, it is advisable to have a small scale trial with a range of materials and combinations to test the medium before large scale commitment. If a medium is going to be unsuitable or toxic to the cuttings it will usually show within ten days but it will take several weeks/months to test for rooting performance.

One further point is to always make sure that none of the materials or containers being used are contaminated with harmful chemicals or bacteria. Sand collected from the sea coast or a tidal river may contain harmful levels of salt. This can be leached out with heavy flushing of water and harmful bacteria may be controlled by sterilizing. Chemical contamination such as herbicides must be avoided at all costs as these materials in a propagating mix will usually result in a total loss of cuttings.

It is inadvisable to use a medium a second time round for propagation unless it is sterilized by heat. There are enough problems without deliberately introducing a re-run of a previous batch's accumulated problems.

2:15 HORMONE AND ITS USE

It is normal practice to treat cuttings with a root promoting hormone as in most cases this helps with percentages that root and reduces the time it takes them to root. The hormone most commonly used is one named Indol -3 -ylbutyric acid (IBA) which may be applied either in powder form mixed with talc, or in a liquid form. Concentrations used vary somewhat between propagators and range from 1000 ppm to 4000 ppm. although I have heard of some propagators using it at 6,000 ppm.

There is a close relationship in the effects that this hormone has on the cuttings and the rate of transpiration of the cuttings at the time of treatment. If a cutting is transpiring rapidly when it is dipped into a solution of this hormone it can get a fatal overdose. It is also a fact that not all species and varieties have the same tolerances to either the hormone or the levels of alcohol sometimes used to dissolve it. From early rates of 3000 and 4000 ppm, I have now reduced the rate to 1500 ppm and in some cases 1,000 ppm. for the softer material and 2000 ppm. for more mature material rising to a maximum of 2,500 ppm. for

Fig. 7

Fig. 8

very mature material in the winter months. These strengths are a little below optimum for some varieties but are safe.

A check can be made which will indicate whether a certain strength is satisfactory for a particular batch of cuttings. To do this take a few cuttings, prepare them and treat them with hormone of a pre-determined strength. Set the cuttings and place under mist. After five to seven days inspect the bases of the cuttings. If they have gone black the hormone was too strong. If they are showing tiny whitish spots at the nodes where leaves were removed or if the lower 3cm of the stem has swelled by about 25% in diameter, the strength has been correct (figure 6). If you can detect no changes at all it was too weak. In the case of very mature material a strength that is too strong will cause callousing at the cambial layer right at the base of the cutting and no swelling of the stem diameter (figure 7). This will usually show quite distinctly by the fourteenth day and if it does the cuttings may never root. The correct strength causes the whitish dimples to show and the stem to swell with preferably little or no callousing. Cuttings don't have to callus to root (figure 8).

Early uses of this hormone at 3000 and 4000 ppm resulted in tissue burn to cuttings which either destroyed them or retarded their rooting phase for a long time. Of those that did eventually root, some were either blind in their growth buds or went through a further long period of dormancy. This effect has been noted on a number of occasions when near toxic strengths have been used on varieties and species other than Proteaceae. The problem is very common in Rhododendrons.

IBA is usually dissolved in alcohol which is then added to the water. Do not pour the water into the alcohol/IBA solution as it will separate out the chemical. To mix a solution to the strength of 2000 ppm take 5 mgm concentrate crystals and dissolve in 500mls of alcohol. Add this to 2000mls of clean water and keep in a refrigerator. Never expose it to sunlight as bright light will destroy the active ingredients.

I.B.A. can be applied in a dry powder form which is available in three different strengths. Those that are suitable for Proteaceae are the ones recommended for the semi-hardwood and hardwood material. Powders generally do not give such consistent results as the same strengths in liquid form, but can be used with some success especially on the semi-hardwood material. In some varieties for reasons not known, powder can work better than the liquid. This has been noted several times with Pr. grandiceps.

Another hormone which can be used is Napthalene acetic acid (NAA). This is applied and used in the same manner as the IBA and gives similar results. Some varieties should be treated with lower strengths especially the varieties with grey and hairy leaves.

If available I strongly recommend the use of laboratory prepared concentrate solutions of IBA or NAA which can then be diluted to the required strength. The best of these are not just a mix of alcohol/water and the active chemical but contain other ingredients to give better penetration and give some protection against fungi. These formulas give excellent and consistent results.

2:16 FUNGICIDES

Within the propagation area it is necessary to maintain a programme of treatment to control fungal infection [ref.6:4]. Some of these problems could be water-borne, some air-borne and others may be introduced on cutting material. The control of most fungal problems during this phase can be achieved with Captan and occasional use of Ronilan or similar chemicals, provided they are applied regularly before problems occur. New chemicals should be monitored for side effects. As an initial treatment I always treat all freshly set cuttings immediately after handling by drenching them with a mix of 1ml Terrazole and 2mgms. Captan per lt. of water. Use 500mls per tray of 100 cuttings. For more detailed information on the uses of fungicides during this phase see 8:16 and Section 9 for full outline of fungi control.

SECTION THREE

Production of Cutting Material

3:1 OVERVIEW

To be able to consistently and economically produce good quality plants by vegetative propagation, it is necessary to have a supply of healthy clean and fresh cutting material. The health, source and type of cutting material that you have available to use will influence the end results and will often be the difference between success or failure. If at all possible it should only be collected from plants that have a clean bill of health and of a known performance rating. Failure to observe these fundamental criteria will result in some disappointing results in poor rooting, and later in poor flower forms, a point that is particularly valid if stocks are being increased for cut flower production. [Refer to Section 15 for information on clonal selection].

The success or failure of propagating Proteaceae begins well before material is harvested from the stock plant. Every effort should be made to make sure that the material you will eventually use is as healthy and as near to the correct condition and type as you can make it.

Ideally plants should be of an age that are past the first flush of juvenile growth and before the decline of old age. For most Proteas and Leucospermums this will be in the three to seven year age bracket and Leucodendrons in their second to fourth years. There are of course exceptions to all of these and I still regularly take cuttings from a Leucospermum which is now 30 years old and some Protea neriifolia that are 25 years old.

To get the best from stock plants, they need regular tending throughout the year to keep insect and fungal infection under control as problems associated with these are carried through to the propagating phase. There is some evidence to suggest that repeated use of some insecticides, fungicides and wetting agents may inhibit the rooting of some varieties. Where propagators notice a falling off of percentages rooting they should check this out. [Ref. 9:2].

3:2 SEASONAL CARE OF STOCK PLANTS

Stock plants well prepared and cared for can be made to produce many times the amount and a better type of material than those not under control. This may be achieved by manipulating the plant in various ways and is particularly productive with Proteas and to some extent with Leucospermums. Preparation of the plants begins just prior to or at the start of spring growth or just before a

midsummer growth if the particular variety being handled makes one in your climate.

Initial procedures consist of removing all internal weak growths to give better air movement and removing flower buds or the tips of the strong terminals from the last flush of growths. This promotes lateral growths with a resulting increase of from six to eight times the number of cuttings available for harvest later (figure 9). Besides this, lateral growths produced in the spring growth flush, are better material to propagate from than terminals as they invariably give better percentages rooted and usually a better root type. Laterals that are produced after pinching out the tips in midsummer to promote autumn growths need some special procedures during preparation and setting. This is outlined in section [5:6].

The timing of the removal of terminals in the spring is important. Protea stock plants should be processed in this manner just as the terminals start elongating prior to the spring growth flush, while Leucospermums are better done after growth has really started. If Proteas are pinched out too early (midwinter) it can result in growth starting from the lateral buds too early and if it is checked by adverse weather such as late frosts it can become dormant and may fail to continue with the flush of growth. Leucadendrons generally produce better propagating material if they are allowed to have their spring flush and then have 30% of the length of the strong terminal growths removed. This will result in a spate of secondary growth (figure 10). This is particularly so with the strong growing forms such as L. laureolum, gandogeri, cv. 'Safari Sunset', etc. Most of the spray type leucadendrons need no preparation to produce satisfactory propagating material (figure 11).

A recent trend in the production of Proteaceae is to harvest and use cutting material from plants that are in the nursery production beds rather than to have stock plants to harvest material from. There is no doubt that cuttings harvested from these plants, which are under two years old, do root easily particularly Leucadendrons. There is however the fact to consider that by continually using this type of material from each successive generation, that the form of some varieties does change from being predominantly of a strong upright form of plant to being prostrate to semi prostrate.

The type of material and where it comes from the plant has a significant bearing on the resulting growth form of the progeny. This syndrome is well known in the propagation of some conifers as well as in Rhododendrons and Camellias where if a cutting is made from a low pendant branch from a plant that is predominantly of an upright stance, the resulting plant will be low growing with a pendulous growth habit (figure 12). This same result has been observed in Proteaceae with Leucadendrons being the most affected but all species will show some effects. As the practice progresses from one generation to another we can expect to see more varieties showing pendulous growth form when they should be straight and upright (figure 13). [Ref. 17:4 for further information.] If plants are being produced for future cut flower production it is very

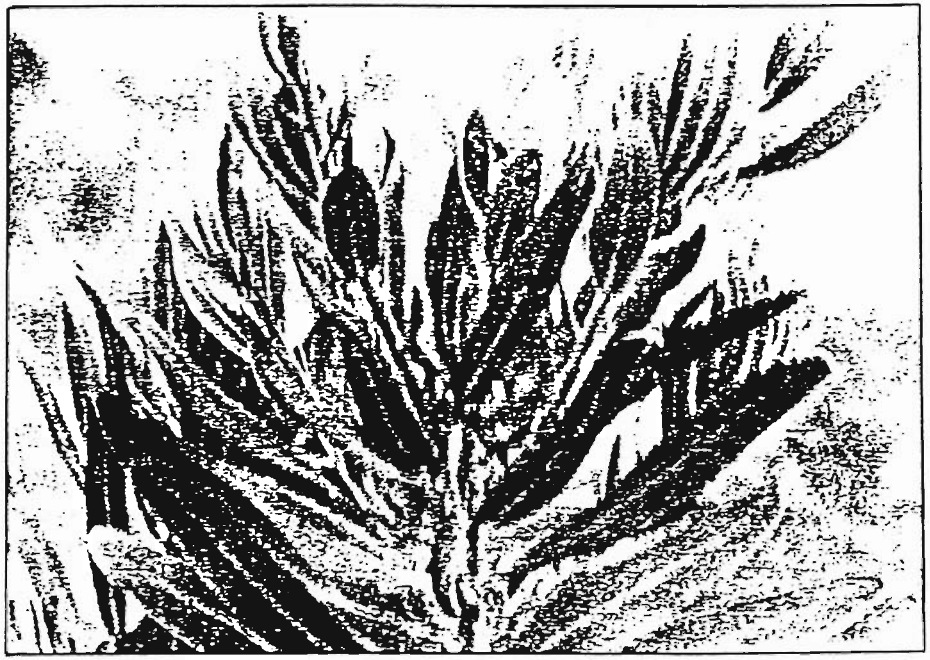


Fig. 9

Fig. 10

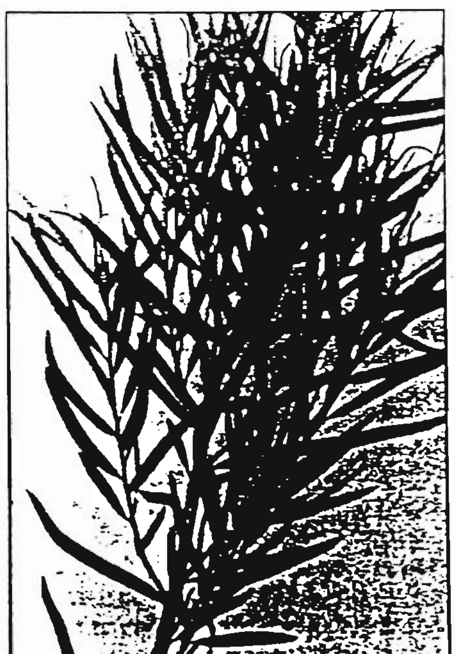


Fig. 11

important to retain and encourage the strong upright characteristics of selected clones. Propagators should pay attention to selecting only material that will produce strong upright plants.

3:3 PRE-HARVEST PLANT PREPARATION

In the period just prior to harvesting material, you should thoroughly spray all stock plants to make sure they are as clean and healthy as possible. For insect control use a good broad spectrum systemic insecticide and miticide and for fungal control two fungicides, one to control botrytis and one to control the pythium types. [Ref. 6:4; 9:13 to 9:18 & 9:25 to 9:27 for information on chemicals]. Application of chemicals should be carried out not more than 15 days ahead and preferably not closer than three days before harvest for fungicides and seven days for insecticides. The chemicals used should be known NOT to inhibit rooting or to cause foliage burn. For this reason never use a previously untried chemical just before harvesting cuttings.

Every effort should be made to ensure that the plant is fully turgid before harvesting cuttings from it. Plants may be in a state of stress from a number of causes with the principal ones being dehydration from frost damage, hot dry winds or a lack of adequate soil moisture. For optimum results, plants should have access to water if they are sited in areas that experience dry weather conditions at the time when material will be harvested (late summer/autumn).

When plants are under severe stress from a physical moisture shortage within the plant tissue they may go into a state of inertia as a means of protecting themselves from permanent damage [ref. 12:2]. Dehydration is very difficult to detect in older field grown plants and may only show as a slight paling and loss of luster in the leaves. When plants are dehydrated to this extent, it will take three days following the application of water or after the frosts or dry winds cease, to completely reverse the state of inertia and for them to become fully turgid again. If the dehydration was caused through frost or dry winds, the application of extra water to soils that already have adequate levels will have no effect at all on the plants' condition. Dehydration from these causes is through the action of frost/wind on the leaf area and not because of any lack of adequate soil moisture. Only a time factor which will correct the problem. When plants are dehydrated it is best not to harvest material until it has been corrected. Material collected from plants that are under a high degree of stress has a problem in that it continues to dehydrate faster than it can take up water, even if it is under mist.

Undetected dehydration of field grown plants is the prime reason for the blackening of leaves and rapid break down of flowers and or cuttings following harvest [ref. Section 14 for further information on this subject].

3:4 SEASONAL MANIPULATION

It is not always possible to propagate when you want to because of the seasonal growth patterns of the stock plants. This is especially so with young plants in

Fig. 12

Fig. 13

Fig. 14.

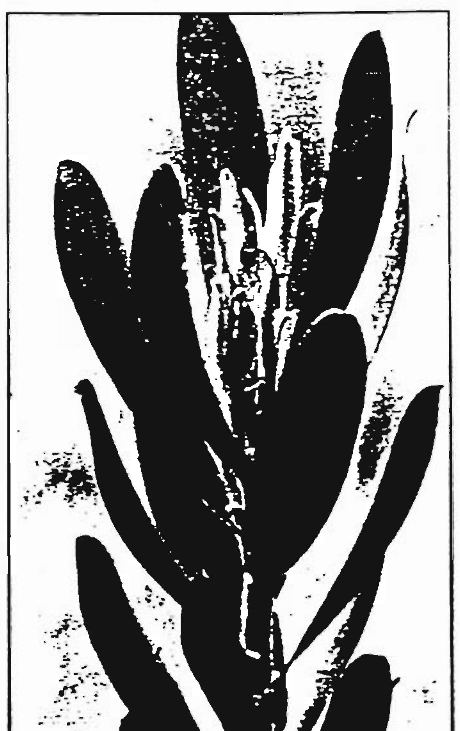


Fig. 15

what I term their teen-age stage of growth (two to three years). It has been found that the removal of the terminal growth tip of the cutting material a week or so before harvest not only makes it possible to propagate out of season but it can also greatly improve percentages that do root and the resulting plants commence growth much sooner. In some cases it also breaks the long term dormancy problem associated with some varieties (Pr. magnifica & grandiceps etc.) which often go through this dormant phase following a prolonged period in the propagation area. Some varieties can take up to six months to come into vegetative growth following rooting without this treatment.

This technique is only in the early stages of investigation and more work is needed to get consistent results. The key seems to lie in the time lapse from the removal of the terminal to harvest of the cutting which needs to be related to the maturity of the material on the stock plant, the prevailing temperatures and the season of the year. Tests carried out in the autumn indicate a time lapse from tip removal to harvest of 10 to 14 days for very soft material and 5 to 7 days for more mature wood. In winter this could be doubled.

When the tips are removed it stimulates the development of the top three or four lateral buds (figure 14). The material should be harvested and set before these develop into a leafy type growth (figure 15). If this should happen the cuttings often fail to root.

3:5 MANIPULATION OF PROTEA CYNAROIDES

When this variety is handled in the same manner as other varieties and the cutting material is taken from the current years growths, most variants yield wood that is very large in diameter and often in small numbers. These large stems are not good material to propagate from and often give poor percentages and sparse root formation on those that do root.

It is possible to produce up to fifty times the number of cuttings per stock plant of a type that will give much higher percentages rooted and have a better root formation. To do this you must be prepared to forfeit any chance of it producing flowers for at least two years. Where a superior clone has been identified and a large number of plants are required as quickly as possible the forfeiting of the flowers is a small price to pay for the extra stock.

The method involves sawing all stems of the plant off just above the level of the majority of the latent growth buds. On a plant that is four or more years old this is usually about 20 to 30cm. above ground level. A close inspection of the stems will show that there are a large number of small indentations stretching from the ground to about that height (figure 16). These are latent growth buds which in nature following a fire, would come into growth. The act of sawing the whole plant off (figure 17) stimulates almost all of these latent growth eyes to come into growth simultaneously (figure 18) with the result that a few weeks later it is possible to harvest up to a hundred or more good cuttings from one plant and sometimes a further crop a month or two later. Because they are from a lignotuber it is quite safe to harvest them when they are still in a juvenile stage

Fig. 16

Fig. 17

Fig. 18

Fig. 19

[ref.5:8]. If they are left to full maturity they become elongated and somewhat weak owing to the excessive crowding on the stumps of the plant. For best results it is best to harvest them progressively as they start to mature and before they become elongated. This also gives the plant less shock than to totally remove all foliage at the one time. If preparation is carried out in the spring it is possible to harvest these cuttings by soon after midsummer. These cuttings will usually root within eight weeks and often come into growth again before winter. If they do it is possible to remove the new terminal tips off these plants and set them to root. In this way it is possible to produce between two and three hundred plants from one stock plant in about two years. It is probable that this method could be used on any lignotuber and it is known that it is successful on Telopea.

3:6 HARVESTING "IN THE WILD"

It is sometimes necessary to harvest material from plants that have had no pre-harvest preparation. These plants can often be in poor health and condition. When this is the case it is necessary to follow certain procedures to assure the best possible results. When harvesting, care should be taken to select material of the current seasons growths that are clear of fungal infection. In many instances it will be necessary to harvest terminal growths especially from young plants. If the plants are of an age that have commenced flowering, it should be possible to select the lateral by-passes that have grown away from behind the old flower heads (figure 19). If there is fungi present it must be trimmed off immediately following harvest before it is packed into containers to minimize the chances of it spreading further.

Material gathered under these conditions usually has little uniformity in maturity or type and unless it goes through a post harvest process, results in rooting will be inconsistent. The best method of handling this material is by the wrap and refrigerate method. [ref. 4:5]. The wrapping process can be carried out immediately following harvest and if no refrigeration is available at that time, the material is quite safe held in this manner for up to two days pending refrigeration provided it can be kept below 28°C (80°F.). If it is held for two days under such conditions and no refrigeration is then available, it may then be treated as outlined for the delayed propagation technique [ref. 4:4] for two or three days before final preparation and setting. Under no circumstances should it ever be kept in a vehicle that is standing in the sun as temperatures can rise to 35°C. even in the winter.

Material which is of a "mixed bag" in type and condition such as this is best held for three to five days at 3°C. to 4°C. (35 to 38°F.) before it is processed and set to root. Where there is a big variation in the maturity it should be sorted and the over-mature material then treated at the higher rates of hormone [ref.2:15].

3:7 JUDGING MATURITY AND HARVESTING CUTTINGS — GENERAL

The maturity of the material at the time of harvesting for propagation is more

Fig. 20

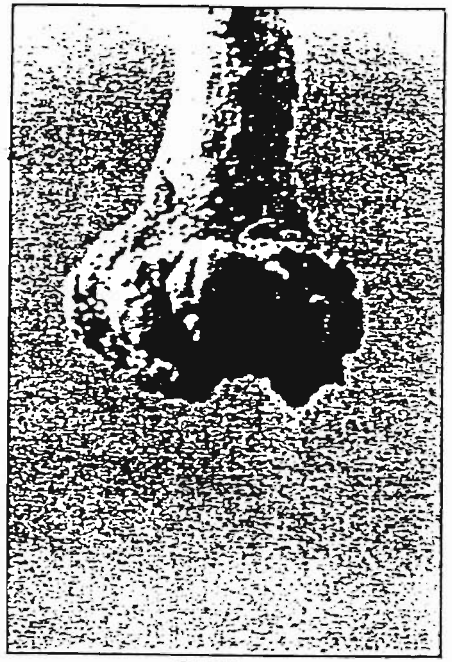


Fig. 21

Fig. 22

Fig. 23

important than the time of year though seasons do influence the rate of development and maturity. Bearing this in mind, the successful propagator will observe, test and assess the maturity of the cuttings rather than watch the date on the calendar. In New Zealand a variation of a month from year to year in many varieties development to the correct stage of maturity is quite common. To a large degree this is governed by weather patterns principally rainfall and temperature variations particularly those prevailing through the period leading up to and during the spring growth flush. In continental climatic areas, growth and maturity patterns tend to be more evenly regulated.

Experienced propagators have their own methods of telling when material is ready to process. This varies from just touching it with their finger and thumb, twisting it, cutting it with a sharp knife or just clasping it in their hand and gazing up into the heavens. These persons are in fact all doing the same thing in that they are gauging the condition of the material to suit their particular method of propagation.

There appears to be little difference between propagators in the condition of material they select for a given method of propagation, but there is a difference in the material used between species and even varieties within species. Herein lies the secret of being successful every time, or only sometimes. If you are a very observant person, success will come with experience, if you aren't you will have to become more so to be really successful. With Proteaceae especially Proteas and some Leucospermums it is the little things you do or the special conditions you provide for a particular clone that makes the difference to the end result.

All Proteaceae have in common the fact that their new growths are slightly oval at the base of the stem where it is attached to and has grown away from the older wood (figure 20). As it matures it gradually becomes rounded the same as any other branch material. While the base of the material remains oval, the material is too soft and should be left to mature until it has become rounded and firm.

Cuttings harvested too soon will do one of two things: they will either sit in the medium for a long period as they continue to mature and they will then root, or, they may just sit there forever and do nothing. I have seen cuttings that were too soft when set, sit for two and a half years and never change. There is no advantage in using material before it is ready and there are higher than normal risks of fungal infection and dehydration to this soft material.

Harvesting the cuttings in the early morning, which is usually the time of day when the plants are under the least stress, will go a long way in alleviating problems associated with dehydrated cutting material. Under extreme conditions this may not be enough without taking further steps to condition the parent plant prior to harvest. I have seen whole batches of cuttings die within hours of setting when they have been harvested from a dehydrated plant. This is one of the main reasons for failure when propagation is carried out when temperatures are high and humidity is low or when material is under stress from

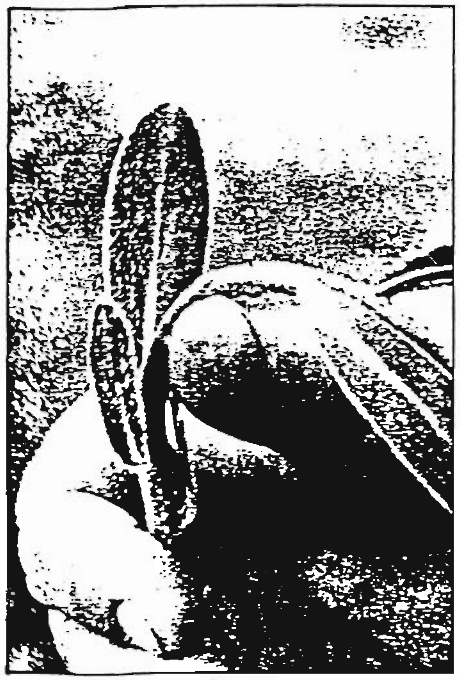


Fig. 24

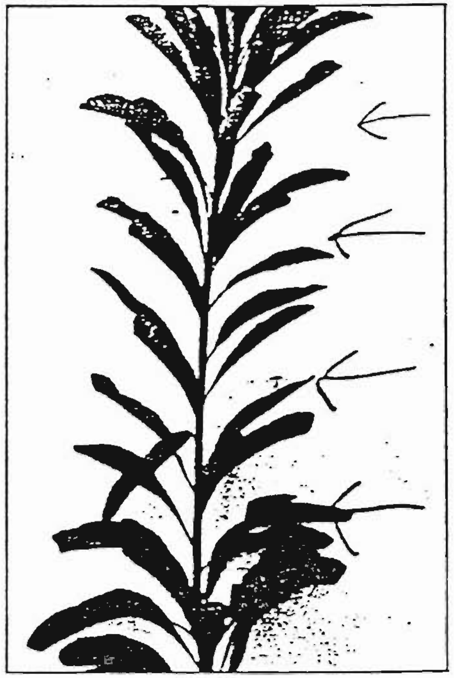


Fig. 25

other causes such as insect infestation. When cuttings are in a dehydrated condition they will not only take up more hormone than is good for them, but they will also go on transpiring faster than they can take in moisture.

As each species has its own particular peculiarities in when, how and what should be harvested, (which may vary from year to year), the following guidelines are given to judging the maturity and assessing which are the best seasons for harvesting and processing. Generally if the condition of the material is correct the season is of little consequence unless it is in the full flush of spring.

3:8 PROTEAS

In every variety that I have had experience with, better results have been obtained by using material that is a little old rather than too young. This is particularly so in varieties with the larger diameter stems, P. magnifica, grandiceps, eximia, etc. However, if Protea material is allowed to get too old you will experience heavy callousing and no root development (figure 21). On the other hand if it is harvested and set to root too soft, then the lower parts of the stems will take on a crinkled appearance like crepe paper and will never root nor even callous up. The optimum lies between firm wood and hard wood. My method for testing Protea cuttings is to take the cutting and bend it sharply to a 90 degree angle around my thumb. If it is too soft it will break with a clean severance (figure 22). If it is too hard it will also break but will hang on the

under side, (figure 23) but if it will bend to 90 degrees and only breaks the bark on the outside of the bend it is about right (figure 24). A final test is to cut the base of the stem with a sharp knife while it is resting on the bench, and if it gives a good satisfying crunch it is right.

With Proteas it may be necessary to have two or more batches of cuttings of each particular clone or variety each year as not all material will be at an optimum condition at any one time. In my locality I set most Proteas in mid-autumn to early winter and usually have two batches of each clone. There is material available from midsummer onwards but this early material is usually either left unused or it has the tips removed at midsummer to promote another growth flush which is used later in midwinter. If set to root by a month after the shortest day, material from this flush will root successfully by late spring but it is almost a full year behind that done earlier. Once day temperatures have dropped below 18°C. there is less likelihood of dehydration or fungi invasion during the propagation phase but results in this time slot without bottom heat must be expected to be much slower than in summer - autumn.

3:9 LEUCOSPERMUMS

The maturity requirements of Leucospermums has been found to be more variable than for Proteas but if it is judged right they are easier to root. Lsp. cordifolium consistently gives best results when it has reached a level of maturity at the point of when the base of the stem is just changing from oval to round. The tips of the material is then at a very immature stage and needs special care at setting [ref. 5:9 & 5:13]. Lsp. cordifolium responds well to having the terminal pinched out 5 - 10 days before harvest. With most other Leucospermums, best results have been obtained with material at a stage as described for Proteas except that Lsp. reflexum and any other grey leaf forms need to be a little older. Never let Leucospermum material get too old. They may eventually root but they will be slow and have a sparse root formation.

Leucospermums are best handled a few weeks either side of the longest day with most being in optimum condition about four weeks past that date. It is possible to use material from a midsummer growth flush in late autumn but rooting will usually be slow in this period unless it is done indoors with bottom heat.

3:10 LEUCADENDRONS

Most varieties are relatively easy to propagate which gives you more latitude in the type of material you may use. They do not root well from strong terminal growths if these are used too soft. The best material is that which is becoming stringy in its texture at the base and gives the same satisfying crunch as the Proteas when cut. Partially-matured material which is sometimes available in the winter as a result of having removed the terminals of the strong growths in mid autumn needs special handling. [Ref. 4:7 & 5:6 for further information on this material].

Leucadendrons can be propagated from when the spring growth starts to harden, which is normally about a month after the longest day, on till late winter. A few varieties will root quite well if set in the early spring provided it is done three weeks before growth breaks. The summer batches will normally root well before winter but those set later may not root up until late spring if outdoors. Spring-set batches will either root rapidly or collapse when vegetative growth starts.

3:11 OTHER SOUTH AFRICAN SPECIES

A number of other varieties have been propagated which include Serrurias, Aulex, Mimetes, Paranomus etc. Propagators wishing to try these should use the material a little on the firm side rather than too soft. With S. florida and some other varieties there is a marked difference in rooting depending on where the cutting is taken along the length of the stem. This is because there is a big variation in the maturity from the base of the stem to the tip. The base can be too old and the tip too soft while the middle is O.K. The condition of the whole stem can be improved by removing 1cm. of the terminal tip ten days before the cuttings are harvested as outlined in 34. [For information on the post harvest handling of immature cutting material refer to 4:7].

Generally all these species are best handled in the autumn as the temperatures are falling. At this season all of them will be maturing their summer growths which are the best material. This will normally be rooted by spring if it is set to root under normal outdoor conditions.

3:12 TELOPEA

Most clones of Telopea will root easily from material produced in the spring growth flush. Quite often these growths are so long that they will produce four or even five cuttings from one length (figure 25). However maturity varies greatly from the base to the tip and by the time the tip is mature the base is too old. This problem can be overcome by removing the terminal tips from the spring flush about the longest day. This will mature the upper part which would otherwise have to be wasted. If the material looks as if it is bruising when it is cut with a sharp knife or clippers it is too immature.

Telopea give best results if they are harvested and set about 30 days after the longest day although even very mature wood will root if it is set as late as the end of winter. The vigour with which cuttings root diminishes from a peak with those set in midsummer to poor with those set in winter. Quite often the base cutting on a long growth has very underdeveloped growth eyes and may remain vegetatively dormant indefinitely although it will root satisfactorily. To a large extent this problem can be eliminated by leaving the base cutting on the stock plant when the first harvesting is carried out. This will cause many of the dormant buds to develop active vegetative eyes within twenty to thirty days. If they do, they can then be harvested and set. If they don't they should be cut off and discarded.

SECTION FOUR

Post Harvesting Conditioning

4:1 OVERVIEW

The post-harvest handling of cutting material is very important, even more important than for flowers. Flowers are expected to last for about two to three weeks to give good value, but cuttings must live for periods of up to 200 days with only the environment to sustain them. Not only is this so but they are also expected to sprout roots which is a mammoth task to ask of any piece of plant material.

Much of the success in vegetative propagation hinges on the condition of the stock plant at the time the cuttings are harvested and the post-harvest treatment of the cuttings. Over the past eight years we have developed several methods of holding and post-harvest conditioning cuttings. In investigating these procedures it has been found that greatly improved end results can often be achieved by using one or a combination of the methods. The following is an outline of the various methods and procedures that have been developed.

4:2 GENERAL CONDITIONING PROCEDURES

In the handling of all Proteaceae material whether it is cuttings or flowers, the aim must be to keep it as cool as possible and to constantly protect against dehydration. It has been established that at temperatures above 25°C (78°F) there is a greatly accelerated break down of plant tissue (both cuttings and flowers) with the degree of damage being a compounded result of a temperature X moisture loss X hours of exposure. When cuttings are harvested at 25°C and above, irreversible damage will be done to the material unless special post harvest procedures are implemented. For safest results handling and processing of all material should cease at temperatures above 28°C (84°F).

One of the greatest dangers to cutting material after harvest is exposure to ethylene gas. All plant material gives off ethylene and other gases from damaged tissue and in the case of Proteaceae this appears to be particularly so in the first few hours following harvest. Ethylene is very damaging to Proteaceae foliage and for this reason cuttings should never be sealed in air-tight containers. PLASTIC BAGS SHOULD NEVER BE USED as their use will often result in rapid tissue breakdown causing the foliage of many varieties to go black within hours. To alleviate the danger of damage from gases, harvested material should be kept as cool as possible and not packed too tightly in containers. Only containers that can "breathe" should be used, ie. those that air can pass into and out of such as cardboard cartons.

Tests with cutting material and flowers of Proteaceae, show that at the time of

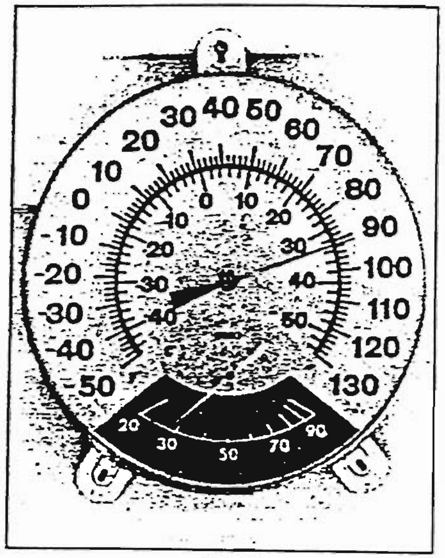


Fig. 26

Fig. 27

harvest their temperature is almost always exactly the same as the shade temperature for that time of day. If harvested material is packed into a container to a depth of 20cm. (8") or greater, and left in an area out of the sun, the temperature of the contents (cutting material) of the container will rise by 2 degrees C. above the prevailing day temperature in the first two hours. This rise in temperature is the reaction of the material to the damage sustained when it is cut from the parent bush and subsequent handling. The rise in temperature will increase to 3 to 4 degrees C. above day shade temperature if the material is roughly handled (which causes leaf bruising) and it is then packed tightly into an air tight container or if there is an active sap flow in the plant [ref. Section 14]. If the material is left in a container without temperature control, the internal temperature of the contents will usually not drop below that at which it was harvested within the first 24 hours. This means that if material was harvested during the day when the shade temperature was 28°C and it was then left in a sealed carton or plastic bag for more than two hours, it would experience temperatures as high as 30° to 32°C and probably not below 28°C for at least 24 hours if it were left in the container for that long and not put into refrigeration. If you were to subject flowers to these conditions they would give a very poor vase life and cuttings will respond in the same way.

4:3 FIELD HANDLING AND IMMEDIATE POST-HARVEST TREATMENT

When harvesting cuttings it is important to keep them out of direct sunlight from the moment they are harvested. Even periods of three to five minutes in direct sunlight in summer can do irreversible damage. If the temperature is above

25°C the material should be placed in a cool place within 15 minutes of harvest. At 20° to 25°C the time lapse could be 30 minutes and for 15 to 20°C 45 minutes. Temperatures below 15°C will pose few problems unless the humidity is extremely low (below 20%).

If the material is to be processed within 24 hours of harvest it may be held in several ways. If the harvest temperature has been below 23°C the cuttings may be held quite safely by packing them lightly in a carton which does not exceed 20 lt. volume. The contents in containers larger than this tend to heat up more and take much longer to cool down again. Following harvest, water should be lightly sprinkled through them and the lid then folded down. In this state cuttings may be held for up to 36 hours provided the cartons are placed in a cool place where there is no chance of direct sunlight striking them.

At above 23°C the harvested material should either be placed in a chiller for a few hours at 3 to 5°C or if one is not available the cuttings should be spread out thinly in a totally shaded area where there is no air movement and then damped down. With an occasional damping down they will be quite safe for a day or more. If temperatures are above 28°C, and humidity below 30% (figure 26) it is better to delay harvesting unless there are good chiller facilities available where they can be cooled without becoming dehydrated.

4:4 DELAYED PROPAGATION TECHNIQUES

These systems of post harvest have been developed and when implemented, can greatly improve the percentages of cuttings that will root, increase the vigour with which they root and usually reduce the time that they take to root. It consists of harvesting and holding cuttings under specific conditions for varying lengths of time before final preparation and setting.

Investigations into these procedures began about nine years ago when I noticed that cuttings imported into New Zealand from Australia and Hawaii almost always gave 100% rooting. It was deduced that either the change of climatic location or the time lapse, (usually three to five days), was the reason. As Australia and New Zealand are both in the same hemisphere the possibility that a change in the seasons was the reason for the high success rates was ruled out.

Since that time many tests and experiments have been run with the results always indicating that a delay of several days from the harvesting of the cuttings to setting is greatly beneficial in percentages rooted, provided the material is properly cared for during the holding period. There are two principal methods under which the cuttings can be held and conditioned in preparation for final setting. To be successful each procedure has some specific handling requirements. These are outlined below.

4:5 WRAPPED AND REFRIGERATED METHOD

It is imperative that material that is to be held by this method is free from fungal infection and that wetting agents have not been used when applying fungicides within five days of harvest. No insecticides should have been applied within ten days of harvest. [Ref. 9:2 for further information].

Cuttings should be harvested with as little crushing damage to stem and leaf as possible. Where stem lengths are long enough to make several cuttings they should be left unsectioned at this stage. Cutting material should be made up into small bundles by laying them on dampened newsprint. and then rolled into a package sealing them by folding the ends and fastened with a rubber band (figure 27). Bundle size should not exceed 30 cm. in length and 75mm. in diam. (12" by 3"). The moisture content of the newsprint about half an hour after packing should be just short of being soggy. Completed bundles are best packed into a carton before being placed in a refrigerator at 3° to 5°C. A check should be made every few days on the moisture content as the air in refrigerators can be very drying. Provided the packages are prevented from drying out in the refrigerator, material handled in this way will hold for up to two weeks and give excellent results once set to root. It is this method we use when sending cuttings by international airfreight. In carrying out this method do not take any shortcuts in procedures and make sure the cuttings are reasonably mature at harvest. Do not put the completed bundles into plastic bags. Cartons may be lined with plastic provided it does not cover the top. If the bundles are completely enveloped in plastic either in bags or in a carton the material will go black either while still packed or soon after being exposed to air when it is unpacked and set to root. This blackening is usually the result of the effects of ethylene gas which builds up to serious levels if the packages are sealed.

4:6 MIST METHOD

The holding area must be well ventilated but not subjected to strong winds. There must be a reliable misting system which is capable of keeping the whole area fully damped down to 100% moisture level on the cuttings at all times. The entire holding area must be in total shade, approx 3000 ft.c but not less than 2000ft/c during daylight hours. On no account may it be totally dark during daylight hours nor may full sunlight ever shine on them. If full sunlight strikes the under side of the leaves of almost any Proteaceae, even if it is under mist, there is a good chance it will destroy it as a viable cutting. Conversely, if Proteaceae material is held at light levels of less than 2000 ft/c or below a daily aggregate of 20,000 j/lu's for more than three consecutive days when it is exposed to normal day temperatures under these conditions, irreversible tissue break-down will occur. [Ref. 9:19 for further information].

Cuttings should be free of fungal and insect invasion and left unsectioned at this stage. Following harvest they should be spread out thinly, about two to three deep, in the misting area.

The optimum delay period will vary somewhat depending on the time of year, climatic conditions before harvest, temperature after harvest, varieties etc. A number of tests have been run using many different varieties with processing and setting being carried out from day two to day twenty following harvest. In

almost every instance, optimum results have been obtained when processing and setting has been carried out on day three. The results of one documented test are recorded in Appendix Two. These results are typical of most tests that have been carried out with day three and four being the best and a rapid fall of in performance by day seven especially with those varieties with grey or hairy leaves.

4:7 PROLONGED PERIOD POST-HARVEST

Some varieties have given excellent results after twenty days of being held under the following conditions. The varieties that benefit most from a prolonged holding period are those that tend to be in a rapid growth phase through a long period of the year such as some Leucadendrons and Serruria florida. These may be harvested and set to hold as outlined above but they should be spread out as a single layer and not heaped up. They should be sprayed or dipped in fungicides such as Captan and Antracol at the time of harvest. Note that there are two fungicides one to control botrytis and the other to control the pythiums. Cuttings being handled in this way are usually very soft at the tips at the time of harvest and these should be left on as it is best to cause as little tissue damage to the material as possible.

On about the tenth to fifteenth day following harvest, it will be seen that the tips of these cuttings will start to turn upwards towards the light. This is the sign that they are then ready to process and set to root. When material is held in this way it is usually possible to use the entire length, including what had been the soft tip as it will have matured during the holding period.

When material is being held for this extended period it is important to monitor the light levels. If there is a period when there is less than 20,000 j/lu per day, it will have to be increased in some way. Provided attention is paid to this and the moisture level is kept to the 100% level it is possible to exceed even this twenty day holding period. I have used material quite successfully after fifty days provided it was clean when it was harvested and it never ever dehydrates from that moment until it is finally set to root.

SECTION FIVE

Procedures and Methods of Setting Cuttings

5:1 OVERVIEW

The final choice of method that is adopted to set cuttings to root is usually governed by the facilities available and the varieties/species being propagated. Of the several basic methods that may be used, the principal ones are individually in tubes, collectively in pots, in trays and finally in beds.

When filling the pots, tubes, trays etc. with medium that you will be setting the cuttings in, make sure that they are slightly overfilled and that the medium is reasonably well consolidated without being too compacted. The overfilling is necessary because the cuttings will be set in these containers for several months during which time the medium will always weather away through the action of water, wind and consolidation. A container that is only half filled with medium at the time of rooting will not foster a good root system. Reasonable initial consolidation is important as without it cuttings are difficult to hold firm when they are set to root.

Just prior to the setting of the cuttings, it is important to have the medium properly soaked no matter whether it be in tubes, pots, trays or beds. Many cuttings of Proteaceae meet an early death sentence by being inserted in medium that is not properly and uniformly soaked. If cuttings are set in a medium that is too dry, they will dehydrate at the base and there is little chance that they will ever root. This can happen inside half an hour.

5:2 SETTING INDIVIDUALLY IN TUBES

This is the method I most favour when handling a species/variety not previously propagated. It is time consuming and does take up more space than other methods but does have some marked advantages. If a cutting fails and dies for any reason, it is to some extent isolated from the others and its problems will usually not be transmitted to the adjacent ones as can be the case with the tray and bed methods. Plants in tubes can be sorted by checking to see if the roots are through the bottom and the unrooted ones can be left in the propagating area without disturbance thus eliminating problems associated with hardening off those cuttings already rooted without damaging by exposure those that have not rooted.

To carry out the tube method, tubes which are 4cm diameter and 8cm long are pre-filled with medium as outlined above. To insert the prepared cuttings in these tubes, a hole is made **down the side** with a nail or similar device which

is approximately the same diameter as the cutting. The cutting is then inserted **down the side** of the tube (figure 28) making sure its base is touching the wall of the tube about two thirds of the depth down from the top. For some reason this practice of putting the cutting down the side with the base touching the plastic gives greatly improved and faster results than just placing down the middle of the tube. The discovery and adoption of this practice has been the greatest contributing factor to the successful rooting of Proteaceae plants that I have experienced. Using this method improved percentages and stronger root system are achieved in all varieties of Proteas and Leucadendrons. The effect is not as noticeable with Leucospermums. When using this method, Leucadendrons will often produce a strong root mass in twenty days.

As with many facets of propagation this method was discovered by chance when one time I had a few more cuttings than there were tubes in a tray for, and I put the last few in two to a tube spaced down the sides. When they were being sorted after rooting, it was noticed that the few that had been put down the sides had rooted 100% whereas the others were considerably less. Subsequent experiments using a number of different varieties as controls showed that this method was consistently better in all varieties tested except in some Leucospermums. Further experiments showed the 4cm x 8cm tube to be superior to the 5.5cm x 10cm tube or the 5cm square liner. Another observation made on a number of occasions shows that there is a further marked improvement in the rooting of those cuttings that have been placed in a tube that has a crack down the side. This indicates that if you could get tubes with small slits in the sides from the base up halfway you could expect even better results.

5:3 POT METHOD

This is an adaptation of the tube method which is sometimes preferable to use. It is very useful when handling small numbers of a variety and gives much the same results as the tube method. In this method pots are filled with medium and the cuttings are placed down the sides the same as in the tube method (figure 29). One of the advantages of this method is that where varieties with large leaves are being handled, (Pr. magnifica, grandiceps etc) or varieties with grey hairy leaves (Ld. daphnoides, nervosum etc.), more space can be given to each cutting by regulating the number in each pot so that their leaves are not touching. Very good results have been obtained using this method on difficult subjects or varieties that may take up to a year to root. Only shallow pots with good drainage should be used, not the ones with only one central drainage hole.

5:4 TRAY METHOD

With this method the choice of tray will greatly influence the end result. Trays (flats to some readers) come in many forms and materials. These range from the old type wooden ones to the newer plastic ones which come in never ending forms and alternatively the polystyrene fruit tray. To date the most successful tray that we have used is of plastic construction with a very open

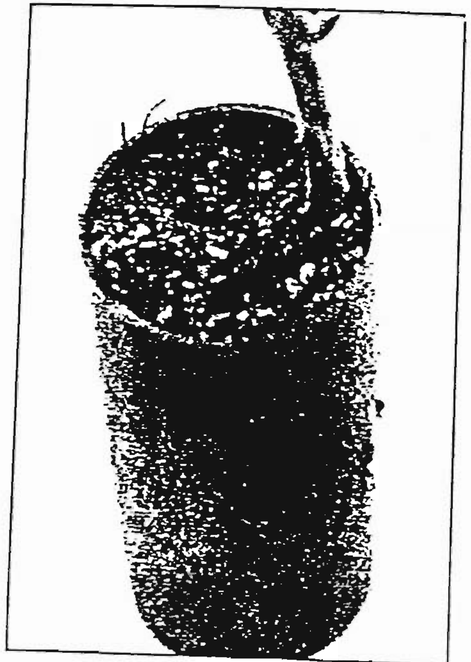


Fig. 28

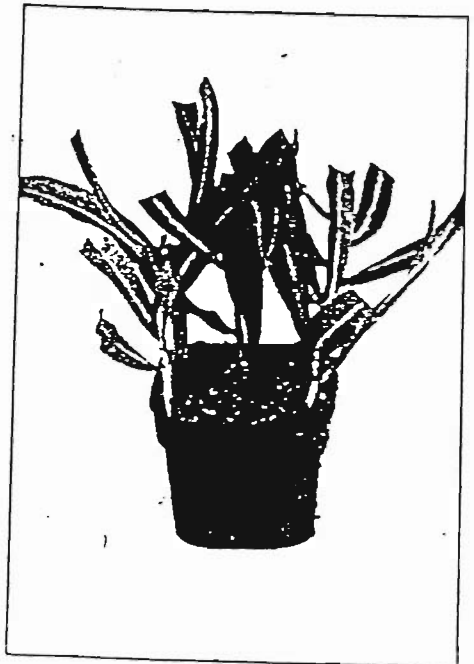


Fig. 29

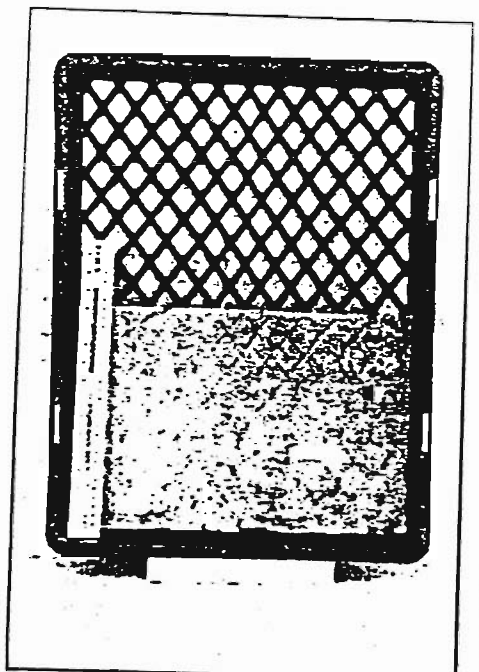


Fig. 30

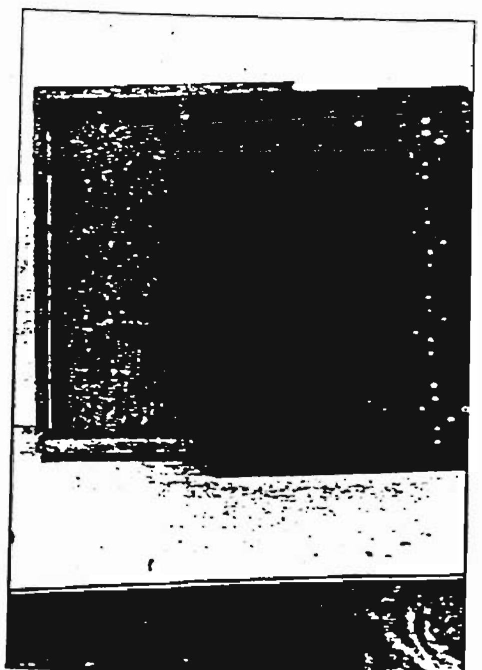


Fig. 31

mesh bottom. When this tray is used in conjuncture with a special liner (figure 30) it has given results at least equal to and in many instances superior to the tube and pot method. The liner is made from a polyester material and is similar in weight and texture to the vilene cloth that is used in the clothing industry for interfacing. Results are a great improvement over the wooden or solid bottomed plastic types trays (figure 31).

When the cuttings are being inserted in the trays with liners, best results have been recorded when the cuttings are put in to a depth so that the base end is just touching the liner. This is contrary to the usual practice when setting cuttings in solid bottomed trays when they should be kept 5mm. (1/4") from the trays bottom. To be able to insert cuttings this extra depth it is necessary to make the stems of the cuttings a little longer from the bottom leaf to the base to ensure that the lower leaves are still clear of the medium.

When using the tray method it is important to keep a very close watch for signs of fungal infection as it may spread rapidly throughout the tray. This problem shows up about 10 days after the cuttings have been set and for the next 10 days it is as well to watch daily and remove any unhealthy looking material and re-treat with fungicides as necessary. After the 20th day there are normally few further problems unless they are introduced from other sources such as contaminated water, fungi splashed from the ground, wind-borne fungi from nearby host trees, etc. or the light levels (j/lu) are being kept too low. No matter how careful you are in the selection and preparation of the cuttings there are always a few that will fail for some reason in the first twenty days.

When setting cuttings in this method, draw a large bladed knife across the medium to almost the full depth of the tray using an up and down cutting motion. It is then possible to insert the cuttings in this slit. As each row is completed firm the cuttings down with your fingers before drawing the knife through for the next row.

The density that the cuttings are set is important. If they are too dense they often suffer from fungal problems associated with low light and lack of air circulation. Most varieties are satisfactory at the rate of one per 20 sq. cm (approx. one cutting to two sq. inches), but those with large leaves or leaves that are set straight out from the stem will need more space. This is dealt within more detail later in this section where the preparation and setting of cuttings is outlined.

5:5 BED METHOD

This is a simple form of the tray method. The cuttings are set in a bed of medium which may be at ground level or on a bench. This method is more economic on space and bottom heat if it is being used. The procedures for setting are identical to those used for the tray method.

There are some serious disadvantages in this method, namely an outbreak of fungal infection is difficult to control and has often spread extensively before it can be controlled. The other main disadvantage is that the hardening-off process is difficult to implement owing to the fact that it is most unlikely that all cuttings set will be ready to harden off at the same time. When cuttings are set to root in tubes, pots or trays they may be moved away from the propagation area as they root up and be hardened off prior to tubing up. This is not possibie when the cuttings have been set in a fixed bed.

The bed method is satisfactory for many easy to root varieties that are resistant to fungal infection and many Leucadendrons may be increased in this way. It is not recommended for large scale operations where it is necessary to produce even grades in large numbers on time.

5:6 SECTIONING AND LEAF STRIPPING - GENERAL

Some growths collected from stock plants will be long enough to make two cuttings but if this is doubtful it is better to have one good strong one rather than two that are too small. Experience will soon show from which stems to make two and from which to make one large cutting from. If you are making two from a growth or even sometimes three, the aim should be to have a minimum of three true leaves on a cutting which is not less than 8cm (3 inches) long for base cuttings and four to six leaves on a stem of not less than 10cm (4 inches) long for tip cuttings. Less than these lengths will present problems of having leaves too close to the rooting medium or a leaf area that is too small for good results. [Ref.5:7 to 5:11 for information on each species].

When handling material that has developed as a result of having removed terminals from the stock plants in midsummer, it will often be found that this does not fully mature and it will stay in a semi-mature condition right through the winter. With this type of material it is important to harvest it with the heel intact and to retain that heel when preparing the cutting for setting. If these are not retained results will be erratic and often poor. For the mature types of wood that come from the spring growths there is no need to actually retain the heel but best results are usual from base cuttings where the cluster of nodes are.

In the preparation of cuttings, the unwanted leaves should be stripped off the stems taking care not to rip the bark of the stem unduly. If there is damage to the stem caused by stripping leaves, the cutting material is almost certainly too immature to be handled. There are however some varieties of Proteas which will always give trouble. When this is the case the leaves must be clipped off.

The remaining leaves on the cutting should have approximately 30% of their length removed by trimming with a sharp knife or cutter. There are two reasons for this. First, by removing some of the leaf area you reduce the area from which moisture can transpire, thus reducing the dehydration rate. The other reason is that it allows you to set more cuttings in a given area, as by reducing the area and spread of the leaves you are decreasing the density of foliage within that given area. This in turn increases the air movement which is necessary in the successful rooting and the plants future survival.

Care should be taken not to overdo the leaf trimming. If they are reduced too much, rooting will be slowed down appreciably and in some cases inhibited especially during the winter when there is less light radiation. As cuttings have no roots they can only sustain themselves by transforming sunlight into energy and if the leaf area is reduced too much, rooting can slow down or completely stop until the light intensity increases the following summer. For this reason only remove 20% of the leaf length when preparing cuttings that are being set to root during the winter months.

5:7 HORMONE TREATMENT

The use of root promoting hormones is now almost a universally standard practice in vegetative propagation. Without its use, Proteaceae tend to root erratically, sometimes slowly and poorly. When it is used at the correct strengths and in the correct manner, it will improve the overall results in most varieties.

When applying hormone to the cuttings, the base should be trimmed with a sharp knife just before dipping it into the liquid or powder. Always use a sharp knife and not clippers as it is important to have a clean, unbruised cut which can not be achieved with clippers. The base should be cut just at the moment before dipping and a quick dip is quite sufficient to the lower 2cm of the cutting. This cut and dip is very important. Cuttings must not be sectioned up, stripped of leaves and then left on the bench to be treated with hormone later. Even if the base has only been cut 30 seconds before it must be recut again and then dipped immediately. There is no need to hold a cutting in the hormone for five seconds as is often recommended. The hormone will stay wet on the stem of a cutting for at least three minutes even on the hottest driest day and another five seconds isn't going to make any difference to the end result.

Some propagators wound cuttings by taking a sliver of bark off one side of the stem on the last cm of the base. I have done trials with this using several varieties as controls and have not found any advantages in doing so. There may be an advantage if the material is over mature as this method does give a greater area for the penetration of the hormone and exposes more cambium layer where the roots initiate from. It does however expose a greater area where fungi can enter the cutting.

5:8 PREPARATION OF PROTEA CUTTINGS.

Proteas are highly variable in their growth forms with the result that the material that you will have to work on will differ greatly between some varieties. There is a similarity in the foliage/branch structure and growth habits of many of the more usual varieties found in the nursery/cutflower trade such as Pr. laurifolia, neriifolia, repens, punctata, eximia, magnifica etc. However there are considerable differences between these and Pr. nana, scolymacephala, acuminata, acerosa etc. and again differences between these two types and Pr. cordata, cynaroides, amplexicaulis, and recondita.

Dealing with the type of material that should be collected from the Pr. laurifolia,

Fig. 32

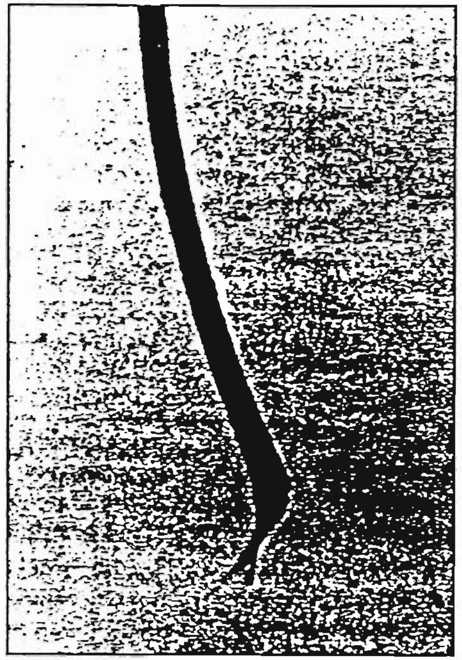


Fig. 33

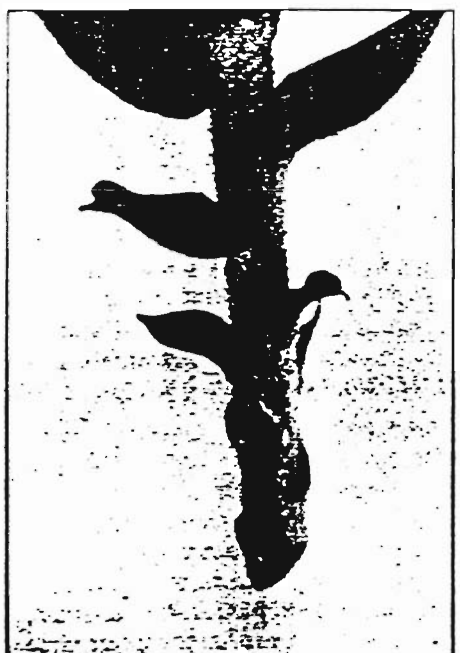


Fig. 34

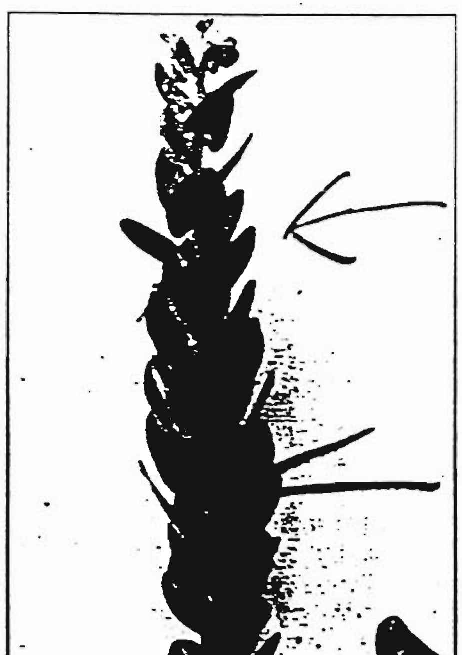


Fig. 35

neriifolia, repens types first, it must always be from the most recent growth flush. In these varieties, terminal growths will often be long enough to make two cuttings. If however the terminals were removed as outlined earlier, then the growths will probably only be long enough to make one good cutting. Cuttings should be sectioned to a length of about 125mm. (5"), always retaining the base section unless the material is over mature when then the part of the total stem length which is at the best maturity will be used. Always remove the terminal tip of Protea cuttings as the flower bud which is in the tip will if left, inhibit or slow down rooting. Reduce the leaf area as described above and treat with hormone at 2000ppm. When finished the cutting should look like the one shown in figure 32. If the material will not take this strength of hormone they have almost certainly been too soft to process.

With the Pr. nana, scolymocephalla types it is important to harvest and retain the heel part of the material on the cutting (figure 33). Failure to do so will result in erratic and often poor percentages rooted. As cuttings of these types often root poorly from plants that are more than 18 months old, the length of material is often limited to 75mm. (3"), as it has to be harvested from small young plants. This means that a little more care must be taken in preparing and setting them. Retain as much foliage as possible but always remove the terminal tips. It is important that there is no foliage left touching the medium. As these are harvested from young plants and the material tends be of a juvenile nature, hormone strength should be kept down to 1500 ppm.

When handling the Pr. cynaroides, cordata types the best material is found at or near ground level. [Ref. 3:5 for description on the special method of preparing cynaroides]. Cuttings from near ground level of these types are usually of a fleshy nature and they may be harvested and set to root when quite soft. If they are in soft and almost juvenile condition, it is important to retain the heel on the cutting. If this is not possible the material should be left to mature until it is in a similar condition to that described for the Pr. laurifolia, neriifolia types. If they are harvested and set in the soft condition it is necessary to remove the top end of the cutting to a point where it is no longer showing wilt. It may be necessary to use one of the post harvest methods to stabilize this material before final preparation and setting. Hormone strengths should be kept to 1500 ppm for the soft material and 2000ppm. for the harder. Cuttings can be harvested and set from these types in the same method as for the others but there is usually a scarcity of suitable material and results are often slow and erratic. Another method of propagating Pr. cynaroides is described in the file on ABC propagation in 17:5.

Proteas should be set to root as previously outlined. They will benefit from having a lot of water on them for the first ten days provided the rooting medium is of the correct texture and the light levels are adequate. They should be watched closely for cuttings which show fungal problems and these should be removed promptly.

5:9 PREPARATION OF LEUCOSPERMUM CUTTINGS

The aim when collecting from the stock plants should be to gather growths that will make one good cutting of 100 to 125mm. in length. (4 to 5 inches). When preparing the cuttings it will be seen that most varieties of Leucospermums have a concentration of very small leaf nodes near the base of the stem (figure 34). This is the area where most rooting activity will take place and the cutting should be sectioned up and trimmed so that this part makes up the first 20mm. of the base of the cutting. This will give better rooting than cuttings made from further up the stem provided the material used is not too mature. To get material that is at the optimum stage of maturity at the bases, it usually has to be harvested while the tips are still quite soft. This makes it necessary to collect and process material every two weeks or so over a period of four to six weeks for a particular clone/variety. This is especially so with Lsp. cordifolium which will give near 100% results if handled in the right condition. If the material becomes too mature at the bases, use the tip and discard the older base wood (figure 35). Always remove the terminal tips from Leucospermums. Failure to do this will create fungal problems in the terminals because of excessive water retention and lack of air circulation. Leucospermums do not usually have their leaves trimmed but they should be reduced to a maximum of five to seven (figure 36). Treatment with hormone is the same as for Proteas except that it should be kept in the lower range (1500 ppm) unless the material is over mature when 2000 ppm should be used.

Cuttings should be set in the medium of polystyrene and peat or sand peat/perlite in trays as described earlier. Good results have been obtained by using polystyrene trays as used in the fruit industry for setting Leucospermum cuttings provided some extra drainage holes are made in the bottoms. A density of not more than one cutting per 20sq. cm.. (one to every two sq. inches) should be observed and in varieties that have large leaves even more space should be provided. The leaves of one cutting should not touch those of its neighbors.

It is very important in the preparation and the setting of Leucospermum cuttings to make sure that they do not have any leaves touching the medium when they are set. If they do it will be necessary to remove more of the bottom leaves so that when they are set they have an air space between the surface of the medium and the bottom leaves (figure 37). If this is not done, losses will occur especially in varieties with hairy leaves. All Leucospermum cuttings should be held out of mist for 30 to 45 minutes, as outlined in the last paragraph of 5:13. They are then put under mist and treated with the Terrazole and Captan drench.

A very close watch should be kept on Leucospermum cuttings for the first 20 days after setting for fungal invasion. When preparing the cuttings always throw away any material that has brown flecks on the stems as these will rapidly develop into fatal fungi infection and spread to surrounding cuttings. No matter how careful you are some of these will slip past you during preparation and give trouble later. By far the best control of this is achieved by thinning out the

unwanted foliage on the stock plant especially near ground level and the regular spraying with fungicides prior to harvesting the material.

If Leucospermums are being set to root late summer/autumn, it may be necessary to use bottom heat on them as they tend to become somewhat dormant in root development as the ambient temperatures drop. This dormancy persists through until about midwinter. Best results are usually from fresh active material set just after midsummer.

5:10 PREPARATION OF LEUCADENDRON CUTTINGS

Most Leucadendrons are very easy to propagate by cuttings provided you process the material at the right stage. As some varieties can produce growths that may be sectioned up into three or even four cuttings it is sometimes necessary to waste some of the length from these long growths as it is rare that you will get good material from the full length of terminal growths. You should aim to handle these varieties when the base and next length up are in good condition rather than when the tip and the next one back are at the correct stage of maturity. The reason for this is that Leucadendrons are similar to Leucospermums in having a cluster of nodes near the base of the new growths and these will give best results. If there is an abundance of material, I prefer to use all base cuttings for these varieties. Where material is providing only one cutting per growth always remove the tips as they tend to hold water in their cup-shaped bracts which can cause problems with fungal infection as the pollen develops. Another reason for removing the bract is that if it is left on, the cutting will try to grow it on to maturity rather than putting its energy into producing roots.

Cuttings should be prepared in the same manner as Proteas and Leucospermums using hormone at the rate of 2,000 ppm. On the smaller leaf varieties try to leave seven to nine leaves (figure 38) and on the larger leaf ones, five to seven (figure 39). Leucadendrons that have hairy leaves may need more leaves removed as they must not have their leaves touching each other or the medium when they are set to root. These hairy leaved varieties are less tolerant of IBA hormone and for them the strength should be reduced to 1000 ppm or not used at all.

Leucadendrons may be set in tubes, pots or by the tray/bed methods. If in tubes or pots they should be placed down the side as outlined for Proteas. If in trays or bedded, they may be set at a density of one to 10 sq. cm. for small leaf varieties and one to 15 sq.cm. for the larger leaf varieties, (approx one cutting to one and a half sq. inches and one to two sq. inches). When they have been set they must have an air space between the lower leaves and the surface of the medium of at least 1cm. (half and inch).

5:11 PREPARATION OF OTHER SOUTH AFRICAN SPECIES

Similar procedures should be used in the propagation of other species. Generally base cuttings will give best results as long as they are not too old but there

Fig. 36

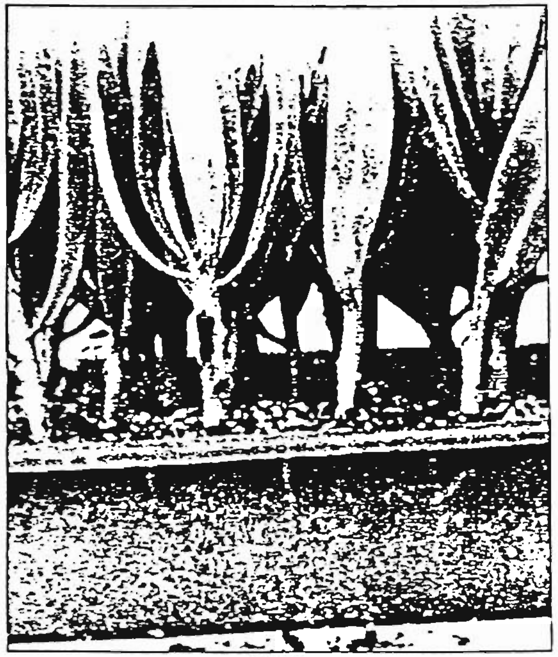


Fig. 37

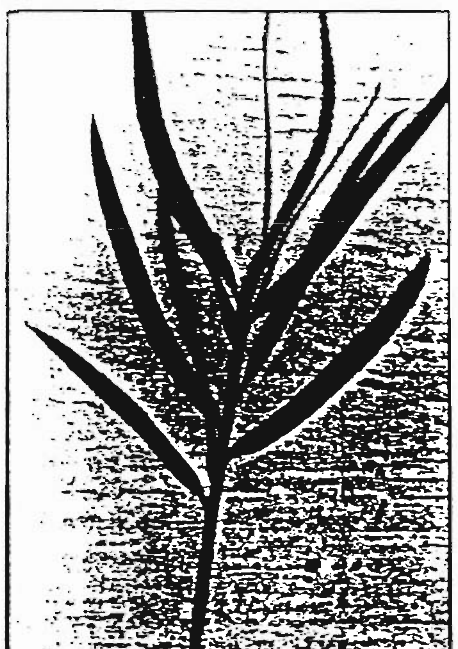


Fig. 38

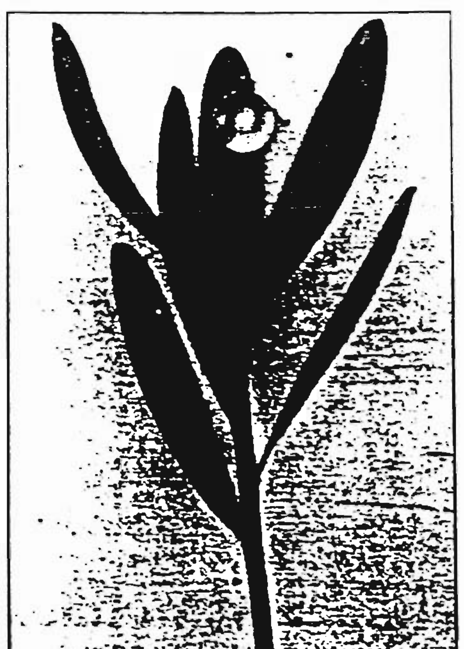


Fig. 39

are exceptions to this. It may be found when handling species that have needle type foliage. (Serruria. Paranomus. Aulex etc). that they are best when the stem wood is nearing the stage of turning from green to light brown.

Good post-harvest treatment should always be a part of any propagation and when handling material that you are not conversant with this is even more important. In the preparation of the cuttings always aim to retain a good leaf area without crowding. For these species it is better to set the cuttings in tubes as this gives a greater chance of success and gives you the option of shifting them around and manipulating the conditions they are subjected to. Use IBA at 1500 ppm. as a starting point and always test cuttings of any species for tolerance to hormone strength and the conditions you will subject them to before large scale commitment. Nothing is impossible to propagate by cuttings but some may prove very difficult.

5:12 PREPARATION OF TELOPEA CUTTINGS

Telopea should be sectioned into lengths. each with a minimum of three leaves for cuttings from near the base and four or five for those from further up the stems. Owing to the size of the stems the sectioning may have to be done with sharp secateurs as it is almost impossible to cut the heaviest of them with a knife. The leaves on the base cuttings should have about 40% of their length removed and the upper ones about 25%. Hormone should be used at 2000 ppm. with the summer batches increasing to 3000 ppm. for the later ones. The tray method of setting has been found to be very successful with Telopea especially with the earlier batches. With the later ones the pot method has been found to give best results. When setting. the cuttings must be inserted deeply to the full depth of the tray or in the case of the pot method down the sides and almost to the bottom. Telopea love to get their roots onto a hard surface and the deep setting lets them do this.

5:13 PLACING CUTTINGS TO ROOT

When cuttings have been prepared by sectioning them. reducing the leaves to the right number and length. and dipping in hormone. they are ready to insert in the medium. This is done by placing the cutting down the side of the tube/pot or in rows in the trays as described above. being careful not to leave any leaves touching the medium. Cuttings should not be left any longer than 10 minutes from the time you have dipped them in the hormone until they are inserted in the medium and less than this if there are hot dry conditions prevailing. The bases must not be allowed to become dry and dehydrated.

Following setting. the cuttings should immediately be placed in the misting area and treated with a solution of 1ml liquid Terrazole and 2mgm. Captan per litre of water by drenching with a watering can. at the rate of 500mls to 100 cuttings. The only exception is if the tips of the cuttings have been removed because they were in a soft condition. In this instance the cuttings are better held for 30 to 45 minutes in complete shade before watering as this gives the wounds of the tips a chance to seal off. If you watch a cutting that has had its soft tip removed, you will observe that the skin (bark) around that area will shrink and seal off. They may then be put in the watering area. Failure to observe this small but important point can result in rot setting in down the stem which may eventually destroy the cutting.

SECTION SIX

Care While Rooting

6:1 OVERVIEW

When I first started growing plants commercially some thirty years ago, an old nurseryman one day said to me, "Any fool can make a cutting but not just any fool can make it root". I have never forgotten that statement and it is in this phase of caring for the cuttings while they are rooting that determines which category you come into.

6:2 WATER REQUIREMENTS

When Proteaceae cuttings are being propagated under an automatic watering system they must be regularly supplied with water from the time they are set until they are rooted. If they are ever allowed to dehydrate there is very little chance that they will root successfully. Whatever system of watering is decided on and used, it must be reliable at all times. As outlined in 2:4 & 2:5 it should be able to "read" the day and as long as the drainage of the medium is good, a little over wet rather than a little dry is recommended, especially for the first fifteen to twenty days and/or at temperatures above 20°C (70°F).

Within three to five days from setting, the cuttings should be flooded in to the medium by heavy watering from a hose while at the same time taking care not to wash them out with too much concentration in one spot. This heavy watering is necessary to make sure they are firmly set in the medium and cannot be rocked around by wind.

6:3 LIGHT CONTROL

The amount of light during root initiation should be at a static level. It is however important to ensure that it is and remains relatively static within the allowable high and low limits as outlined in section two.

When cuttings are set in the summer/autumn period, the light will be regulated in the propagation area to that which is prevailing at that time. As the autumn progresses into winter it will be found that the amount of daily radiation will fall by about 25% from equinox to the middle of winter. If the level at equinox was set at the maximum of 5,000 ft/c and 45,000 j/lu or alternatively 6,000 ft/c and 60,000 j/lu, then with a 25% reduction by midwinter the amount of daily radiation will be too low to initiate rooting. Alternatively if the levels were set at the spring equinox, then the light levels by midsummer would be too high.

For best results light should be monitored at least on a monthly basis and increased or decreased as necessary to maintain radiation levels as close as possible to those recommended as serious tissue break down of the leaves will occur if light levels become too low.

6:4 DISEASE AND PEST CONTROL

Immediately following the flooding in process the watering system should be turned off so that the cuttings can have the first of their bi-weekly maintenance sprays with fungicide. It is important that the chemical should be allowed to dry before the misting system is turned on again. DO NOT FORGET TO TURN IT ON AGAIN or by the end of the day you will have no viable cuttings left.

The chemicals used should be those that will control botrytis and pythium with Captan acting as a good general spray provided it is backed up with others such as Antracol Ronilin, Difolatan etc. Provided the cutting material has been clear of fungal infection when it was harvested the only initial problem that is likely is botrytis. However as time passes and especially in the late autumn other foliage and soil-borne fungi may appear. It is for this reason that two types of chemicals should be used. Fungal control should be carried out every two weeks while temperatures are above 18°C with the chemicals being alternated. Below this temperature treatments can be extended out to three weekly intervals.

Systemic chemicals such as Benlate should not be used at too frequent intervals as control of some fungi will be lost and they must not be used within six weeks of setting the cuttings as it will inhibit the rooting of some varieties. Chemicals such as Ridomil and Alliette may be used as drenches in the propagating phase a month or more after the cuttings are set but care must also be exercised in the use of them because under certain circumstances they may create a toxicity level, [ref. 9:2].

A close watch should be kept on all cuttings especially during prolonged warm periods and again just as winter is beginning. If an unidentified fungal problem appears, my advice is to spray the cuttings with at least three fungicides provided they are compatible, three times, two days apart. Never use any of the copper/hydrated lime sprays unless these are the only ones ever used as these are incompatible with most modern chemicals. If the chemicals are alternated as outlined above it will maintain a broad spectruim of cover against fungal attack. The greatest contributing factors to fungal invasion are a lack of adequate air movement, followed by inattention to providing the correct amount of light particularly in the late autumn.

It is not usual that there will be any problems from insects during this phase provided the material was clean when the cuttings were made and the propagation area is well ventilated. If any do show up they should be dealt with promptly. The cardinal rule with maintenance for fungi and insect invasion during the propagation phase of Proteaceae is, if a problem is noticed SPRAY IT NOW, not tomorrow or the next day, BUT NOW!.

6:5 TIME LAPSE SETTING TO ROOTING

Rooting of some varieties of Leucadendron, Leucospermum and Telopea may

commence in three to four weeks. With experience you can identify the varieties that are rooting by the appearance of the foliage which takes on a "bloom" at that time. [Ref. 8:14 for further information on "bloom"]. When cuttings are thought to be rooted they should be inspected at frequent intervals by either looking at the underneath of the tube if they have been set in that method, or by removing a few for inspection from the medium if they have been set loose in trays.

Cuttings of various varieties and species can be erratic in the time they take to root especially if bottom heat is not used. Bottom heat will often but not always hasten the rooting process. Without bottom heat Proteas could be expected to take from 100 to 200 days, Leucospermums 30 to 100 days. Leucadendrons 20 to 100 days and Telopea 30 to 60 days.

There are a number of factors governing the time that cuttings take to root which include the prevailing light and temperature conditions in the propagation area, maturity of the cuttings when processed, the variety or clone and the season of the year.

The fact of whether cuttings root quickly or slowly will have little bearing on their later life and future development or the percentage that eventually will root. Because they are rhythm plants, and are genetically controlled by the conditions they experience in nature season by season. Proteaceae cuttings are sensitive to seasonal light and temperature variables and have certain periods of the year when they are more apt to produce roots. If they are left to their own seasonal pattern without the stimulation of bottom heat, each species/variety will usually root up in its own particular period.

Proteas have one period of early winter to early spring and another just at the longest day. They can however be made to root up during the falling temperature period of mid-autumn if a lot of overhead water is applied. Leucospermums have their main period about 50 days after the longest day through to mid-autumn and again just as the days start to lengthen in spring which coincides with the flower bud development of the parent plants. Leucadendrons respond in the late summer/early autumn and again in the early spring. This is not to say that cuttings of any variety/species will not root at other times. Very often they will, but if a batch has been a long time in initiating roots, it is more likely to root up in these periods. The sequence of these periods fits in with the natural growth patterns of each particular species and generally corresponds with the periods of active primary root development of established plants as outlined in the growing on section. [Ref. 8:14 for further information on root development].

Provided cuttings stay healthy they may eventually root even after a year in the propagating area. Such a prolonged period is usually associated with the cutting material being too immature when set, having hormone that was too strong applied to it or becoming dehydrated during some part of its handling. Any of these will cause it to go through the process of maturing or regenerating before it is in a stable physical condition to produce roots. Cuttings that have had this

Fig. 40

Fig. 41

Fig. 42

Fig. 43

happen to them and take this long to root up often suffer from a further period of vegetative dormancy before making growth or sometimes a total dormancy that will never break. If you have such a plant and it is very valuable it is worth keeping for up to three years as I have had plants that have eventually grown into good healthy bushes take that much time to root and commence growth.

If all the preparation procedures have been carried out with care and conditions have been adequate during the rooting period, the propagator should be able to expect that most of cuttings of Proteas made in the autumn will be rooted by mid-spring, Leucospermums set in midsummer by late autumn and Leucadendrons set in early autumn by late winter.

6:6 ROOTING ON STATIC LEVEL CAPILLARY BEDS

It is possible to carry out the entire process of propagation on a capillary bed or alternatively use this method to finish the rooting process following root initiation under automatic water.

Most success will be achieved with cuttings set in late autumn after temperatures have dropped and the material is well matured. Cuttings are prepared and set in trays in the same manner as for the automatic watering method. The tray method should be used in preference to the tube method unless the tubes/pots are to be stood directly onto the bed surface. Water does not transfer very well if it has to pass through the bottom of a tray and then into the tube/pot.

The trays should be stood on the bed and lightly worked into the surface to ensure there is good contact between the sand and the underside of the tray base. If this is well done the water level can be set much lower. Light levels should be left the same as for rooting under automatic watering, but if temperatures are above 15°C the light should be reduced by 25% for the first five day and strong drafts should be excluded to reduce dehydration.

In the early part of the rooting process the water level should be set at 5 to 7mm. (1/4 to 3/8 inch) below the bed surface. As the risks of dehydration diminish and the cuttings initiate roots, the water can be dropped to 12 or even 20mm (1/2 to 3/4 inch) below the surface.

If this system is being used to complete the rooting phase following root initiation under automatic water, the trays of cuttings may be removed from that area as soon as the first signs of root initiation show (figure 40). In many instances this will be within twenty to thirty days from setting. Trays should be bedded as outlined above and light reduced by 50% for three to five days. Following that it must be restored to the same levels as for the automatic water area or there will be problems with plant tissue break down [ref. 9:19]. It may be necessary to dampen the trays down once or twice during the afternoon for the first few days to prevent dehydration. The water level should maintained as above.

Cuttings of many varieties handled in this manner root much quicker and with

Fig. 44

more vigour than when they are left under the automatic system. This method also reduces the incidence of fungal invasion but does not eliminate it. Maintenance application as outlined above should be continued. Plants once well rooted (figure 41) should either be removed from the capillary bed or the water level should be dropped even further to a level of 25 to 30mm. (1 to 1.1/4 inch) below the surface. Failure to do this may result in the degeneration of the root system in some varieties through the invasion of soil-borne fungi.

The success of any propagation carried out on capillary beds is the result of the skills of the operator being able to control and manipulate the water and light levels in relation to the prevailing dehydration rate. Almost all Leucadendrons can be rooted in this manner and it is an excellent way of finishing off Leucospermums following root initiation under automatic water. The method is particularly useful when handling any varieties with grey hairy leaves as these often start to deteriorate after twenty to thirty days under automatic watering.

6:7 HARDENING-OFF FROM AUTOMATIC WATERING

Once the cuttings are reasonably well rooted with several roots of 2cm. long, (figure 42), the batch should be removed from the misting area to be hardened off. This is simplified if they have been set in tubes or pots as they can be sorted by inspecting for roots through the bottom of the container (figure 43) or if they have been set in trays a check can be made by gently removing some for inspection (figure 44).

When the rooted cuttings are removed from the mist area and temperatures are above 15°C (60°F) they should be placed in an area that has no more than 3.500 ft/c of light or a daily aggregate of 25,000 j/lu for five days, and if the day temperature is above 15°C kept damped down several times a day. Below 15°C they may be exposed to 6000 f/c for short periods or 40,000 j/lu but a close watch must be kept for signs of dehydration. Try to pick periods when cooler cloudy weather is prevailing as this reduces the shock considerably. Never attempt to harden-off during periods of hot drying winds as these will do more damage to the plants than just high temperature. After about five days plants may then be placed in a situation which is protected from strong winds at a light intensity of 6000 f/c or 60.000 j lu and allowed to continue to root up. If the hardening-off has been well done further root development will be rapid especially if they are kept slightly moist underneath and dry on top. As the medium that they are in is very free draining, a close watch should be kept to make sure that they do not dry out unduly or they may be lost. This can happen in five to six hours if they are exposed to high temperatures, full sun and drying winds. If all or any of these conditions are a problem, consideration should be given to the use of a capillary bed for the hardening-off phase.

SECTION SEVEN

Seed Propagation

7:1 OVERVIEW

Propagating from seed is still the most common way of increasing Proteaceae stock particularly in nurseries catering for landscape planting and unless there is some specific reason for vegetative propagation such as retaining a characteristic in a clone for cut flower production, seedlings give good reliable results.

As natural progeny, seedlings have some built-in survival kits that plants propagated from cuttings do not have, at least in their first two years of life. Because of this they are generally easier to establish. The two principal aspects in which they differ from their cutting grown counterparts are first in their ability to handle temperatures below freezing and second how they perform under conditions of high dehydration.

Seedlings of almost all varieties will tolerate far more frost without damage than cutting grown plants will in their first year but by their second winter there is little difference. I have had batches of seedlings of many varieties frozen solid to -4°C just after germination and in one instance to -6.5°C for several hours at the four leaf stage yet they survived with no apparent ill-effects. Frosts of those magnitudes will destroy or badly damage young cutting grown plants of those same varieties.

Because seedlings of all varieties have a strong tap root that is the basis of their primary root system they are able to withstand dry soil conditions without becoming dehydrated better than cutting grown plants of the same varieties. Cutting grown plants do not naturally develop a strong primary root system until later in life, usually between their first and second years. The exception is when cutting grown plants are manipulated into developing a strong primary root system by special procedures during their growing on phase [ref.8:4 & 8:15].

There are three basic forms of seed among the South African Proteaceae. A knowledge of the characteristics of each type is helpful in understanding their pre- and post-germination handling. The three types are; the flat winged ones which cover most of the multi-head type Leucadendrons and some others such as salignum and laureolum; the hairy ones which cover almost all the Proteas excepting magnifica and holoserica, and the hard nut types which include all the Leucospermums, the Leucadendrons which do not have the flat winged types, most Serrurias, Paranomus, Mimetes and Proteas magnifica and holoserica.

There is very little difference in the handling of the flat winged and the hairy

types. Provided they are fresh and viable these germinate easily and relatively evenly, usually between the seventeenth and twenty-sixth days following sowing. The flat winged ones should be kept a little on the dry side rather than very damp from sowing to germination as if they are kept over damp during this period they may rot before germination or damp off at ground level immediately following germination.

The hairy types normally have few problems but can be erratic in germination with some coming through at the three week point and another lot about three weeks later. This is almost certainly due to the fact that the seeds have been harvested from both the fresh current year heads and those from past years. It appears that although seed from older heads is viable it goes into a state of semi-dormancy and this explains the germination time lag which often occurs. This problem can be alleviated to some degree by the hot water treatment as outlined in 7:6.

The nut types are quite different to the others in that almost all of them are shed from the heads each year as they mature and are not held captive in the spent flower or bracts as most of the others are. Experience in handling this type of seed indicates that it is very viable when it is first shed from the heads and in nature if conditions are right germination will take place soon after they fall to the ground. However if conditions aren't conducive to germination and survival, they then go into a state of dormancy the depth of which depends on how long they are held pending the right conditions and the amount of dehydration the seed is exposed to. This is nature's way of protecting it from germinating in hostile conditions.

If this type of seed is not germinated within four weeks from harvest, most of these varieties will stay dormant for from three to fifteen months following sowing. A substantial drop in temperature within thirty days of sowing will often trigger the germination of a percentage of them and it has been observed that some varieties germinate quickly and evenly following being frozen to -3°C (28°F) for several hours. However this is not always consistent which is probably due to the time lapse from harvest to sowing which is often unknown. It appears that when these hard nut seeds are held for more than thirty days from harvest to sowing, then for every extra month they are held, a high percentage of them will remain dormant for an extra month after sowing, ie. if they are held for three months then they will remain dormant for three or more months.

This dormancy can be broken to some extent by two different treatments. The hot water treatment alone (outlined in 7:6) will help provided the seeds have not aged past the two month stage. If they are older than this then the hot water treatment followed by a period of stratification in damp sand at near zero temperatures will help. The stratification periods tested have been three and five weeks both of which have given improved results over untreated seeds.

The viability of all three types of seeds are variable and in some years germination can be near 100% where-as the following year that same variety may be as low as 10%. A good average percentage from hand sorted seed is 70% and this figure can be relied on with most varieties most years.

Viable seeds are relatively easy to germinate but the real challenge starts following their emergence through the medium surface. The problem experienced by many propagators is being able to get them to survive through their first six months development. The health and vigour of the tiny plants when they first come through the surface and the handling of those plants in the first few weeks has a lasting influence on their future.

7:2 EQUIPMENT AND FACILITIES

To carry out seed propagation it is necessary to have certain facilities, equipment and materials. These differ somewhat from those needed for vegetative propagation and the basics are outlined in the following text. The information should be used as a bench mark and may be varied to suit the size of the operation, climate and varieties being handled.

The equipment and facilities needed to germinate and grow seedlings are found in most places where horticulture is practiced and the operation may be carried out either outdoors or under cover in an airy structure provided you have control over the light levels. The control of light is very important from germination to at least the end of the plants' first year.

Because I live in an area where it rains frequently through the late autumn/early winter when most seed is being germinated, my preference is to germinate seeds in an environment which is outdoors but where I have control over the amount of rain that will fall on the seed until they have reached the four to six true leaf stage. After they reach that point there is no further need to withhold rainfall from them and indeed provided they have developed a root system which is predominantly of the primary type,they are better to become accustomed to the local climatic pattern as early as possible. If they are kept in a closely controlled environment such as a glass or tunnel house through the winter they tend to produce vegetative growth rather than roots and because of the imbalance of leaf area to root development that then exists, high losses can be experienced in the spring when they are shifted to an outdoors environment. Another problem with growing indoors is that the plants often become physically weak at ground level which necessitates staking at an early age.

My seed germination is carried out under a water proof structure which has a roof made of opaque PVC sheet with a shade rating of approximately 30%. The frame carrying this sheeting has wheels on it which run on rails so that it can be rolled back off the germination area. This makes it possible to expose or protect the seedlings from rain, night dews and light. There are no sides or ends on the structure to obstruct air movement. In continental climates where the weather pattern is more predictable, outdoors but under controlled light levels would be satisfactory.

Seeds may be germinated in trays (flats) at ground level or on benches. My preference is to have the trays on benches because air circulation is more

constant at this height which not only reduces the risk of short periods of high temperature build-up, which can be very damaging to germinating seeds but also gives better protection against fungal invasion. This is important as seedlings can be wiped out in a matter of hours by fungi if it is not detected at an early stage. It is much better to take every precaution to avoid the problem than to have to treat it.

7:3 WATER

The quality of the available water is important and can be the governing factor in all propagation. Water with high pH. and/or salts content is even more damaging to seedlings than to cuttings and will cause irreparable damage to germinating seed making it impossible to succeed. Water quality for seedling growing should be as good as or better than that outlined for vegetative propagation.

7:4 METHOD OF GERMINATION

The two great dangers during germination are:-

(a) being kept too wet, which is the prime cause of fungal invasion.
(b) just as fatal, allowing the seed to dehydrate in the few days just prior to their emerging as seedlings.

Both are usually fatal.

The following is a step by step outline of the particular method I have developed and modified over the years. It is not a common practice method but it can be used as a bench mark which individual growers may either follow or adapt to suit their own situation.

7:5 PREPARATION FOR SEED SOWING

For seed germination, I use a soil based mix made up of 5 parts loam top soil (preferably with decomposed turf included to give it some fibre), 3 parts of pumice or perlite and 1 part of coarse river sand. If the pumice/perlite is fine grained it should be partially replaced by extra sand. It must also be ascertained that the pumice/perlite does not contain high levels of phosphate. If the water or the loam being used are high in pH., then add up to 2 parts of peat to act as a buffer.

It is best if the medium is heat sterilised to 95°C (190°F) for 20 minutes, at least 30 days prior to the seeds being sown. This time lag is necessary as a temperature of this level will destroy all micro organisms and a period should be allowed for these to start regenerating before germination is started. Some very poor germination and growth rates have been experienced if freshly sterilised mix has been used.

If methyl bromide is used for sterilizing it is important that the mix is not used for at least 30 days following treatment and it must be turned several times to aerate it prior to seed sowing. Every endeavour must be made to exclude the possibility of harmful chemical residues remaining in the mix. Failure to take these precautions will result in poor germination and growth rates.

Seeds are sown in wooden or plastic trays which must have adequate drainage. They should not be more than 5cm (2 inches) deep or the seedlings will develop a root system that is too long to handle with safety when you come to pot them on. By keeping the depth of medium to 5cm. it is possible to pot them on with the minimum of root damage.

In some places it is common practice to use wooden trays that have been treated with preservatives. If preservatives have been used the trays must be subjected to a long period of weathering to ensure there is no possibility of the chemicals leaching into and contaminating the medium. If the medium does become contaminated, you can expect a 100% failure.

When filling the trays in preparation for sowing, they should be loosely filled to the top with medium that has a moisture content so that when you squeeze it in your hand, it will just stay together. This moisture level is very important and the medium should be slightly damp rather than too dry. Firm down with a block of wood which should then leave a lightly packed surface approximately 6cm (1 4 inch) below the lip of the tray. They are then ready to have the seed sown in them.

7:6 PRE- AND POST-SOWING TREATMENT OF SEED

It has been reported from South Africa that improved germination has been achieved when seeds have been held in water at an even temperature of 60°C for specific periods before sowing, usually fifteen to thirty minutes. My research indicates there is some doubt whether the hot water treatment actually improves the overall gemination percentage but what it will do is to cause them to germinate all at one time instead of over a period of several weeks / months.

My method of carrying out the hot water treatment is to place the seeds in jars and then pour water at 60°C (140°F) over them and leave to stand for 15 minutes. They usually need stirring to make sure that the seeds that are floating become submerged. If a lot of the seeds do float it is an indication that the seed was either harvested from aged heads or that it has been harvested and held for several months. After fifteen minutes drain the water off and then gently squeeze the seeds to expel any surplus water held in the hairy coatings. The seeds should then be mixed with dry sand, 200 seeds to 250mls volume of sand to which is added 2mgm of the fungicide Captan making sure the seeds, sand and Captan are well mixed. It may be necessary to separate the clumps of seeds with your fingers as they sometimes cling together. It is for this reason it is necessary to have dry sand as this assists in the separation process.

In many instances it is not necessary to soak seeds in hot water to get satisfactory germination. Provided the flat winged and hairy types are fresh and have been harvested from the current years flower heads they will germinate evenly and at satisfactory percentages (70%+) without treatment. In the case

of the nut types it is usually advisable to treat them as outlined above. An exception to this is Pr. magnifica as these always germinate with reckless abandon. If seeds are not treated in any way they should be mixed with sand inoculated with Captan and sown as outlined below.

Sow the seeds evenly over the previously prepared surface of the tray at a maximum density of one seed to six sq. cm (one seed to one sq. inch) which is about 200 seeds to the average sized tray. Firm down, do not pound down hard, only press the seed lightly into the surface. Top up the tray with medium to overflow and draw a lath across the top leaving the surface levelled off but not pressed down.

The completed trays are then stacked one on top of the other in an airy place that is not exposed to strong draughts or direct sunlight. When stacking place a layer of newsprint or a material such as the tray liners or weed mat on the top of each completed tray. If this is not done the bottom of the next tray may stick to the surface of the previous one and when un-stacking it will lift the seeds off the lower one.

Do not cover the stack of trays with plastic or any other impervious materials or you will induce fungal problems that are difficult to control later. A single layer of 14 ounce hessian is permissable to minimise dehydration from draughts. Make a note of the date they are due to be un-stacked as it is bad news for seeds to be emerging for several days while still stacked.

The principle of this method is to keep the seeds at relatively constant moisture and temperature levels during the initiation of germination, while at the same time almost totally eliminating the chance of fungal invasion or over watering. Seeds can be destroyed or the young plants permanently damaged by over watering during germination. This is sometimes given the name of "collar toxin" which is in fact tissue damage to the stem at ground level or sometimes to the seed just prior to emergence and is caused by applying water at the wrong time of day, over watering, or both.

After sowing and stacking no further watering or handling is usually needed from the day they are sown until the 17th. to the 26th. days unless there are very drying conditions prevailing. If it is hot with dry air conditions, it is as well to check some trays ten to twelve days after sowing to make sure that they have not dried out unduly. If they have, a very light sprinkle of water may be given and then restack.

In temperatures from 15° to 25°C (60° to 80°F), most seeds handled in this manner will start germinating on the 17th to 26th days while at temperatures below 15°C (60°F) they will take 20 to 35 days. There are some varieties that will take longer and these may be left stacked for up to 50 days before being spread out and exposed to light and water. Seeds that take this length of time to germinate are usually those varieties that have the built-in dormancy period such as Lsp. cordifolium and Ld. argenteum.

7:7 HANDLING AT GERMINATION

Upon un-stacking on the appropriate day (experience will teach you to gauge the day with accuracy), the trays should be spread out in a well-lit, airy environment and watered very gently, remembering that the top layer of medium was never firmed down and the vigorous application of water from a hose could wash the seeds out.

Following this light watering, take some coarse sand to which has been added 2mg of Captan per lt volume of sand and broadcast this over the surfaces of the trays to a depth of 2 to 3mm, (1/8th inch). The reason for this layer of sand is two-fold. It is a means of placing a fresh layer of fungicide right on the surface where the seeds are pushing through while also providing a loose layer of material that can fall in around the tiny seedlings as they emerge, thereby helping to keep them firm. Only if a very sandy medium has been used for germination should the application of this sand layer be omitted in which case Captan can be applied from a watering can at 2mg to lt. water. Many seedlings are lost at this point as they are particularly susceptible to fungal invasion or dehydration through exposure to the tender stems at ground level. The exposure factor can be aggravated by the rather vigorous simultaneous germination of the seeds (figure 45). This is why it is important not to exceed the density of seeds recommended as a near 100% germination even at that rate can cause the whole surface of the medium to lift by a centimetre (half an inch) resulting in some of the seedlings being suspended in mid-air. If this does

Fig. 45

happen a very light watering may be necessary to re-settle the seedlings and surface.

7:8 POST-GERMINATION

From the point of emergence on, the seedlings must be kept well ventilated and well lit. However exposure to full sun at any time of the year is too severe for most varieties and if the prevailing weather is sunny no matter what the season, some shading will be necessary to give a light level of between 4000 ft/c to 6000 ft/c maximum at midday. It is important to have a daily aggregate of 40,000 to 50,000 j/lu. In light control, account must be taken that if a week of cloudy conditions prevail, then the shading should be removed and replaced again when brighter conditions prevail. In most locations cloudy conditions with no screening will give a maximum light factor around 4000 f/c and a daily aggregate of approximately 30,000 j/lu in winter. This is the absolute minimum that they will take before there are problems with tissue break down and fungal invasion of the roots and or foliage.

A quick check can be made by inspecting the stems of the young plants and if they have a white translucent appearance, it is a sign that the light level is too low and it must be increased immediately. Stems should always have a green/brown or brown/red appearance. If they are very dark brown to black there is too much light.

7:9 WATER APPLICATION

Light watering only is needed at this stage especially during periods of low temperature. Apply water at sunset and leave damp over night. When watering at this time of day the volume of water may be halved to that which would have to be applied during the middle of the day to maintain adequate soil moisture.

Once they have developed their first pair of true leaves they may be left uncovered at night so that the dew can settle on them. This is very beneficial to them and almost totally eliminates the necessity of watering them at all during the winter months. The medium should be kept a little dry rather than constantly wet.

Trials have been carried out using capillary watering methods which show promise if well engineered but there is a danger of having the medium too wet in the bottom of the trays which causes the primary tap roots to rot off as they reach that level. If capillary methods are used the water level must be set very low, 5cm. (2 inches) or more below the surface.

7:10 DISEASE CONTROL

It is important to prevent fungal invasion rather than have to control it. It has been reported that certain fungi are present on the seed coatings and that these are the cause of the very high loss rates that some growers experience at and soon after germination. Whilst the fact that fungi is sometimes present on

Fig. 46

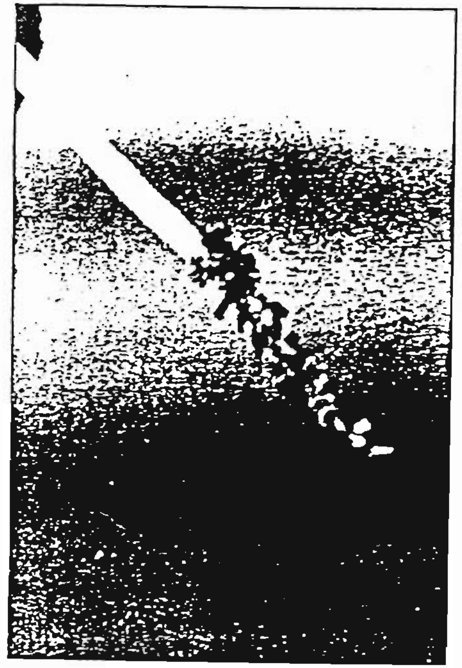


Fig. 47

Fig. 48

seed coatings is no doubt true, it is my opinion that this would very rarely be responsible for the "collar toxin" or other reasons for losses. The treating of seed and medium with fungicides prior to germination should eliminate any contamination from seed. If contaminated seeds were the cause of fungal invasion of the freshly germinated plants, it should occur prior to, at and immediately after germination. Most losses are experienced several weeks after germination and sometimes not until following tubing up. Because of this it is my belief that fungal invasion is principally of a local nature and is the result of poor handling practises including over-watering and a lack of attention to adequate control of light levels and air movement. It would only very rarely originate from the seed.

Following germination a fungicide should be applied about every ten days especially at temperatures above 18°C. During this stage the seedlings are growing very soft tissue and a fresh protective cover of a mild fungicide such as Captan should be kept on them. This should be applied at a time of day when it has a period to dry on the leaves before it is washed off by watering, rain or heavy dews. If the high water volume method of applying fungicides, is used [ref.9:6] then this amount of water may be sufficient which eliminates the necessity to water especially in winter, spring. Systemic fungicides are not generally satisfactory to use on very young plants. Toxicity has been detected with some chemicals on some varieties.

7:11 TUBING UP

Seedlings will reach the four true leaf stage quite rapidly, usually within two to four weeks from germination. When they have four to six leaves they are then ready to tube up into individual tubes. They should have been treated with fungicide not more than five days prior to the tubing up process. There is always some tissue damage at handling and if fungi are present they will enter the plants at these points. There is also the danger that if the plants have not been treated there may be one or two infected plants and this can be transmitted to a whole batch through contact from hands and equipment.

With plants of all ages and with seedlings and freshly rooted cuttings in particular, it is very important to ensure that they are not in a state of undetected dehydration in the root zone at the time of handling and potting. If they are there is a good chance that they will be lost within a few days of being handled. Plants that are to be tubed-up should be thoroughly watered one or two days before being handled to ensure that they are not under any stress from dehydration at the time of handling.

Tube up into the same medium that was used for germination using a container size that the roots will fill quickly; 5cm square or round tubes are ideal. Never over pot, it is much better to have to handle the plants one or even two extra times than not to have them to handle at all, which is usually the case if they are over potted.

The young plants in the trays will have roots about twice as long as their top growths (figure 46) and care is needed when extracting them from the medium. The root system can be greatly improved by "wrenching" the seedlings about seven days prior to handling. If the seeds were sown in a tray that has an open mesh bottom with a liner in it, wrenching can be carried out by pushing your finger up through the bottom or alternatively you can work over the area from the top using a knife blade to gently disturb the seedlings. Another method of wrenching is to take the tray and toss the entire contents lightly into the air letting it fall back again. It does take a little practice but it is an effective way of wrenching seedlings and rooted cuttings. The medium should be damp but not wet and they should NOT be watered for at least two to three days following wrenching. Lightly disturbing the young plants will break the tap root and cause lateral rooting which will develop rapidly at about 1mm. (1/24") per day. Figure 47 shows a seedling before wrenching and figure 48 shows one four days later.

When removing plants from the tray I find the best method is to start on a face at one end and work through using a table fork or something similar to loosen the plants. If wrenching has been well done it is possible to extract the plants from the medium with little damage to the roots. Never give them a tug from the top as they will invariable break off about ground level and be lost. Always set the seedlings in the tube a little deeper than they have been in the trays otherwise as the medium settles it will leave the plant exposed above its correct level. Seedlings of Proteaceae plants are rather particular about being planted at the correct level.

For the tubing-up operation the medium should have a similar moisture content to that in which the seeds were sown and it should be left only lightly firmed down in the tubes. It is imperative that for them to produce roots, they must have oxygen in the medium. Tightly packed and over wet mediums have little or no oxygen in them and this is the reason why they sometimes fail to produce a well balanced root system.

7:12 CARE - FIRST SIXTY DAYS

Following tubing-up, the plants must be kept out of direct sun and strong draughts for seven days. If the moisture level of the medium was correct they should need little or no watering with the exception of a very light sprinkle following tubing-up to settle the surface and set the plants firm. If you are in an area where very low humidity prevails more frequent attention will be needed but never apply heavy watering. If the plants have been properly handled and cared for they should be showing some new root movement by the third day and by the seventh day, under reasonable temperature conditions (12 + degrees C), there should be 5mm (1/4 inch) of new growth on the main roots.

Although it is better to withhold watering totally if at all possible for the first few days with the exception of the light sprinkle to settle the plants in, it is however quite acceptable to let rain fall on them in any quantity except torrential downpours. A week after tubing, provided the roots are showing new growth, the

plants may be exposed to more light and air and watered prudently when necessary. At this stage they should be protected from frosts as with the disturbance to their roots they can not handle the dehydration which frosts cause quite as well. If weather conditions are settled with no risk of frosts they may be exposed to natural climate conditions including whatever rain may fall, but not to direct sunlight for long periods. However if it is considered that conditions are not conducive to root development (cold and wet) they should be kept under controlled conditions in an airy well lit place and allowed to dry out a little so that they have to hunt for moisture. At all times the aim is to grow a sturdy, balanced plant with a good root system rather than a large top with small under developed roots. The most important part of any plant is the part below the ground and if that is healthy and well- founded then the part above the ground will follow naturally.

One of the principal reasons for losses during this period is excessive watering in the belief that they need to be kept wet to survive. This is not correct, what they do need is protection from conditions that will dehydrate them and plenty of air in the medium. Seedling Proteaceae have the ability to get most of their moisture requirements from the atmosphere, particularly night dews. During the season from autumn equinox to spring equinox, provided they are exposed to rains and night dews and they are growing in a soil based medium they usually need very little watering. At all times the soil moisture level must be at the minimum level that will sustain steady healthy development both above and below the ground. A little dry rather than too wet is the motto that should always be followed.

In the period from the first tubing-up until the plant is to be re-handled (re-potted or planted out) a constant watch should be kept for fungal and insect invasion. In most instances if air movement and light levels are adequate a three weekly spray with standard horticultural sprays should be all that is necessary. Additional care should be taken during periods of warm humid weather when greater attention is needed to ventilation. This is particularly so with the hairy and grey leaved varieties.

Some varieties grow very rapidly even during cool weather and a watch should be kept to make sure that the plants do not grow together to such a degree that ventilation and adequate light at ground level is lost. This is dealt with in more detail in the section on growing-on.

SECTION EIGHT

Growing The Plants On

8:1 OVERVIEW

Having grown the seedlings through their juvenile stage and the cuttings to a point where they have become plants. the next step is to grow them through to a point of maturity where they may be safely planted in their permanent sites. In most cases this will take a full summer.

To be able to accomplish this effectively the growing-on phase should be carried out in an area that is well ventilated without being too exposed to strong winds. The site should not be influenced or shaded by tall trees and buildings as it is necessary to control light levels accurately. A water supply which can be regulated to the demands of the plants must be available.

While the principles of controls of these three elements remain the same as for propagation. there are differences. During the propagation phase the controls remain virtually unchanged for the whole time that the cuttings are rooting. In the growing-on phase the amount of air movement and light will be increased, while the frequency and volume of water will be decreased. Because of this it is necessary to provide facilities which are somewhat different from those needed for propagation.

8:2 AIR MOVEMENT CONTROL

Where strong winds prevail steps must be taken to break their velocity as young plants do poorly under severe buffeting. Wind-breaks can be made from wind-cloth which will act as a general barrier. In extreme conditions it may be necessary to have solid wind-breaks near ground level (made from corrugated iron. plywood etc). along the windward side of each bed. This will control the worst buffeting while still retaining adequate air movement, provided they are not more than 70 cm. high and arranged so that they do not shade the beds. As in the propagation phase they should stop about 10cm (4") above ground level. If the operation is in an area that has seasonal wind patterns such as windy springs and calm summers, it may be necessary to encourage more air movement at ground level during the low wind seasons.

During this stage of the plants development the foliage canopy will be considerably denser than it was at any time during the propagation phase. This means that the growing area will need more air movement than was provided during the propagation phase. Because of this, care must be taken when designing the growing-on area not to stop air movement to such an extent that the atmosphere becomes stagnated especially during periods when the temperature is above 20°C (68°F). If this does happen two problems will occur. First it will

create a situation that will foster fungal invasion such as Drechslera and Septoria on Leucospermums which in some cases will be almost impossible to control unless air movement can be improved. The second problem is that plants. especially those still in their more juvenile stage of development. will suffer heat stress at much lower temperatures unless they have adequate air movement.

Because air movement is a necessary part of the environment for the successful handling and cultivation of Proteaceae. it is in my opinion a mistake to grow plants during any part of their production in a structure such as a walled enclosure. glass-house or tunnel house. These structures have inadequate air movement unless there is forced air cooling. and they are a haven for fungal development. Although fungi can be controlled with the constant application of chemicals. there is evidence to show that plants can become infected in these airless conditions and carry it latently into the nursery or even the field situation where it will develop at a later stage.

Another result of growing plants in walled structures. particularly when they are used for wintering over young plants. is that the conditions promote vegetative growth which is not balanced by adequate root development. The results of this can often be detected in container grown plants that have large tops by mid-summer but are unstable in their container with the result that they are often lying over or need staking. An inspection of the root system will show poor root development in relation to the vegetative growth. The roots that are present will be mostly of the proteoid type with very little development of the primary system.

8:3 WATER AND ITS APPLICATION

During this phase of the plants' development it is necessary to have at least some basic facilities for supplying water in regulated quantities. There must be a reliable supply of good water and if the operation is of any size it should be coupled to a well planned and engineered watering system that is able to distribute water evenly at controlled quantities at pre-determined periods of the day. Where an overhead sprinkler system is being used it is best to set sprinklers to give a 100% overlap as this eliminates the problem of having dry spots around the perimeter of the sprinkler distribution pattern.

The time of day that plants are watered will affect their health, growth pattern and survival rate. Since we installed a system of controlled night watering, as opposed to on demand daytime watering, practically all problems associated with fungal invasion both above and below the ground as well as disorders associated with leaf scorch etc. have disappeared. The practice of night watering is contrary to all articles I have read on Proteaceae production as these have always advocated morning watering so the water will dry off quickly. The idea behind this appears to be that by having them dry off you will avoid fungal infection as they are not wet for so long. In fact, watering during the morning creates a situation which is far more likely to foster fungal invasion as watering then increases humidity which when combined with rising day temperatures creates a much more dangerous environment than night watering does. Morning watering, especially during summer is contrary to the plants natural environment where they often experience late afternoon showers or mist banks and for much of the year heavy night dews. These showers, mist banks and dews cause the plants leaves to be wet all night, often for more than twelve hours and provide them with water which they can take in through their leaves. It is the only source of moisture for some varieties during the seasons when soil conditions are dry. Clean water on its own does not create fungi. There are a number of factors which create conditions that cause fungal invasion of plants: temperatures above 15°C (60°F), high humidity and poor air movement are always components [ref.9:1].

I strongly recommend night watering especially when day temperatures of above 18°C (65°F) coupled with humidity of 75% and above are being experienced. Growers must make allowances for the fact that less water is needed with night watering owing to there being less evaporation when water is applied at lower temperatures. In the summer, best overall results have been experienced when the water is applied twice each night — once around sunset which cools the atmosphere, plants and medium, and again about 3 hours before sunrise. When this system is used the amount of water needed can be reduced by approximately 30%.

8:4 LIGHT CONTROL

Almost all species and varieties of cutting and seedling grown plants will show stress if exposed to too much light in their first year. This first appears as leaf disorders and later as general ill thrift. The effects experienced under cultivation are the same as in nature where seedlings, especially Proteas, are seldom exposed to full sun during their first summer. If they are, they usually fail to survive. Although they germinate on bare or near bare ground (usually from late autumn and through the winter), by the time summer arrives there is other vegetation much of which is taller than the Proteaceae seedlings which partially shades them. Ideally, growing on areas for plants up to one year old should be set up with beds that have a system of removable shade over them, running north-south.

During summer days in New Zealand at temperatures of 30°C and a daily aggregates of 110,000 j/lu, plants that are smaller than those able to fill a 400cc (4 inch) pot with their roots and that have sufficient leaf area to shade the surface of the pot, should not be exposed to more than half of this radiation per day and for some varieties especially Proteas with green leaves this may be too much. This amount of light is equivalent to full sun for the first and last three hours and 50% shade for the rest of the day where the mid-day light reads 9,000 ft/c. For plants larger than the 400cc size, light levels can be increased on a pro rata scale with a maximum of 80,000 j/lu. From the longest day and for the following sixty days almost all plants of less than two years old of all species and varieties of cutting and seedling grown plants will show stress if they are

exposed to full light for the maximum hours of summer sunshine. As the plants become more established they will stand more light and attention should be given to this in the overall management bearing in mind that the gross daily aggregate of radiation is reducing as the seasons move from summer to autumn. The difference on a clear day midsummer to a clear day at equinox amounts to a drop from 110,000 j/lu to about 80,000 j/lu, a difference of 25% and the same again from equinox to midwinter.

Light levels below 40,000 j/lu for prolonged periods will result in weak development both above and below ground level and almost invariably result in an outbreak of fungal invasion and tissue break down of the leaf system. This should be borne in mind during winter with its associated short hours of sunlight and/or in periods when there are seasons of cloudy weather. [Refer to 9:19 for further information on the effects of low light levels].

8:5 CONTAINER MEDIUMS — General.

The medium that plants will be grown in during these initial phases of development is important, not only for their general growth and root development but also for their eventual establishment in field or garden. It must not only sustain the plant during this phase but it must also promote and develop a root system which should be predominantly the primary type and not proteoid.

Mediums must be free-draining but able to retain a sustainable level of moisture in the container for at least a day without being watered in the hottest, driest weather that you experience and it must be of a texture that does not airlock when it gets dry thereby making it difficult to get moisture in again. It must not act as a sponge when subjected to wet conditions, i.e. periods of heavy rainstorms or prolonged wet weather, and most important of all it must be compatible with the soil types and climatic conditions where the plant is to be finally placed. Unsuitable and incompatible container mediums are the prime reason for poor performance and losses during the first three years of establishment particularly in plantations that are not irrigated. The same problem occurs when plants are planted in soils that have poor moisture retention capabilities.

8:6 SOIL-LESS MEDIUMS

Early experiences some 30 years ago with seedling Proteas bought from a nursery that used its standard seedling mix containing 40% peat for tubing-up its plants, repeatedly gave high loss rates when the plants were being grown under "open ground" nursery production methods. It was noticed however, that if the seedlings were lined out before they had a root mass that would hold the peat together and it therefore fell away during lining out, the problem was alleviated. This observation led to some experiments where seedlings were grown in peat and non-peat mediums. The results from these early trials and subsequent experiments have resulted in my never using peat mediums (except in the root initiation phase) since that time because of the problems its use

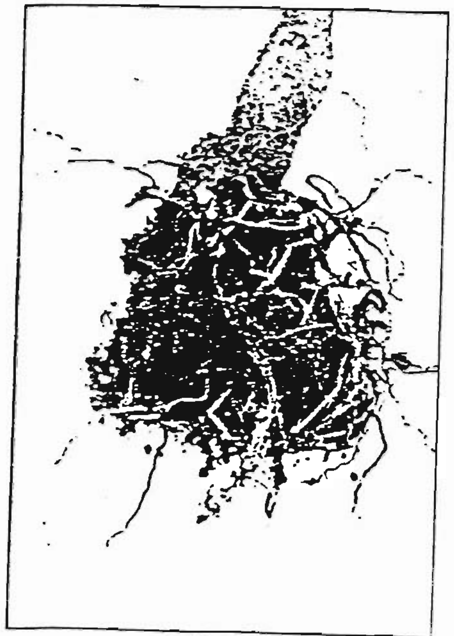


Fig. 49

Fig. 50

causes in the establishment of Proteaceae plants in plantation and garden environments in many New Zealand soil types.

This syndrome was virtually unknown in New Zealand until the early 1980s as until then almost all stock produced was grown under the "open ground" method of production. The plants were then wrenched and either bailed in hessian (burlap) or placed in containers for delivery to the retail shops or commercial plantations. Since the early 1980s most nursery production has changed from the open ground method to container culture where the use of soil-less mediums is common.

Whilst the plants grow quite satisfactorily in these mediums during the nursery production phase, it is when they are planted out in their final site that problems start. This observation is not restricted to the genus Proteaceae but is applicable to many plants found in cultivation.

In the case of Proteaceae, plants that are grown in peat/pinebark mediums often show a greater growth rate above ground during their time in a container than those in a soil-based medium. This is especially so when close attention has been paid to the application of balanced fertilizer blends throughout the year and to regular topping-up with liquid fertilizers. This growth however is rarely balanced by adequate root structure, especially in the case of Proteas and Leucospermums. It is not as evident in Leucadendrons.

Peat and pinebark are both of a texture that create several problems for Pro-

teaceae. Both get air-locked when they become dry and will then not take in moisture by normal capillary action from the surrounding soil. To be re-moistened they must be flooded to expel the air which then causes them to act like sponges and become excessively wet. Not only does this create a perfect harbour for soil-borne fungi, but also acts as a collection point for damaging water soluble minerals, i.e. salts, phosphate, lime etc.

The other principal problem associated with soil-less mixes is that plants often have great difficulty establishing a root system outside of their original container mass in the surrounding soils. It is common to see plants that have been planted for three years with little or no root activity past the perimeter of the original container (figure 49). By comparison those that are grown in mediums that are compatible to their planting site will rapidly become established in the surrounding soil type (figure 50). This locking up of the root system is not restricted to Proteaceae but is very common in many genera of plants that have been grown in soil-less mediums. It is a serious problem in Proteaceae however owing to their dual root system. The proteoid roots that peat pinebark fosters within its mass play little or no part in supplying moisture to the plant.

Comprehensive trials which involved the testing of the effects of various commercial mediums on the development and survival of Proteaceae plants were run over a period of three years and were completed in 1986. This trial has been documented and the results are published in Appendix One in this book. There is scope for further research in this area as the problems of establishment are widespread.

S:7 SOIL-BASED MEDIUMS

The medium I use for growing on consists of 50% fibrous loam top soil and 50% pumice. If the pumice is fine grained I add 10 parts of coarse river sand. It is appreciated that many growers do not have pumice or even perhaps a suitable loam top soil. In such instances some locally available materials should be tested, such as mixes of soils, sand, scoria, decomposed granite etc. always bearing in mind the texture of any potting medium will have a bearing on the subsequent development and type of roots your plants will produce, with coarse open mixes producing coarse brittle roots.

Stock-piling of turf or other materials that will break down into fibrous matter should be considered where sources of good loam are not available. Decayed fibrous materials do not have the same properties or effects as peat.

Some trials have recently been implemented to investigate the possible effects of micro-organisms on plants growing in soil based mediums. This has been done by incorporating aged (more than a year old) pinus radiata sawdust in the mix at 33%. Initial results indicate that provided ammonium nitrogen is kept supplied in sufficient quantities, development of primary roots is excellent. A side effect of this trial was that there was a total absence of fungi on Pr. magnifica whereas the control plants without the sawdust were infected. [Ref. 17:3 for further information on micro-organisms]. Further trials are needed to determine if these results are consistent and results will be published in an Addendum at some later date.

Not all materials that make up a medium have the same pH. or contain the same levels of nitrogen, phosphate and potash (NPK), the three principal minerals that control plant growth. For container production it is important that the pH. level be stable, preferably 5.0 or lower and the phosphate level in particular be very low (around 15 ppm). Proteaceae are not tolerant of phosphate at other than low levels unless the pH. is in the 3 to 4 bracket. Phosphate then becomes locked into the soil. Nitrogen and potash should only be present in moderate levels. If the levels of these three materials and pH. are not known the medium should be analyzed prior to large scale use.

Provided the medium you use fits the criteria as set out earlier of being free draining yet able to retain some moisture, with pH. and NPK levels within the acceptable range, the results of the growing-on phase will be very much related to your ability as a horticulturist.

8.8 HARDENING OFF

Before plants are potted on they should go through a further hardening off process. This hardening off is a continuation of the process that was carried out when the cuttings were being weaned at the end of the propagation phase. In this present case it involves reducing the plants dependance on water even further while at the same time increasing exposure to light and air movement to a point the plant may be handled without it being stressed. It is a simple but important operation and usually takes a week or so. If at any time during this phase the plants appear to be under undue stress (which will first show as a lack-lustre appearance of the foliage), the process should be slowed down until they recover. Failure to harden off can result in losses or a severe retardment to the plants development.

8:9 CONTAINERS

The type of container you will use for growing the plant on is a matter of personal choice and economics. The use of planter bags is now widespread and is a cheap and reasonably efficient means of container growing plants. I used them for a number of years but have now reverted to the use of hard pots for all phases of growing on. The decision to do this followed some extensive trials carried out on a number of varieties using planter bags and hard pots. In these trials there was no noticeable difference in the growth rate above the ground for a given capacity of container but there were marked differences in root development with the pots giving much better results. In addition to this there were fewer losses in pots and handling efficiency was five to two in favour of pots. Nevertheless I have seen some very successful crops grown in planter bags provided they are set out on beds that are free draining.

Containers are available in a never-ending array of shapes and sizes. For the production of Proteaceae the standard shape where the depth is slightly greater

than the diameter is quite satisfactory. From time to time plants are seen in containers that are very deep in relation to the diameter, as much as three or four times depth to width. The theory behind the use of these deep containers is that it stimulates a deeper root system in the plant thereby making it more resistant to drought following planting out. Whilst it is true that plants will follow these deep containers to their full depth this is of little use unless those roots are of the primary type and even then it is doubtful if there is any advantage over a well grown and prepared plant in a standard container.

As rhythm plants, Proteaceae go through surges of development both above and below the ground with either the roots being in active growth or the leaf and branch system, but never together at the same time. It is almost impossible to manipulate them against their seasonal growth patterns. If plants are planted just prior to or during the main primary root run which coincides with the onset of winter and runs through to early spring, and again from late spring to about the longest day, the roots are capable of penetrating to a depth of 60cm (24") in a three month period. With this capability there is little advantage of having an extra 10cm. of root on the plant when it is planted. If attention is given to providing a medium that is compatible with the final site and the plant is well prepared and planted at the correct season any standard containers are quite satisfactory.

8:10 PRODUCTION BEDS

The choice of material that the plants will stand upon can have quite a bearing on the amount of water that will have to be applied during hot and/or drying conditions. Plants standing on 10mm (3/8") free-draining gravel will need a lot more water than those standing on fine grained sand. The choice of material is often determined by what is available locally and provided the operator is aware of the differences and can adjust management to compensate there is little difference in performance. If a very fine silt sand is used there may be problems with drainage if planter bags or pots that are flat bottomed without a recess are being used. This is because they tend to "seal off" as they settle into the fine grains.

The use of almost any free-draining material that is available is permissible providing it is inert or does not influence the container medium in any way to the detriment of the plant. It is thought that the use of pinus radiata sawdust as a base for growing on may be beneficial to the plants because of a transfer of micro-organisms from the sawdust to the container medium.

8:11 GROWING "OPEN GROUND".

It is possible to grow Proteaceae plants under the "open ground" method of production and until the early 1980s this was the principal method used in New Zealand.

In this method of production the plants are lined-out in cultivated ground, usually in the spring. They are then maintained as a cultivated crop through until early winter when they are then wrenched, packed and dispatched as outlined in 8:6. It is a method of production which does carry some risks at the wrenching and lifting phase but does eliminate some encountered during the summer in container culture. It does however have the drawback that it is not possible to lift the plants until temperatures have dropped appreciably in the autumn/winter and if the plants are required for final planting out in the autumn it is therefore impossible to lift them to meet that deadline.

8:12 GROWING ON CAPILLARY BEDS

Water can be provided to the plants at this phase of production by capillary methods. It may be done either by the timed-flood method (see description below) or by the static level soak method as outlined in 6:6 for use during propagation. I have used this latter method and find it an excellent method during the summer especially if only small containers (400cc and under) are being used. At midsummer, evaporation is high, night and day, at ambient temperatures of 25°C and above and the use of static level capillary beds enables the operator to set a water level in the beds to maintain a supporting level of moisture to the plant under any prevailing conditions.

The timed-flood system of capillary watering consists of frames which are set up as shallow beds (about 2cm deep, 3/4 inch) with a hard base which has a slight fall to one end. The beds are filled with a coarse sand and the plants are set on its surface. In practice water is released at the higher end at predetermined times and it then runs down the hard surface beneath the sand wetting it as it goes. The plants standing on it are able to take up water from the sand. Flooding is normally carried out several times per day depending on the transpiration rate.

There are two problems that have been identified in the use of capillary watering during this phase of production. One is that the sand in the bed must not be of a nature that packs down too hard and in doing so creates small puddles under each plant if the level of water is set a little too high or during rain-storms. If this does happen for more than short periods it can create conditions in which soil-borne fungi can start. For this reason it is best to use a fine gravel for the bed rather than sand and make sure the bed is designed to drain automatically during rain storms. This can be achieved by providing a fall from side to side of 1cm. per metre (1/2" to 3ft) and filling the beds to an overfull level.

The other problem is that where the water supply carries unwanted chemicals i.e. salts or a high pH., the system of capillary watering will cause a build-up of these which may reach danger levels in both the bed and the medium in the containers especially during high evaporation periods. This can be controlled by heavy flushing with water from an overhead source at regular intervals if there are long periods without rain. Provided the operator is aware of these problems, capillary watering is an excellent way of establishing the plants in their first potting-on phase. This is particularly so if the operation is not continuously manned. I have left plants very successfully on a well-designed capillary bed for five weeks in midsummer with no attention whatsoever.

Plants should not be left on capillary beds for extended periods as the roots will pass through the bottom of the container and will become firmly established in the bed material. In extreme cases plants become dependant on the root mass outside of the container and may be lost when they are wrenched free of the beds.

8:13 TUBING-UP

Rooted cuttings should be potted up into a growing medium as soon as it is considered they are well enough established in their root development and they have been hardened-off. Cutting grown plants should be treated the same as seedlings are on their first potting, taking the same care and precautions against fungal invasion and possible dehydrated root zone.

When tubing or potting-on, certain procedures must be followed. At all times it is important to have the correct moisture level in the medium, which is the same as outlined for seedlings. If the medium is too dry it will dehydrate the roots and even a half hour exposure to this will do considerable and sometimes irreversible damage to the roots. Plants should always be handled quickly and never left lying bare-rooted on the bench.

Each plant must be set in the container (tube or pot) at much the same height as it was previously. If it is set too low it will not be able to produce a well-balanced root system while if it is set too high it will not stand up well and will also tend to dehydrate in the base of the plant. When setting the plant in the pot all roots should be turned downward (figure 51) and not left spilling over the top (figure 52). For this reason plants should be handled before they develop a root system that is longer than can be easily placed in the container. It is essential that the medium is left just firmed down enough to hold the plant tight. On no account should it ever be pounded down hard and tight as roots must have access to air to develop properly. When topping up the container it must be filled to overflowing (figure 53). This is the secret of successful container production of Proteaceae plants in soil-based mediums. By overflowing the container it makes it impossible for water to lie on the surface during heavy rainstorms or through over-watering as it just flows off over the sides. If these guide lines are adhered to there will be few problems in production.

Following tubing-up from the rooting medium the plants should be kept in an environment that is comparable with that in which they were conditioned prior to handling. If weather conditions are bright and hot they should be kept at light levels below 6000 ft/c and out of strong draughts for at least four days. By this time they should be showing some new root activity in the form of white translucent tips to the roots if the plant is gently tipped out of the pot and inspected (figure 54). This is the sign that all is well and they can then be exposed to more light and air movement while keeping moisture levels to a minimum without putting the plants under undue stress.

Fig. 51

Fig. 52

Fig. 53

It is important during this phase from about the seventh to the twentieth days, to make the roots hunt a little for moisture. Moisture levels are easier to control if the plants are bedded onto a moisture-bearing surface such as sand or saw-dust rather than left in solid bottomed trays. The open-bottomed trays illustrated in figure 30 are excellent for this phase as they may be bedded down onto a moisture bearing surface.

8:14 POTTING-ON

The timing of the initial tubing up is determined by when the seedlings or cuttings are ready to handle. Subsequent potting on, although not critical, should be scheduled to fit in with seasonal growth patterns. If this is done the development of the roots and subsequent vegetative growths will be stronger and larger. On no account should plants be left lingering for months without being moved to a larger size container. If they are left for months in a container which is too small for continued development they will go into a state of limbo. Although they will eventually come into a growth after re-potting or planting out, it almost invariably affects their development, health and life span. It is like a child getting rickets through malnutrition.

During a year most plants of under fifteen months old will go through at least two growth flushes and very often three if they have been well established by early spring. Just prior to each of these growths, the plants will take on a "bloom" appearance which is easy to see if the plants are viewed in the hour before sunset. The foliage of the plants show a radiance around the edges and tips of the leaves. This can be seen in all species and varieties and is the sign that the roots are on the point of making a rapid growth which will be followed about 20 days later by a vegetative growth flush.

When this "bloom" is first seen it is the time they should be re-potted into the next size pot or planted out into their final site. It is usual that the first potting of seedlings and rooted cuttings is made in 5cm (2 inch) pots and it is possible on the next move that they may be put straight on up to a 15cm pot (6 inch or PB5) which would probably be the final size before planting out.

My preference however is to shift them up in stages from 5cm to 10cm and then to 15cm. By doing this, although it is more work there is always an improvement in growth and percentages of well-finished plants compared with the single shift (5cm to 15cm). If it is spring when they are re-potted from a 5cm to a 10cm pot, the roots should develop rapidly and be showing around the perimeter of the whole pot within 15 to 20 days (figure 55). The plants will then make a rapid vegetative growth and will usually show a "bloom" phase again about 60 days from the potting up. This is when the re-potting cycle should be repeated, this time shifting from the 10cm to 15cm sizes. Plants handled in this way and grown in a well-designed growing area will usually make two further growth runs by late summer.

When the shift is done from 5cm to 15cm in one stage, the growth flush is more staggered and often confined to one or two terminals creating a "leggy" plant.

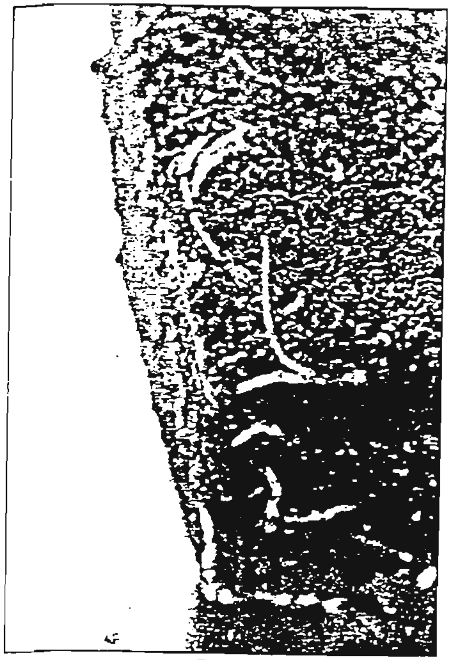


Fig. 54

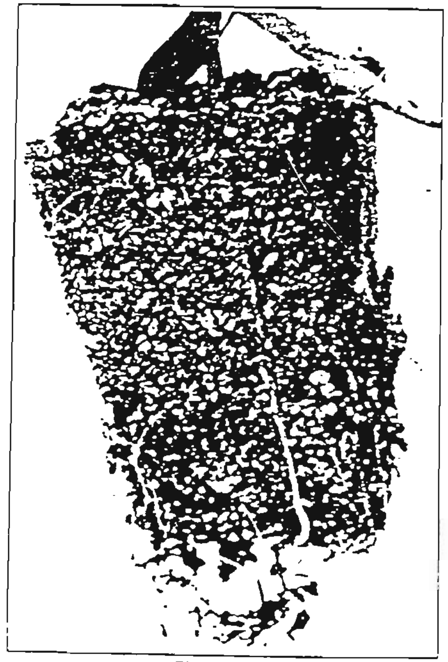


Fig. 55


Fig. 56

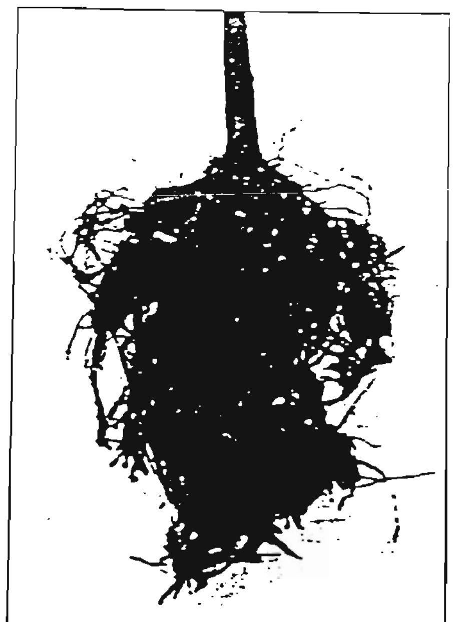


Fig. 57

This single shift will usually result in a total of only two growths for the summer which may then be followed by a weak winter growth. Winter growths should be avoided if at all possible as it puts plants at great danger from frost damage which not only affects the soft tips but also the lower section of the stems. This is dealt with in more detail in 10:6.

8:15 FERTILIZERS

Soils, sands, alluvial conglomerates, pumices, peat and any other materials that are used in a growing-on medium can each vary greatly in their base pH. and NPK levels. If these are unknown it is advisable to test them either individually or the finished mixed medium to ascertain whether the levels are within the safe range for Proteaceae plants.

The analysis can either be carried out by a soil testing laboratory or it can be done by the grower using a nutrient test kit. The one that I have used is the "Warrior" test kit which was developed by the Levin Horticultural Research Centre, a division of the New Zealand Ministry of Agriculture and Fisheries. This kit is available in two forms, one for testing mineral soils and the other for soil-less mediums. They are now available in many countries. Their use enables growers to ascertain with some accuracy the nutrient levels in their mixes and or plantation sites. The read out from these test kits is given as MAF units. To convert these to a ppm. rate the following formula is used:-

Nitrogen,	MAF unit	X	1 = ppm.
Phosphate,	MAF unit	X	1 = ppm.
Potash,	MAF unit	X	20 = ppm.

Not all varieties of Proteaceae have the same needs or tolerances of fertilizers nor do they all need them in the same NPK ratios. Because of this it has been necessary to arrive at a compromise that suits most varieties that are under cultivation. In the uses and levels of fertilizers during the growing-on phase there are two aspects of the plants' tolerance of nutrients to consider. The first is from initiation (seed or cutting) to the point of development when it will be moved from its first container (usually a 5cm. liner) to a larger container. The second phase is from that point onwards through its development until it is ready for planting out. The following recommendations pertain to soil based potting mediums with a pH. of 5. to 5.5. If pH. levels can be kept at around 4 or less the phosphate level in the media is not quite so critical. Soil-less mixes tend to leach quickly and rely more on being "topped up" periodically to keep the plants going. The fertilizer base is the same for both soil and soil-less mediums, only the quantities may differ.

In the first stage of growth all varieties have a very low tolerance of phosphate and care should be taken to eliminate this from the potting mix by making sure that the materials used in the medium do not contain it at any significant level. It is best not to add any fertilizers at all to the medium that is to be used for this first potting up, leaving it "hungry". The base levels of all nutrients should be kept on the low side as it is better to have to add nutrient by liquid feeding rather than to have an over-dose already in the medium. Nitrogen at 20ppm., Phosphate 15ppm. and Potash 100ppm. should be satisfactory in any good free draining mix. The values given are for NPK status.

In a soil-based mix, the roots of young plants tend to hunt through the pot and produce a vastly superior root system to those that develop in peat based mixes. The plants in the soil-based mix develop a strong primary root system (figure 56), where as the peat-based mix promotes proteoids (figure 57). The primary roots in the soil based mix can be even further improved by the application of sulphate of ammonia particularly during the mid- to late-winter months. This is applied as a drench at 5000 ppm. at ten to fourteen day intervals which will give results as seen in figure 58. The first application can be made fourteen days after tubing-up. If sulphate of ammonia is applied to plants growing in peat-based mixes it stimulates even greater development of proteoid roots. Never apply sulphate of ammonia to plants that are suffering from dehydration - water them first.

In the second stage of production it has been found that although plants have relatively low requirements of fertilizer, the application of slow- release (nine months) fertilizers is beneficial provided they are of the correct balance and are applied prudently and accurately. A medium with the same base nutrient level as used for the first tubing up can be used for this second stage as although the NPK is somewhat low the application of the slow release fertilizer will bring the levels up.

Following on from experiments done at the Levin Horticulture Research Centre in New Zealand several years ago, it was recommended that a slow-release fertilizer with an analysis of 19 nitrogen, 2.6 phosphate, 8.3 potash plus iron should be used at a rate not exceeding 1.7gm per lt. of medium. This recommendation was based on soil-less mediums. When this rate has been used as a single application in a soil-based mix it has given a reading twenty one days following application of:- Nitrogen 35ppm, Phosphate 50ppm. and Potash (K) 500ppm. This level is a little high in Phosphate and Potash which explains a slight intolerance by some varieties (see text below).

Provided this fertilizer is split into two applications it has proved satisfactory in most respects of plant health both above and below the ground when used at the annual rate of 1.7gm/lt (or even up to 50% higher for some varieties) in soil-based mediums. The exceptions were in Ld. laureolum, Pr. pudens, longifolia, scolymocephala, coronata, stokoeii, Serrurias and all Banksias which all show chlorosis in the leaf indicating an excess phosphate level even at the basic 1.7gm/lt rate especially when it has been applied as a single dressing. With Proteas it has also shown as tip burn on the leaves but this is usually of a short duration indicating a temporary overdose of salts probably derived from the potash.

Best overall results have been obtained by applying the fertilizer as an over-dressing at the period just prior to rapid growth commencing in spring with lesser results as the summer progressed. The safest and most sustained boost to

development was obtained by splitting the quantity into two applications which were then applied as a top dressing, six weeks apart. Fertilizers should never be used to boost late autumn growths as this makes plants very susceptible to frost damage.

On no account should fast release fertilizers such as ammonium phosphates and nitrates be used on container stock as they will cause severe damage.

8.16 SOIL-BORNE FUNGI

During the entire growing-on phase which is usually at least one year, plants must be maintained in a healthy condition free of pests and diseases both above and below the ground. There is no doubt that the soil-borne fungi Phytophthora Cinnamomi, Rhizoctonia and Fusarium are the greatest fungal dangers in Proteaceae production and unless adequate steps are taken to avoid and control them there will be many losses both during this phase and following planting out. During this production phase most problems will come from Rhizoctonia and Fusarium, while Phytophthora Cinnamomi will be the principal problem in the plantation phase. It is important that growers should be able to recognise the symptoms and results of these diseases as the control is not the same for all of them.

Rhizoctonia and Fusarium are diseases that invade a plant (which are almost always less than a year old) at ground level and cause the main stem to die. As the effect of the infection progresses the plant dies in both an upward and a downward direction with the first noticeable symptoms being a slight yellowing of the leaves and a lack-lustre appearance of the whole plant. By the time this is seen the plant is well and truly dead (figure 59). The onset of these diseases is not accompanied by the wilting of the terminal tips as it is with Phytophthora which invades the plant below ground level, entering through the root system and there by killing the plant from the bottom up and not from the middle as do the others. The principal causes of Rhizoctonia and Fusarium are a lack of adequate light and air movement at ground level aggravated by over watering, while Phytophthora is induced by high temperature and water content within the soil.

Applying fungicides by the high-volume water method is by far the most effective means of control of these soil-borne fungi [ref.9:6]. The control and treatment of these fungi is dealt with in the section on fungi control [ref.9:10 & 9:11]

8:17 GENERAL MAINTENANCE AND HANDLING

General maintenance of plants during this growing-on period consists of keeping a protective coat of fungicide on the plants during hot humid conditions, especially where a combination of temperatures above 25°C and humidity above 80% prevails. This is very important when handling any grey leaved types and those with soft succulent growths.

With Proteaceae, more than any other genera of plants, it is important to

Fig. 58

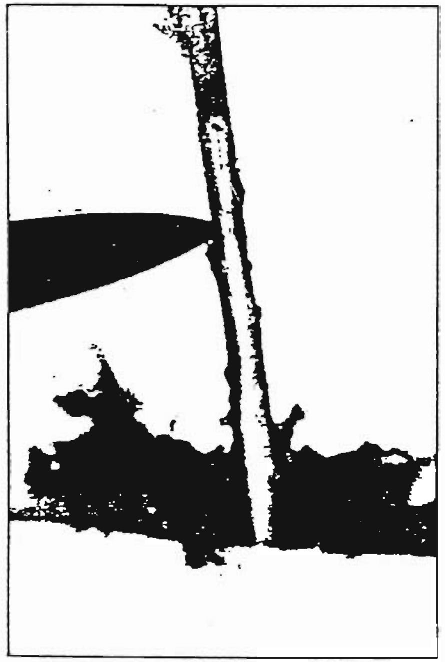


Fig. 59

prevent the incidence of fungal invasion both above and below the ground rather than to try to cure it once it has become established. This should be borne in mind at all times and in all conditions, with the necessary measures of control implemented before rather than after problems occur. Infestation by insects both above and below the ground should be kept in mind but is not normally a great problem provided a regular maintenance programme of control is maintained during this phase.

As the plants grow through their summer flushes, it is important to watch that they do not become crowded in the beds. This will usually occur about 40 to 50 days after the longest day if they make their second growth without being shifted up into a larger container size. If they are already in their final container size they should be double spaced on a grid. This will give them room to finish their development prior to final planting out. This is important with all Leucospermums and Leucodendrons with grey hairy leaves, (daphnoides, nervosum, eliminese etc) as without sufficient air movement these will become infected with fungi. Always space plants so plenty of air can pass between them.

8:18 CONDITIONING PLANTS FOR FINAL SITING

This is the final phase of the propagation cycle. It consists of conditioning the plants so that they do not suffer a serious set-back at planting out.

This phase is usually done in the autumn and normally takes about a month. It

is the same as the programme carried out at the post-propagation and pre-tubing phase except at this final stage the water should be reduced to a level just above the dehydration point while at the same time increasing light and air movement to full exposure taking care not to do this too rapidly. To do this the plants should be well spaced out (at least double spacing) and have the quantity and frequency of water gradually reduced to a level where the plants are having to hunt for moisture. Depending on the season, the plants may have to be shaded for the initial stages of this programme as the supply of water is reduced. This will depend on the prevailing temperature, humidity and wind conditions.

Conditioning plants prior to planting out is very important and planting should not be attempted until the plants are in a condition of hardiness matched to their planting site.

SECTION NINE

The Control Of Diseases and Pests

9:1 OVERVIEW

In the cultivation of Proteaceae it is necessary to control against the invasion of fungi and pests that are harmful to the plants. The amount of control that is needed depends on the climate in the location where they are being grown, what fungi and insects are present in that location, the end use of the crop and in the nursery situation, the skill of the operator.

Climatic conditions have a great influence on whether fungi are a problem in a particular location and will also determine which ones are present and the intensity of their invasion of the plants. The incidence of fungal invasion both above and below the ground in Proteaceae is always related to temperature, humidity conditions. In areas where there are high temperatures (+30°C +85°F) and low humidity (35%) or conversely where temperatures are low (below 15°C) 60°F) and the humidity is high (over 85%) there will be fewer problems.

However in climates where temperatures above 18°C (65°F) occur regularly at the same time as the relative humidity is +75% you can expect fungal invasion to some degree in most varieties. The problem will compound as the temperature/humidity aggregate increases to a point that when the temperature in Celsius is added to the humidity percentage and the sum total is 105 and over, fungi becomes very difficult to control in some varieties. If the temperature is recorded in Fahrenheit the sum total then reads 160 and over.

Example:- temperature 25°C added to humidity 80% = 105
" 78°F " " " 80% = 158

For the purpose of identification of these conditions, the symbols th/c105 and th/f160 are used throughout this book when referring to a temperature/humidity climatic situation.

It may be seen from the foregoing why there are fungal problems in some areas where Proteaceae are being grown. In New Zealand for instance, some locations are subjected to periods during the summer when tropical storms drift south which are carrying very wet warm air which can be present for many days, sometimes with little or no air movement. Proteaceae plants especially the grey, blue-grey and hairy-leafed varieties can not tolerate such conditions and can be badly damaged or lost by fungal invasion during these periods.

Insect infestation of plants is also governed by the climate as well as location. Insects either thrive or become subdued in population numbers depending on

temperature and moisture levels prevailing. Populations of species present and active vary greatly season by season and from time to time they can become a problem particularly in cut flower plantations.

In an outline such as this it is impossible to cover the huge range of fungi which can invade Proteaceae or identify the individual species of insects that will affect plants as each location will have its own local form of fungi and insect populations. What it can do is to distinguish those fungi forms that are common to all growing areas and identify the different types of insects that will be encountered. It can also outline how to combat and control the problems caused by fungi and insects, and in general terms this is what the following text does. There will be occasions when problems will be encountered outside of those covered here. In such circumstances it is important that expert advice should be sought for information on what they are and how to control them.

There are a number of ways of combating the presence and or the problems that are caused by fungi and insects. In the culture of Proteaceae the provision of the correct environment by paying attention to air movement, light levels and selecting the correct variety or variant for a particular location will go a long way in reducing problems. There are also biological means of control such as providing a sward of clover through a plantation which will assist in suppressing Phytophthora or using birds to keep down the insect populations. It is probable that the fostering of high levels of micro - organisms in the soil assists in making some varieties more resistant to fungal invasion [ref. 17:3]. Natural and bio- logical measures are often sufficient to enable Proteaceae to be grown sat- isfactorily in a garden/landscape situation but when they are being grown as a commercial crop and being sold internationally it is usually necessary to use chemical controls to ensure the product is clear of phytosis and therefore acceptable in the importing country.

9:2 TYPES OF CHEMICAL FORMULATIONS

The chemicals used to control fungi and pests are of two basic types, contact and systemic. Contact sprays work by forming a total cover of chemical enveloping the plant and are effective until it becomes oxidized or weathers off to such a level that it is ineffective or the plant has grown new tissue thereby by-passing the protective layer. When any of these happen a new application of chemical must be applied to retain control.

The systemic types work by entering and becoming a part of the plants sap stream and are efficient as long as they do not become diluted to an ineffective level through an ageing process or when the plant grows more tissue. This happens more frequently when the plant is growing rapidly in the spring/summer than it does in the winter. To keep a controllable level of chemical in the plant, systemic compounds must therefore be applied more frequently during growth than dormant periods. Systemic chemicals are very effective if they are applied at the recommended rates but when they are applied at those rates it has been found that some varieties of Proteaceae are susceptible to foliage damage. It has been noted on a number of occasions that formulations of both fungicides and insecticides have caused growth regulatory effects particularly on plants less than two years old and Leucadendrons of the multi head types of any age. The effects are usually of a short duration but can cause leaf distortion which makes the product unsalable or in propagation may inhibit rooting. This is particularly so when the plants are in very active growth or chemicals are applied to plants under stress from dehydration. Because of this, care must be taken when using these formulations especially on young plants that have a high percentage of soft tissue. Systemic fungicides and insecticides applied by the high-volume water method outlined in 9:6 minimises the risk of foliage damage.

The systemic fungicide that is most commonly used in the control of fungi in Proteaceae is Benlate. If properly applied it gives good control but it should not be used more than three or four times per year or it will loose its effectiveness. This fact is noted on the container labels.

If systemics are used during vegetative propagation before root initiation has begun, it will often inhibit the rooting process and in some instances arrest it permanently. If possible operators should refrain from using this type of chemical in the propagation area for at least thirty days after setting the cuttings or on stock plants within twenty days prior to harvesting the cutting material.

Both the contact and systemic formulations come in many forms and each one has usually been developed for, and is efficient in controlling one or two fungi or insect groups but none will control all forms and types. Because of this it is necessary to use or have available at least two different formulations each of fungicide and insecticide which may be of either the contact or systemic types.

There are composite formulations available for home garden use which will control a broad spectrum of fungi and insects and in most instances are quite suitable for this use. For commercial production it is much better to use a specific chemical to control a particular problem.

9:3 METHODS OF APPLYING CHEMICALS

The effectivness of any chemical is to a large degree controlled by the competence with which it is applied. This is particularly so when you are dealing with plants that have a leaf structure that is difficult to wet as are a number of Proteaceae varieties. There are many ways of applying chemical sprays. The principal ones are: high or low pressure from spray nozzles; air blast assisted dispersion; high-volume water application.

9:4 HIGH AND LOW PRESSURE METHODS

The most common way of applying sprays is by high or low pressure methods which use nozzles which are either fixed to a boom or are hand-held as a gun. This is an effective means of application provided the booms are arranged in such a manner that they will distribute the chemicals up under the leaf canopy

as well as down from the top. Low pressure application has a problem in that it does not have good penetration through dense foliage especially if it is of the hairy-leaf types such as many Leucospermums. The high pressure method has a much better penetration but if pressures of 400 to 500 psi. are directed at very close range onto foliage, some tissue damage is inevitable. The booms should be arranged to give a pattern matched to the crop and they may have to be altered for each individual variety otherwise much of the chemical is blown past the leaf area and dissipates on the ground. Hand-held and directed spray guns of both high and low pressures are capable of giving good coverage but are somewhat inefficient in man hours.

9:5 AIR ASSISTED METHOD

The principle in the use of this method is that the spray is injected into a high volume air stream and is dispersed throughout the plants in very fine particles. Such a system is effective provided the correct amount of chemical is distributed per area treated and that the foliage is properly covered. It is usual that with this type of application only 35% of the volume of water is used as compared to boom or hand held high low pressure system. Because of this many varieties of Proteaceae plants do not get fully wetted down with this method and cover tends to be incomplete on mature plants. This method is more suited to the application of systemic rather than the contact materials.

9:6 HIGH VOLUME WATER METHOD

This method has been developed to meet the special requirements of Proteaceae plants particularly in a nursery situation during their first two years. It involves injecting the chemical into the flow of water coming from a 15mm. (half inch) hose in accurately calibrated quantities. This can be achieved by the use of an in-line injection pump which is powered by the water as it flows through. This pump picks up chemical and injects it into the water flow in the form of a concentrated solution at a regulated rate, usually 1%. The concentrate is of a strength so that when it is mixed into the main stream, the active chemical is 35% of the normal rate for boom or hand held spraying. This mix is watered over the plants as a full wetting drench which uses three to four times the amount of water that would be used in the high/low pressure method. When applied as a full wetting drench, the active chemical content equates to the same amount of material per area treated as it would by conventual spraying methods.

This method has been found to be an excellent means of applying fungicides, insecticides and liquid fertilizers and virtually eliminates the risks of chemical toxicity and leaf disorders sometimes associated with young plants receiving an overdose. It gives a control over fungi that is much improved on normal spraying methods of application and in most instances allows a longer period between treatments. This is because it not only treats the plant foliage but also the medium and ground surfaces. In doing this it controls both the problems on the plants and also on all surroundings which act as a host.

This method should be carried out early in the day as soon as the overnight watering or dew has dried off. This gives a long period to dry before nightfall which is important. Do not apply while the foliage is still wet as this will dilute the chemical to an ineffective level. Apply as a heavy droplet rather than a directed jet, to a level of wetness just past run-off. The method can also be used through an overhead irrigation system and provided coverage is even it works as well as the hosing method of application.

9:7 HELICOPTER APPLICATION

In plantations planted on difficult terrain this is an excellent means of application and gives good cover as the down draft of the rotors forces the chemicals throughout the crop. Cost evaluations indicate that it is more cost efficient than hand spraying on steep sidings where it is impossible to get ground spraying equipment. Fixed wing aircraft are not fully effective as they do not give a spray pattern that will treat the under sides of the leaves.

9:8 SPECIAL CONDITIONS TO OBSERVE WHEN APPLYING CHEMICALS

The plants of some varieties of Proteaceae are seasonally sensitive to many of the chemicals that will be used on them to control fungi and insects. Because of this it is necessary to take special care under certain conditions when applying sprays and never use a new product without a trial with a few plants.

Plants of certain varieties can be used as indicators and in this Ld. laureolum closely followed by Pr. scolymocephala and stokoei are good early warning varieties of chemical toxicity. These varieties will respond to overdoses or incompatible spray mixtures by curling the edges of their youngest leaves, bleaching the colour of the growth tips, taking on a reddish tinge around the perimeter of the more mature leaves, tip die back or a combination of these symptoms. Whilst tissue damage from chemical toxicity is seldom fatal it does disfigure the foliage and can make a commercial crop unsalable.

Plants should never be sprayed with any chemicals when they are under stress from dehydration from any causes, nor should they have it applied in full sun if the temperature is above 25°C (78°F). Safest and best cover is obtained when sprays are applied in the morning just as the foliage is drying off from overnight watering or dews.

With some chemicals although they are safe when applied on their own they can become toxic when they are mixed with others. In particular insecticides in the liquid forms of concentrate and some wetting agents can cause this problems and are one of the reasons for bud scorch on Proteas during the production period and leaf blackening after the harvest of cuttings or flowers [ref. Section 14]. Never use copper-based sprays within twenty days of any other chemicals as copper is incompatible to almost all other chemicals.

Most problems can be avoided by reading and following the instructions printed

on the packs containing the chemicals. The practice of adding one more for luck when measuring must not be used. It is often that one extra one that will cause foliage damage. If sprays are applied in the early morning and or by the high-volume water method there should be few problems.

9:9 THE CONTROL OF FUNGI — OVERVIEW

Like all plants, Proteaceae have their share of fungal problems. The magnitude, type and intensity of the problems vary from one location to another and also depends on the varieties being grown in any particular climate.

From time to time I am asked: "Do you have any fungal problems in Protea growing?" The short answer to this is: "Yes, if you grow Proteas you will have fungal problems and I do!" However knowledge gained and techniques developed in handling and avoiding the causes of such problems in these plants makes the control of fungi a simple everyday chore.

In the culture of these plants, especially from initiation to the end of their first year, much can be done to avoid conditions that will foster fungal invasion and it is much better to carry out practices to elude the problem rather than have to treat it later. Almost all fungal invasion can be minimised by paying close attention to good soil drainage, air movement and providing the correct levels of light for the particular variety.

A lot of fungi infection can also be minimised if plants that act as hosts are either treated at the same time as the crop or removed from the area where the plants are growing. Host plants can be hedges, grasses, weeds, ornamental plants in gardens, a particular plant or group of plants of a particular clone in a crop or even dead trees or old wooden fittings. Where a problem exists, the identification of the source and its treatment or removal will greatly reduce the subsequent levels of infection.

In spite of taking every precaution to avoid fungal problems, special climatic conditions prevail from time to time which makes chemical control a necessity. This is proving increasingly frequent in the production of Proteaceae in both the nursery phase and in cut flower plantations where the practice of mono-culture at high densities, sometimes in less than ideal situations, creates conditions that foster fungi not previously known to invade Proteaceae. There have been several notable developments of fungi in New Zealand over the past few years in Proteaceae crops. These are: Wiri Wiri Wilt, an undefined problem principally confined to the Leucadendron cv. "Safari Sunset"; silver blight in Leucadendrons; and a new strain of drechslera in Leucospermums. It is also probable that many fungal problems in production nurseries are unwittingly being carried over from one years crop to another by the practice of propagating from material harvested from production beds rather than stock plantations. Early signs of infection are much easier to detect in well maintained stock plantations than they are in production beds.

Most fungi may be controlled but once it is present it is improbable that it will be eliminated in any crop. Because of this it is necessary to continually monitor the crop and apply chemicals to control fungal invasion. If it is uncontrollable, remove the plants. This is particularly so in commercial crops when the plantation is made up of a plant population of mono or near mono species/varieties. Problems will normally be of a lesser degree in landscape culture where plant population is less intense.

The following information is given as a general guide to the control of fungi. As the problems that will be encountered vary so much from one location to another and all chemicals are not universally available it will be necessary for operators to implement their own specific treatments for the special problems they will encounter. In commercial use, expert advice should be sought from the agricultural chemicals division of the parent distributing company for full information of their product's effectiveness in controlling specific fungi and the correct method and rates of application to gain that control. Don't rely on what the local nursery shop assistant tells you.

9:10 PHYTOPHTHORA CINNAMOMI

One of the principal fungi that affects Proteaceae below the ground is phytophthora cinnamomi. This is present in many soils through out the world and it affects Proteaceae plants wherever they are grown.

It is a water-borne spore which under the right conditions can multiply at something like forty eight times every twenty four hours. To do this it needs temperatures of above about 18°C (65°F) and a high water content in the soil. It is in the conditions experienced when heavy summer rains occur that this fungi becomes a problem. Phytophthora is not usually a problem during the winter months when temperatures are often below danger level.

In a nursery or plantation situation there are a number of measures that can be taken to control and avoid it such as making sure that the medium is clean from infection before you start, that it is not like a sponge and holds excessive quantities of water, that it is treated with chemicals as a preventive measure and that there are no "ponds" in the container area. Field control is difficult and every precaution should be taken to choose sites that are well drained and make sure that the plants are free of the problem before planting. There is evidence that indicates that a heavy sward of clover in a plantation helps to minimise the active presence of Phytophthora. Initially this was believed to be because a heavy cover of clover helps to keep the soil temperature down but there are now indications that it may also be because of the increased micro-organism activity clover fosters in the soil. The introduction and fostering of certain micro-organisms in our container mixes and plantations may be the key to the control of many fungal problems including Phytophthora in Proteaceae. [Ref. 17:3 for further information].

The chemicals that have been available and used in Phytophthora control are Terrazole in both wettable powder and emulsion forms, Ridomil and Alliette in

Wp form. All of these have been found to be useful materials but not infallible. Terrazol Wp when incorporated in the potting medium at the rate of 100mgm per cubic metre has been found to be quite satisfactory for a period of six to eight weeks. It should then be backed up with either Terrazole in the emulsion form or one of the other two (Ridomil or Alliette).

If Terrazole in the emulsion form is used it may be applied through the over-head watering system quite safely provided certain precautions are taken. The period when it is likely to have to be used is about the longest day when there will be considerable soft vegetative growth on the young plants. When applying it in this manner it is important to make sure the plants are not under any stress at all from dehydration. The plants should be well watered the day before the chemical is to be applied. They should also be damped down just prior to the application of the chemical which may either be injected into the watering system or sprayed on at the appropriate rate. Whichever method is used it is important to water again immediately to ensure the chemical is washed off the foliage. Never apply any of the chemicals used in the control of Phytophthora when temperatures are above 25°C coupled with bright sunshine.

The rate of application of Terrazole 25% emulsion that has been used safely and with satisfactory control is 25mls concentrate per cubic metre of medium in the pots. This should be applied at a dilution rate of 1:2000 using 200 ml per 15cm. container. This is equivalent to 1ml concentrate to 10 plants in 15cm (2lt) pots or 1ml to 8 plants in PB5's. Failure to keep to this rate and carry out the procedure outlined may result in burn to the foliage and damaged growth buds. This material should not be used on seedlings until they are well established and hardened off unless it is diluted at 1:10.000, (1ml to 10lt.)

Ridomil should be used with restraint especially on smaller plants as Proteaceae have shown an intolerance to other than low levels of this material, especially during hot bright weather. When this chemical is used it must be drenched in as it will only travel in an upward direction in the plant and as it is the root area that is being treated it must be flushed down to that level. On young plants up to eight to ten leaves, a rate of 3mgm of 25% Wp mixed with 1lt. of water (1:330) and applied as a wetting drench and then flushed in has given good control. For larger plants 5mgm in 1lt. of water (1:200) sprayed over 50 plants in 15cm pots (40 pb5's) and then flushed in has been used with safety and provided good protection. A second application at these rates within 60 days may cause disorder in the leaves of some varieties especially Ld. laureolum, Pr. scolymocephalla and stokoei and to a lesser degree in many others. This disorder which first shows up as rainbow colouring in the leaves is not fatal but if acute will cause at least a check in the growth rate or a total stop to growth until the following spring. I have found Ridomil a good material if used prudently but it should not be used on very young plants or unrooted cuttings as it may inhibit rooting.

Alliette has been used under controlled experiments for several years in all phases of propagation, right from small seedling and freshly set cutting stages through to three year old plants. It is a systemic material but unlike Ridomil it will travel in a downward direction in a plant which enables it to be sprayed on and not necessarily drenched in. It also is used at the rate of 5mgm per lt per 50 plants in 15cm pots with good protection and has proven to be safe and effective on all varieties at all stages of growth. There have been reports of toxicity similar to those from Ridomil from some growers in the use of this material. This appears to be the result of it being applied to plants under stress. Trials carried out by the distributors on a range of varieties in our nursery in 2lt pots and applied as a wetting spray at 5mgm per lt water at thirty day intervals throughout the summer gave complete control with no side effects on some 20 varieties tested.

These three chemicals must be regarded as preventative measures rather than a cure for Phytophthora. There are now also several other brand names of chemicals available in some regions and the use of phosphorus acid as a control has also been reported to have had some success.

9:11 OTHER SOIL-BASED FUNGI

There are a number of other soil-based fungi which can infect Proteaceae plants. These are not usually a problem in older established plants but they are of concern in the nursery stage of production especially in seedlings and in freshly rooted cuttings.

The principal ones are Fusarium and Rhizoctonia. These proliferate under the same conditions as Phytophthora and good drainage at surface level will do much to prevent invasion by these fungi into the plants. The incidence of low light levels for extended periods and poor air movement foster the develop of these fungi and close attention should be paid to these points when handling plants that have a lot of soft tissue near ground level. The light level at the base of the plants reduces as the foliage canopy grows, when weed growth becomes excessive and when the trajectory of the sun declines as summer progress into winter. The change in the sun's trajectory is often the reason why ground level fungi become a problem in late autumn. In vegetative propagation the setting of cuttings in the trays/beds at a density that is too high will also cause problems.

Whilst prevention through attention to mediums, watering and the conditions where the plants are being grown is the best method of control, reasonable results will be achieved by the regular use during danger periods of Captan, Antracol, Thiram and Ronilan used as soil drenches. In this the use of the high-volume water method of application has proved very successful in achieving almost total control.

9:12 FUNGI ABOVE THE GROUND

The fungi which invade Proteaceae above ground level are many and vary from one location to another. Because of this it is only possible to generalize and deal with the specific ones which are more or less universal wherever Proteaceae are grown. Two problems in making recommendations is that in-

structions for treating Proteaceae are seldom found in the instructions on the chemical packets and that any country can have different brand names for the same chemical, eg. Captan = Orthocide. However as most of the fungi found on Proteaceae are also found on many other species of plants it is safe in most cases to use the lower rates recommended for ornamentals on the packets of any particular product.

9:13 BOTRYTIS

The most common fungi that will have to be dealt with is Botrytis cinerea. This fungi is present almost everywhere and will be found on most plant species. In Proteaceae it will affect all varieties to some extent with those with hairy leaves being at the top of the scale and those with smooth leaves being least affected. At and above th/c105 (th/f160) conditions all varieties may be affected to some degree in the growth tips, immature leaves and flower buds. Commercial varieties that are particularly susceptible to this fungi are Pr. magnifica and Lsp. cordifolium, but all varieties are at risk.

The problem almost always invades the plant at the soft growth tip or edges of the youngest leaves and forms a grey powdery mildew which under the right conditions can spread rapidly and once established may invade older leaf and stem tissue. The best control is to provide good air movement, but during high risk periods this will have to be backed up by the application of chemicals. It is much better to anticipate the problem and apply the chemicals as a preventive measure than to have to eliminate it once it is established. Captan, Difolatan, Ronilan and the systemic Benlate will all control this fungus provided they are applied as a regular maintenance during high risk periods.

At the same time that Botrytis is present and active there will also be other fungi active and it is difficult without expert identification to identify which ones they are. Fortunately most of these are controlled by the application of the chemicals listed above.

9:14 PESTALOTIA

If fungal problems persist following treatment for Botrytis the plants are probably infected with Pestalotia. This fungi is more likely to appear in the early autumn than the spring/summer seasons and once established can persist through the winter. It can however be a serious problem on seedlings in the spring and is usually fatal. It mostly affects Leucadendrons and Protea and is seldom seen on Leucospermums. It first appears as a brown lesion on the leaf, usually towards the tip but may be on the side about half way along. It appears to start where there has been minor tissue damage to the leaf area caused by photo-sensitivity to sunlight, wind or chemical burn, insect damage etc. In the winter it often becomes active in a plantation or container stock following minor frost damage to the foliage. Its incidence seems to be related to constantly high humidity levels coupled with low daily aggregates of light (j/lu) irrespective of temperature levels. As it develops a dark brown to black fringe shows on the side of the infected part. This fringe is always on the side which is nearest the stem of the plant. If it is left unchecked it will progress quite rapidly along the leaf and eventually it will enter the plant stem via the leaf petiole. If this happens on young plants it will often kill them.

When Pestalotia becomes established it is difficult to eradicate and a close watch must be kept for several months through until spring when in a plantation situation it will usually disappear of its own accord. When it appears in the early autumn, even if it is brought under control it may reappear again during the winter. If it does reappear it must be retreated. If it becomes established, cold weather will do nothing to arrest its progress.

Control is by spraying with Benlate/Captan, Octave and the systemic Tilt. On young plants it may be necessary to apply these at three day intervals three or four times to arrest its progress and control it. Another chemical which has shown quick and good short-term control is Antracol. This is a chemical which is used extensively in the control of late blight in potatoes and has been found to be safe with no toxic side affects.

Treatment should continue until the dark brown/black edge disappears and becomes a grey/brown colour. As long as the black edging is present the fungi is still active. If the infection is not widespread consideration should be given to clipping off all infected leaves and burning them. This is not a substitute for applying chemicals and these should still be applied as outlined above.

9:15 DRECHSLERA

Drechslera can be a serious problem particularly in Leucospermums and in some locations it has made the commercial production of Lsp. cordifolium as a cut flower impossible. It is particularly prevalent in areas that have high humidity and is virtually unknown in low humidity areas.

Drechslera is widely distributed in various forms and has infected Leucospermums in South Africa, Australia and New Zealand with each country having its own particular strain. It is identified initially as a tan coloured spot which develops a purple margin. As it progresses it destroys the leaf and sometimes the stem tissue and in an advanced stage forms a canker like appearance on the stems causing die back and sometimes death. Its natural host is grass and its principal shrub host is Leucospermum but it can also occur on Proteas and Leucadendrons.

Once it is established, control is difficult and not very effective. Preventative protection can be carried out by applying contact type sprays (Rovral, Captan, Difolatan) alternated with systemic (Tilt etc) every two weeks from early spring through to early winter.

9:16 SILVER LEAF (Common name).

This fungi which is commonly called Silver Leaf or sometimes Silver Blight is commonly found in stone fruit crops and has now become established in

Leucadendron plantations in New Zealand. The incidence of this fungi in Proteaceae crops in New Zealand is probably primarily due to the practice of growing willow shelter belts. Willows are one of the principal hosts of silver leaf. It is easily detected in Leucadendron plants as they take on a slightly silvery appearance in the leaf and the bracts become pinkish and are usually slightly stunted. The plants become infected through cuts from harvesting the crop or pruning. Greatest danger of infection appears to be when severe pruning is carried out in the spring especially after sap flow has begun.

Control is by good hygiene at all times and the spraying of all cuts following harvesting or pruning with Difolatan/Captan + Benlate. Once established it is almost impossible to eradicate and it is best to remove infected plants from a plantation as they are a constant source of infection to others.

Footnote:- A very recent development in the control of silver leaf is currently under trial by some New Zealand growers. Treatment involves implanting plugs containing micro-organisms into the infected plants. This control measure was developed to control the problem in stone fruit crops where it is showing promise.

9:17 SEPTORIA

A short period of high humidity about two months after the longest day appears to trigger Septoria infection of plants. It shows as an orange spot with a dark edge and infection can reach a level that the leaf area of a plant is virtually completely covered by these spots. At this level it is very disfiguring and renders the crop unsalable. It has been noted on many occasions that the greatest incidence of this fungi has been where plants have been in close proximity to poplar and willow shelter belts indicating either that these may be a host or that they are creating a humidity trap that triggers off the problem.

Once infected there is no way that the disfigurement of the leaves can be repaired. For a commercial crop it is therefore necessary to carry out preventative spraying with Benlate, and if the host source can be identified by removing it.

Infection by Septoria should not be confused with a condition of similar appearance that is common on some clones of Ld. laureolum. This is a galling of the tissue and appears to be the result of stress from high temperatures and light experienced during the summer. It does not show up to a casual observation until the onset of colder weather. These lesions however sometimes become infected by fungi as a secondary problem.

9:18 DIE-BACK

Tip die back is quite common in a number of varieties. It is often difficult to define whether it is a physical disorder that is peculiar to particular clone, or whether it is the result of photo-sensitivity, reaction to chemicals, fungal invasion or unusual "one-off" weather conditions such as salt burn, wind damage etc. If an analysis is made of tip die-back, the results often show that "there are pathogens present of a secondary nature". or in other words it is an indefinable problem. It is often confined to one or two particular clones in any specific climate, eg. Pr. Clarks Red. Best control is to discard the clones that are prone to these disorders in your particular climate and grow those that do not have them.

9:19 WATER-SOAKED SPOT AND LEAF COLLAPSE

It is not clear whether this is a physical disorder which is then invaded by fungi or whether it is an unidentified fungi which causes the condition. The problem is most prevalent in Leucadendrons but occasionally shows in Protea and Leucospermums. It can occur in both field and propagation situations and first shows as a water soaked patch on leaves. Its appearance is always associated with periods of low light and low daily aggregate j.lu levels. Certain varieties of Leucadendrons are very prone to the problem, notably Ld. strobilinum and hybrids. ie cv."Safari Sunset" and "Red Gem", but almost any variety can be affected.

Research carried out several years ago showed that the problem could be induced in almost any variety of Proteaceae by keeping them under very low light conditions. In the trials cuttings of a number of varieties were set in trays and they were then placed under shade that restricted the maximum light to 2500 f/c with a day aggregate of 15,000 j/lu. By the fourth day Ld. strobilinum and Red Gem were affected, by the seventh day almost all Leucadendrons were showing signs of collapse and by the tenth day almost all varieties under test had contracted the problem.

The problem can occur at any time of the year when there is a period of several consecutive days when there are very low light levels because of heavy cloud cover. The problem compounds during the late autumn / early spring period when daylight hours are short and it will mostly appear during that period.

Treatment with the fungicides Captan/Ronilan plus Benlate at three day intervals appears to restrict its progress but it is not clear whether this is entirely the case or whether an improvement is brought about because of a natural increase in light. Whatever is the case the application of the chemicals does control any secondary infection that may occur in the damaged tissue.

If the problem occurs in the propagation area, the best treatment is to expose the cuttings to as much light as is permissable for their stage of development, and to reduce the frequency that water is being applied. These measures together with the application of the chemicals will usually suppress any further progress of the problem. In a field situation, besides spraying with chemicals, the removal of unwanted foliage to let more light and air movement through the crop will help to lower the incidence of further outbreaks.

Water-soaked spot can be confused with frost damage sometimes seen on set cuttings after a frost of -4°C or more. This has a similar appearance. The effects

from frost damage, unless severe will however disappear of its own accord on the third to fifth day but may leave scarred tissue.

9:20 THE CONTROL OF PESTS — OVERVIEW

In the cultivation of Proteaceae the amount of control that must be exercised over pests depends somewhat on the end use of the flowers/foliage. If the plants are being grown for garden/landscape uses, they will usually perform quite well with minimal pest control. If however the plants are in a commercial plantation and the product is to be used in the cut flower trade the control of insects in the crop is of major importance. All damage caused to plant tissue will either deface it (holes in leaves etc) or will greatly affect its vase life performance.

The efficiency of insect control is dependent on two major aspects. The first is the competence with which the insecticides are applied. Modern chemicals are very efficient and provided the correct one is used to control a particular insect, it is applied at the correct rate for the stage of development of the pest and it is adequately and evenly dispersed through out the crop, control will be achieved. A short cut on any one of these will reduce the efficiency of control.

The second aspect is the presence of host plants either surrounding or within the plantation. These can be anything from weed growth, grasses, shelter belts, ornamental or production plants within the plantation. If these are not treated at the same time as the crop or removed from the cropping area they are a constant source of re-infestation. If they can not be treated or removed maintenance spraying will have to be carried out much more frequently.

It is not possible or desirable to kill everything in an area but it is necessary to control insect populations to acceptable levels to enable a profitable crop to be harvested. The following is an outline of what insects can be expected and how to control them.

9:21 NEMATODES

By far the most serious soil-borne pest problem in Proteaceae is nematodes. These are found in most places where these plants are grown and in some of the hotter climates can become quite a serious problem. In the more temperate climates such as New Zealand they are not a problem. Nematodes are somewhat of a local problem in various locations and expert advice should be sought where they are serious.

Studies in South Africa indicate that although nematodes are present in the soil in many locations, the occurrence of the problem in cultivated plantations probably originates in the nursery phase of the plants development rather than infection after planting.

There are soil treatments that can be carried out to control its presence but once it is established in adult plants there is little that can be done to eradicate it. At high levels of infestation it causes general ill thrift in plants which in an advanced stage become unproductive.

9:22 OTHER SOIL-BORNE PESTS

There are many ground-based pests which will affect Proteaceae to some degree. These vary greatly from one location to another and range from gophers in California to grass grubs in New Zealand.

The soil-borne insects that feed on root tissue are a problem, especially on plants that are less than three years old. In the case of grass grubs and similar pests, the caterpillars feed on the young roots of plants to a depth of 30cm (12 inches) and when populations reach ten to the square foot they can cause serious semi-permanent damage to the root system which will affect the plant's further development.

There are chemicals available which are usually in a prills form which can be used as a control. These are mostly slow acting and to be fully effective must be applied in the autumn twelve weeks before the insects would reach their maximum active period which is just before midwinter. Another method of control is to run bantams (hens and roosters) in the plantation at the rate of seven per hectare (three per acre). These will control virtually all soil-borne insects, slugs, snails, weevils etc. and will also keep the populations of many of the above the ground pests to low levels.

9:23 TEMPORARY VISITORS ABOVE THE GROUND

The temporary visitors are those that visit on a daily basis, bees, wasps, butterflies etc., and those that are mostly found only in the flower heads on a seasonal basis such as earwigs, wood lice, spiders etc. All of these do little damage to the plants but can be destructive to the flowers and are a real problem when flowers are being exported especially when they lay their eggs in the flower heads. Those that are seasonally resident in the flower heads such as spiders are controlled to some degree by insecticides that are applied to control the permanent resident forms. There is little that can be done to control those that are highly mobile.

9:24 PERMANENT RESIDENTS ABOVE THE GROUND

These are permanently resident on the plant or within the plantation and cover three basic types: first, the chewing and sucking ones (leaf rollers, loop caterpillars, weevils, aphids etc.): second, the mites, thrips and red spider, and finally scales. All of these can be serious on commercial crops and to be able to sell the crop successfully they must be controlled. Each of them becomes a problem on a seasonal basis which varies between locations and the particular form in which each is present. Low population levels are present at all times on either the Proteaceae or adjacent host plants. Local knowledge is required to anticipate when sharp rises in numbers will endanger the crop and how to control them.

9:25 CHEWING AND SUCKING INSECTS

Caterpillars, adult aphids and weevils at the highly mobile stage are the problems of this group. Eggs are laid by the adults usually on the under side of the leaf, in the flower head or in the case of the leaf roller within the terminal tip. When they hatch they feed on the foliage. They usually render Leucadendrons unsalable. Control is by the application of insecticides, usually systemic, such as Lorsban, Lannate, Orthene etc. The effectivness of control is reliant on getting total cover and penetration of the crops foliage and this should really be extended to host plants such as hedges etc. These are a constant source of rapid re-infestation of crops especially if only contact type chemicals are being used. In the case of weevils it is ground litter that is the host. Some weevils live there by day and invade the plants by night. As some of these pests cycle about every seventeen days it is necessary to treat commercial crops where problems exist every twelve to fifteen days.

9:26 MITES, THRIPS, RED SPIDER

These can become a serious problem on many varieties of Protea and to a lesser degree on Leucadendrons and Leucospermums. Without control they are present to some extent all the time on many varieties. They normally reach a peak of population by late autumn each year. They are very minute and a 10X magnifying glass is needed to see them. Although they live on the underside of the leaves, the first signs that they are present is an orange brown smudging on the upper surface of some of the lower leaves. This is in fact the droppings from the insects living on the leaves above. Under high infestation the invaded leaves take on a silvery appearance which is at times mistaken for Silver Blight.

Most areas where Proteaceae are grown experience dry autumns and this coincides with the peak populations of these pests. The result of this is that they cause severe dehydration of the plants, sometimes partial defoliation and if the crop is one that produces flowers, causes serious post-harvest problems of the crops. The practice of exercising packhouse control of these pests when the flowers are being processed and packed for sale will do nothing to correct the post-harvest problems they cause. Once a crop has been seriously infested it is unlikely that it will give a satisfactory vase life for the rest of its harvest season.

Severe infestation is difficult to control and it is usually necessary to spray several times four to five days apart using a miticide as distinct from insecticide. A wetting agent must be used and a full cover of spray on the underside of the leaves must be achieved. Best control is by preventing population build-up. Where it is known that the problem exists, miticide should be incorporated in the general maintenance spray programme prior to the build-up period which starts soon after the longest day.

Certain plants are known hosts of these pests, in particular Rhododendrons, some conifers particularly Juniper and Picea and sometimes one particular plant of a Protea in a plantation. If such a plant is present it should be removed from the plantation and conifers and Rhododendrons should be treated at the same time as the crop.

9:27 SCALES

These are insects with little power of locomotion and in Proteaceae they can be on almost any variety particularly Pr. grandiceps. magnifica. repens. neriifolia (some variants only) and cynaroides (some variants only). They also infest Telopea and populations on these can reach immense proportions.

There are several different types of scale all of which live on the underside of the leaves or occasionally on the stems but always out of direct sunlight. Because of this they are often not detected until flowers are being harvested. Like thrips and mites they reach a peak of population in the late autumn and will persist through the winter causing dehydration of the leaves.

In a plantation that has been established from seedling stock it is quite common to find certain individual plants acting as a host. These plants can be heavily infested and if left uncontrolled act as a continuous source of re-infestation of the crop each year. The best control of this problem is to remove the plant from the plantation. This will go a long way to keeping scale populations to a low level. If you live in an area where scale is known to be a problem it is important when planning and selecting plants for a commercial plantation to ascertain whether a particular clone or variant is known to be susceptible to scale. If it is don't plant it!

Control of these pests is difficult as they are to some degree resistant to insecticides. These must be used at maximum rates with wetting agents added which may cause foliage burn on some varieties. It has been found that reasonable control can be achieved safely by using Malathion in combination with a good wetting agent and applied as a spray on its own and not in combination with a fungicide. This must be sprayed on the under sides of the leaves to a full run off level. Control can also be achieved with the application of spraying oil but this must not be used during hot weather or at any time that the plant is under stress from dehydration as it can cause severe foliage disorders. Low levels of infestation can be removed by hand but it is labour intensive.

SECTION TEN

Plantation Environment and Selection of Varieties

10:1 OVERVIEW

Almost all commercial plantations are established on land that is already controlled by the grower and in my experience it is rare that an intending grower decides which varieties/clones will be grown and then selects the perfect site for them. On any site or in any particular environment it is impossible to grow all commercial varieties to high standards of quality and profitability because of their differing environmental needs. The environment of any particular site determines which varieties can be grown successfully and what steps will have to be taken to protect the plants against adverse affects (if any) to produce a satisfactory result.

The growth and performance of plants are influenced by four climatic factors. light. water. air movement and temperature. All of these are significant in the production of a cut flower crop. These factors make up the "climate" as they also did during the propagation and growing on phases. In a plantation there is a fifth factor to consider, that of the soil type and structure. This fifth dimension completes the "environment" of the field situation. As it is virtually impossible to change or influence the soil to any degree, this must be the first consideration when choosing a site.

10:2 SOIL STRUCTURE

The structure of the soil will determine whether Proteaceae plants can be grown at all in any particular site. It is impossible to grow any varieties of these plants successfully in soils such as very wet heavy clays and silts, or in limestone areas where there is excessively high pH.

Because of the composition and structure of the roots of these plants it is necessary to provide a free-draining soil type which never gets waterlogged even during the wettest seasons. Heavy clays and silts fail in meeting this criteria especially on flat land where the water-table can come within a few centimeters of the surface during rainy seasons. This problem can be alleviated to some degree by ridging and planting along the ridges, but this does not change the soil texture, it only lowers the water-table. Observations in many places where attempts have been made to grow in marginal soil types show that even if a plantation can be established, productivity is marginal and the life expectancy of the plants is considerably reduced.

Suitable soil types are those that are free draining to a depth of at least 90cm

(3feet) and preferably retain moisture at least to some degree under dry weather conditions in the lower levels either through their texture or their ability to act in a capillary manner from moisture bearing substrata levels.

Suitable soils are those where the top soils are derived from: decomposed granite, weathered sandstones, loams, pumice conglomerates, lava, and scoria of volcanic origin, alluvial sands and gravels. These are all suitable provided the pH. is below 5.5 and they do not contain high levels of phosphate.

Land that is or has grown upland fern species (bracken) and reed type grasses always grow excellent crops of Proteaceae [ref. 17:3].

10:3 CLIMATE — LIGHT

Plants of all varieties of Proteaceae are sensitive to light. When a plant is subjected to a light level outside of that to which it is genetically attuned, it will react by showing leaf and or bud scorch and general ill thrift at excessively high levels, or alternatively disease accompanied by tissue break down at excessively low levels.

There are areas where Proteaceae are being grown that have too much light to grow some varieties/clones consistently to the necessary quality that some floricultural markets demand. In some areas of New Zealand, Hawaii, California, Australia and in some of the coastal areas of South Africa, it is the grey, grey blue and in the case of Leucadendrons the reddish leaf varieties that perform the best. These varieties will tolerate far more light than the green leaf forms which will perform poorly in high radiation areas and produce flowers that have a burnt appearance that give an inadequate post-harvest performance. In plantations that have been established from seedling stock in Hawaii and California, it is always the blue/grey leaf forms that produce the best and most saleable product. All of the selections that have been made as being superior stock that I have seen in those countries have had that leaf form.

The effects of high light levels on adult plants in a field situation can not be reckoned as a factor on its own. There are many factors influencing the tolerance to light of each variety or variant. Without extensive research and observations in a number of different locations on a world wide basis it is impossible at this stage to make firm recommendations on acceptable levels. The factors that influence this aspect of the environment are the intensity of the light measured in ft/c, the accumulated daily radiation measured in j/lu, the daily temperature/humidity conditions (th/c & th/f) soil moisture and air movement.

When assessing the influence of light it is important to recognise the fact that there are two aspects to consider, that of the intensity in ft/c and that of daily accumulated aggregate of radiation in j/lu. With plants of less than three years old, high levels of either one or a combination of both will affect the plant. With plants older than three years it will be found that they are more tolerant to short periods of high levels of light intensity (ft/c). At this age and older they will tolerate high ft/c. for several hours each day. However in the final analysis it is

the daily aggregate of j/lu that will be the controlling factor.

Observations in New Zealand show that with adult plants, (four years and over), light levels of up to 9,000 ft/c for six hours per day will not adversely affect any commercial variety provided they have adequate soil moisture (50 centibars) [ref 12:2]. If however plants are exposed to 9,000 ft/c for a full day in mid-summer it will give an accumulated day aggregate of 110,000 j/lu and if this level is maintained for several weeks it will affect varieties with green leaves. The first sign of this is usually seen as flower bud scorch. This level of radiation seldom affects varieties with blue or grey leaves but may occasionally cause bud scorch. These observations have been made during average summer conditions with daily temperatures of 30°C (85°F) maximum, little air movement and adequate soil moisture.

In areas where there is evidence of there being too much light for the varieties being considered or grown, it will be found that siting the sensitive varieties on sloping ground facing away from the sun (north faces in northern hemisphere and south facing slopes in the southern hemisphere) will greatly assist those varieties that are sensitive to high levels of radiation. All the best plantations I have seen in any countries I have visited are those facing away from the afternoon sun.

10:4 CLIMATE — RAINFALL

Provided the soil structure is free draining, many Proteaceae will tolerate and in some cases greatly benefit from annual rainfall of up to 2000mm. (80inches), whilst at the other end of the scale they will survive with as little as 300mm.(12 inches). There are however a number of factors governing their tolerance to high rainfall or survival in low rainfall areas.

Proteaceae are rhythm plants, and as such some varieties have a genetic make-up to tolerate high rainfalls during certain seasons of the year. It is when heavy rains are experienced in a variety's variant's traditional dry periods that problems occur especially if the rains are accompanied by high humidity and high temperatures. With all commercial crops, frequent and heavy rains during the season of harvest will cause fungal problems in the flowers particularly at temperatures over 18°C (65°F) and /or when there is little or no air movement.

In areas where there is low rainfall, particularly in the spring during the annual vegetative growth surge, there is little chance of consistently growing a saleable commercial crop unless supplementary water is available. Unless adequate soil moisture is maintained, plants will invariably grow short stems which are often unsaleable. A partial exception to this is where the top soil overlies a moisture bearing substrata and the plants are supplied by capillary watering from that layer. Where this is the case and it is their sole source of soil moisture during dry spring periods, commercial crops may be produced but they are usually inconsistent in stem length and timing of harvest. Whilst this would be acceptable in landscape use, there is a big difference between just survival and a profitable crop. [Ref 12:3 for further information on seasonal supply of water].

10:5 CLIMATE — AIR MOVEMENT

The amount of air movement and the season in which it occurs or is absent will influence the health and cropping performance of plants. A near total absence of air movement at any season of the year will foster the development of fungi. especially if the humidity/temperature total is at, or above th/c105 (th/f160) level. Grey, hairy and glaucous green leafed varieties are particularly susceptible.

A lack of adequate air movement during the summer months creates conditions where plants can suffer stress from high temperatures on the leaf surfaces and/or in the flower buds. This can cause severe damage to the plants which manifests itself as leaf burn and in the flowers either bud scorch or sometimes causes immature buds to abort. The results of heat stress can often be seen on Ld.laureolum as a galling effect on the bracts and in many of the Pr. neriifolia variants as bud scorch. The problem is compounded where there is a shortage of adequate soil moisture, the plant has a poor root system, there are salt-laden winds or the plant is being grown in an area where the daily light aggregate (j/lu) is too high for that particular variety/clone. Fungi infection often initiates later in the damaged leaf and bud tissue. It is important to have some air movement when shade temperatures are 32°C (90°F) and over as the sun temperature on the plant tissue is then usually over 55°C (130°F) which is when real trouble starts.

Too much air movement can be the cause of several problems with the most obvious of these being the rocking effect that wind has on plants, particularly in the first three years of establishment. The effect of wind rock is greatly aggravated where soil-less mediums have been used during the production of plants in the nursery. Another problem, particularly if strong winds prevail through the spring growth period is a shortening of the length of the flowering stems and in some cases a "hockey stick" affect. These problems are the result of the dehydrating effects of the wind and may be confined to the windward side of the plants.

Strong and constant air movement will cause accelerated moisture losses from the plants and ground surface which must be compensated for in low rainfall areas. It does however almost completely eliminate the invasion of fungi in virtually all varieties.

10:6 CLIMATE — TEMPERATURE

In nature each variety/variant of Proteaceae grows in a location which experiences a certain range of temperatures. When they are grown outside of their natural environment they may from time to time experience temperatures above those to which they are genetically attuned. If this should occur they can suffer leaf tissue damage which can be disfiguring or damage to flower buds as outlined above. Such conditions are usually of a "spot " nature and may be confined to just a few plants in one particular location.

At the other end of the scale, sub zero temperatures are sometimes the govern-

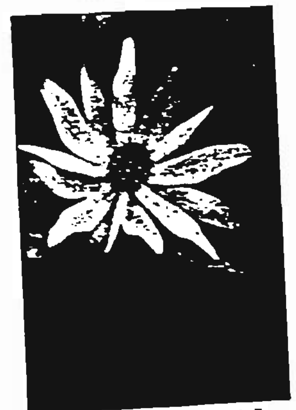
Ld. strobilinum (male)

Ld. hybrid cv. "Wilsons Wonder"

Ld. argenteum

Ld. hybrid cv. "Red Gem" (spring colour)

Ld. hybrid cv. "Pisa"



Ld. hybrid cv. "Julie"

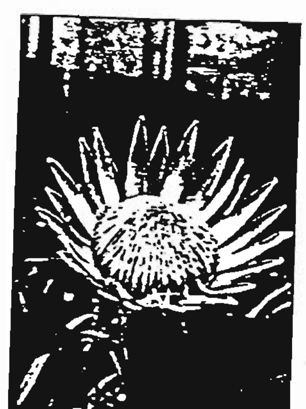
Pr. hybrid cv. "Silvan Pink"

Pr. hybrid cv. "Clarks Red"

Pr. neriifolia "Silvertips"

Pr. neriifolia cv. "Limelight"

Pr. scolymocephala



Pr. cynaroides

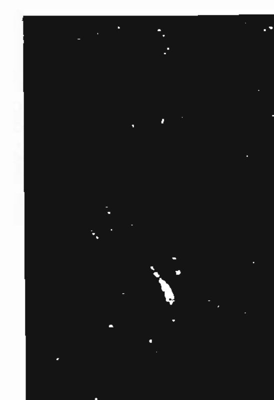
Ld. daphnoides (female)

Ld. salignum cv. "Clone 91"

Ld. strobilinum cv. "Waterlilly"

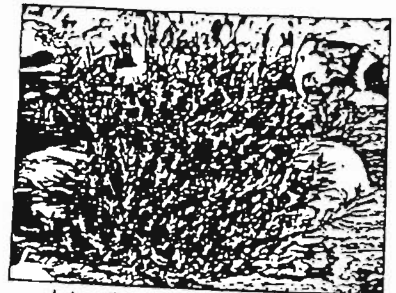
Ld. laureolum (female)

Ld. hybrid cv. "Superstar"

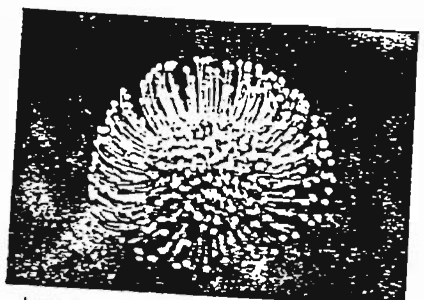


Ld. salignum cv. "Rising Sun"

Lsp. prostratum



Ld. salignum cv. "Red Carpet



Lsp. cordifolium cv. "Harry Chittick"

Serruria florida

Telopea speciosissima

Telopea hybrid cv. "Starburst"

ing factor in the success or failure of these plants. This was highlighted in New Zealand in the early 1980s when large numbers of Ld.cv."Safari Sunset" were planted in the Waikato in what turned out to be "frost pockets" with disastrous results.

Each variety, variant, clone has its own particular level of tolerance to sub-zero temperatures. There are big variations even within a single variety with one notable instance being that Lsp. cord. cv. "Harry Chittick" will tolerate only -3°C. (27°F) without damage where as Lsp. cord. cv. "Riverlea" will take up to -6°C (21°F) without showing any lasting damage. It will however be completely destroyed at -7°C.

The compounded effect of frosts on plant tissue is somewhat like that of light in that the intensity of frost multiplied by the hours of duration compounds the damage caused to the plant. When making observations and assessments it should be borne in mind that although the frost may reach a maximum of -4°C it would not reach that level for perhaps two or more hours after it starts freezing and would probably rise to -3°C an hour before it thaws. Therefore when a frost of -4°°C is lying for a total of eight hours it would give an accumulated "frost factor" of approximately 26 and it will cause the same amount of damage as a -5°C frost of six hours duration with a frost factor also of approximately 26.

This frost factor (f/f) is very important when measuring frosts and assessing whether it is possible to grow a commercial Proteaceae crop in a particular location. Although no research or formal observations have been run to record accurate data, the information so far gathered indicates that a frost of minus two degrees Celsius, irrespective of the time it is lying has virtually no effect on plant tissue. However when frosts exceed minus two degrees Celsius the formula of. "time X minus degrees = f/f" will determine the level of damage to plant tissue. Where observations have been made it shows that most varieties begin to be affected at f/f15. At f/f20 the flowers and younger growths are damaged. At f/f25 serious damage can be expected and at f/f30 most flowers and foliage of a commercial crop will be destroyed irrespective of the variety or age of the plant.

Observations that have been made over a number of years in my own location show that plants will generally tolerate frosts of the following intensities for a five hour duration. The five hour period was chosen because this is the average duration of a frost in the location where I live.

At -2°C (29°F) there will be no visible tissue damage to any variety. At -3°C some varieties of Leucospermums and Proteas will show superficial damage to immature growth tips in the autumn and usually severe damage to soft growth tips in the spring. This damage in the spring is because of the rising sap flow in the plants. At -4°C (25°F) most varieties of Leucospermums and about half of the Proteas will show permanent damage to the last run of growth on plants of up to three years old and in Leucadendrons some tip damage. At -5°C (23°F) almost all varieties of all species up to four years old will be affected at least in the last growths and to some degree in the flowers.bracts. Those that suffer damage at -4°C may die. Some exceptions to damage at -5°C are the blue.grey and grey hairy-leaf Proteas and a rare Leucospermum. At -6°C (21°F) there are very few plants of less than five years old that won't be severely affected or killed and no flower or flower buds will survive to be a saleable product. The cut off point for almost all varieties is -7°C (19°F) unless the plants are very old and mature. One or two variants of Pr. magnifica will survive but are unlikely to produce flowers. One notable exception to this is the Australian Telopea which will be undamaged even as young plants at this temperature. These will survive down to -9°C (15°F) but will collapse at -10°C.

Generally plants will tolerate one more degree of frost for each year of age. ie a Pr.neriifolia cv. "Silver Tips" will tolerate only -2°C at two years but will withstand -4°C at four years old. However the cut off point of -7°C remains more or less constant irrespective of the age or variety of the plant unless it is over ten years and is more than 2.5meters (8 feet) high.

Frost levels should be assessed before any plantation establishment is commenced. This assessment should be carried out over a period of at least one full winter and then correlated with the local meterological records to see if the winter was above or below average temperatures.

When measuring temperatures it is necessary to use maximum minimum thermometers at 40cm. (15") above ground level in a number of locations on a property. There can be variations of two to three degrees Celsius between points fifty meters (150 feet) apart especially if there is an uneven contour. A depression of only 30cm (12 inches) can create a "frost pocket" on flat land where there is little or no night air movement and recordings show that these spot frost pockets are usually one to two degrees colder than the surrounding area. In some areas especially where the general land contour is flat over an area of several square miles. frosts form in a layer with the greatest intensity between 15cm and 70cm above the ground. The coldest part in this layer is sometimes only 20cm. deep and often lies at the 15cm to 35 cm level or the 50 cm to 70 cm level, (5cm = 2 inches). Very severe damage has been noticed at one or other of these levels with no damage above or below. Air temperatures at the 40cm. level on slopes are usually one or two degrees warmer than those on flat ground in the same area and an incline of as little as one in twenty will usually eliminate this inversion layer problem unless there are tall dense hedge rows which prevent ground air movement. I have never seen severe frost damage on any variety planted on land with an incline of one in ten unless the plants have been induced into an early winter growth by feeding or supplying irrigation too late into the autumn [ref.12:4 & 13:9] or the plants have been planted through weed matting. When severe damage is experienced it is necessary to carry out special procedures to assist plants in recovery [ref.11:10].

The intensity of a frost can not be assessed by visual means, ie. it looks white so it must be a heavy frost. The amount of hoar-frost which causes the whiteness, depends on the air humidity at the time the frost is forming. It is possible to have

a -5°C frost with little or no white hoar-frost or there can be a -2°C frost with quite an amount of white showing. The only possible way of visually assessing the degrees of frost is by measuring the thickness of ice which forms on water in a container but not in a puddle on the ground. Every 1.5mm. (1/16 inch) of ice equals minus one degree Celsius. This means that if there is 6mm. (1/4 inch) of ice there is a -4°C frost. If there is 12mm. (1/2 inch) you will not be able to grow Proteaceae. This formula of measurement has been constant in every location where I have had the opportunity to record it.

10:7 ENVIRONMENT — SUMMARY

How suitable the environment of any site is for growing a Proteaceae crop will be a compromise of all of the foregoing factors. Depending on the varieties, variants or clones planted there will be minimum parameters in each aspect that will have to be adhered to ensure success.

The principal ones are:

The soil must be free draining and never get flooded or waterlogged. It should have low levels of phosphate (15 to 20ppm) and preferably a maximum pH. of 5.5. A slope facing away from the sun is much preferred to either a flat site or a slope facing into the sun.
Light levels must be within the allowable levels for the particular crop planted. Not below 40,000 j/lu in winter and not much above 110,000 j/lu for summer should be satisfactory for most varieties.
Rainfall should be adequate to sustain growth particularly during spring or irrigation must be available. Low rainfall is desirable during the seasons of harvest, particularly if temperatures are 20°C and above.
Air movement should be adequate to "dry off" foliage particularly at temperatures above 20°C. It should not be of a velocity that causes the plants to rock in the ground or stunt the growths of the flowering stems.
Minimum temperatures should not exceed minus four degrees Celsius for most mature crops. It is best if temperatures do not go below minus three degrees Celsius except for very short duration, (one to two hours). Areas that have frosts form early in the night and experience eight or more hours at -3°C or greater on a regular basis are not suited to commercial production. Frosts of minus two Celsius for up to about three to four hours are quite beneficial as they will arrest the development of most insects and fungi. When assessing temperatures by the f/f formula, regular frosts of f/f15 over a period of several weeks would put serious doubts on the viability of the site, with f/f20 being too great for most varieties.

10:8 SELECTION OF VARIETIES — GENERAL

Having established that the environment of the plantation site is suited to the growing of Proteaceae, a number of factors which will influence profitability and efficiency must be considered. This file deals with the various aspects of setting up a commercial plantation but as there are so many variables in such things as the terrain of the site, the climatic conditions and available markets for the end product it is only possible to give a general outline.

There have been many thousands of plants planted that will never produce a profitable crop, either because the plants were not matched to the climate, or because the end product is not a saleable commodity. The reason that the product is unsaleable can be because that particular flower (form or colour) is not acceptable to the end user, the flower gives a poor vase life or the flower will not survive travel from the production area to the end user (because of the influence of the climate or it is genetically incapable of doing so). All of these things must be considered and evaluated if the end result is to be a profitable plantation. Plants of a variety should never be chosen because you have seen a pretty picture, you personally happen to like that particular flower (others may not) or because the plants just happened to be available at the supplying nursery. In the last few years I have seen plantations where 80% of the plants would fall into these categories and the production is not nor never will be viably saleable.

Proteaceae flowers and foliage come in many forms, shapes and colours. If they can be supplied to the market and give value to the end user almost all of them would be a saleable commodity. However many of them travel poorly and/or give a very short vase life. It is possible for producers with a market right at their gate to supply local markets with varieties that are unsaleable to growers who must send their product thousands of miles from one country to another. It is a fact however that each year the floricultural trade is becoming more and more discerning in the products it will handle. This is because of the continuous lift in the quality, supply and presentation of all types of flowers in all international markets and it is becoming increasingly difficult to sell product that is less than perfect in quality and value for money at any level of trade whether it be the mass low-priced one or the high-priced "top shelf" one. Poor grades of floral material of all types of flowers from alstromeria to zantedeschia that was saleable eight years ago is no longer so and this trend will continue. There are many floral competitors to Proteaceae and it is imperative that to hold and improve its place in the international markets, that we improve the supply, quality and presentation. In to-day's market, quality and good service mean everything and growers who continue to plant seedling based stock and still hope to supply the "top shelf" level of trade should take stock of their future.

There are two questions to consider when selecting varieties. First is whether the end product of the chosen variety is acceptable to the end user and therefore saleable at prices viable to the producer. Second, will the plants adapt and grow a satisfactory crop in the environment of the plantation. Both of these are of the utmost importance. It is no use planting a variety that grows and crops well if the flowers are not profitable while on the other hand it is no use planting a variety that is known to be saleable unless you can grow and deliver it to the end user at the levels of quality and the price that the market demands.

It is important to research the intended market before making a final choice of

plant varieties. This is not an easy task as it involves evaluating what will be in demand in four or five years time. There are a number of flowers that have stood the test of time and it is unlikely that established varieties such as Pr. neriifolia, cynaroides, magnifica, eximia, repens, some varieties of Leucospermums, well-presented Leucadendrons, Serruria var. and Telopea will go out of favour. However to stay competitive with other flowers it is important to lift the quality and introduce improved forms of these well-proven varieties.

When considering which varieties will be planted it must be borne in mind that Pr. eximia and repens are often very poor travellers especially if grown in high humidity areas and because of this if they are from locations with such conditions they must be considered only for local markets. Varieties of many species other than those listed above can often be grown for a specific "spot" local market.

The screening of Proteaceae species for cut flower clones is dealt with in Section Fifteen. This deals specifically with the selection of individual plants of a particular variety which is then named as a "clone". It does not explore the differences that exist between variants of a variety. [Ref. 1:5 for information on "varieties", "variants" and "clones"].

If seed is collected from a single stand of a variant of a variety in its natural surroundings in South Africa, most plants that come from that seed will have much the same inherent make up. There can however be big genetic differences between variants of each variety from seed collected from different stands. The principal differences that will be noticed in a plantation will be in their overall tolerance to frost, humidity, rainfall pattern and light. The differences in end product will be stem length flowering season, flower colour, bud scorch and in post harvest, vase life and their ability to travel.

Where vegetatively produced plants of selected clones are not available and seedling stock has to be used to establish a plantation, the selection of the variant of a variety that is most suited to the environment of the plantation site is important and can make the difference between success or failure. This is an area that has not been researched to any extent but there is evidence which is substantiated by observations in many places, that this is the key to the production of cut flowers from seedling based stock. To do this it would be necessary to identify which variant of say Pr. neriifolia growing naturally in South Africa was most suited to an environment of X Y Z in the production country and would then produce a flower that was acceptable in market A B C in Japan. A high percentage of the resultant crop would be more or less uniform in flowering season, colour, form and post harvest performance and would eliminate the problems of the variables that are encountered at present. This is already being done to some extent in South Africa.

Irrespective of whether vegetatively or seedling produced stock is used to plant a plantation, every effort should be made to ascertain whether the particular clone or variant of that particular variety is suited to the environment of the intended location. Just because a plant has been cutting grown does not mean that it is superior stock and will suit all locations. It won't. Some plants are cutting grown because they happen to be an easy clone to root. not because they are a good cut flower. Local knowledge or expert advice from persons active in clonal selection and the production of flowers should be sought. It is not an area where pure theory is enough.

10:9 VARIETY — FINAL CHOICE — (MARKET)

The choice of varieties to supply the market will fall into three general categories with the final selection depending on which market will be supplied. If it is the local domestic market the range of acceptable product is greatly increased as the material from most varieties will give at least a reasonable vase life if it does not have to sustain long distance travel. At the other end of the scale if production is intended for distant and very discriminating and high priced markets, great care is needed in the final choice as there are few clones of any variety that will produce a product that will sustain up to a week's travel and still give the consumer value for money. In the middle is the situation where it takes no more than three days for the product to get to a consumer who only requires a low value, mass market type of flower. Quite often the production from a plantation will supply two of these possible markets. However there are production areas, such as New Zealand, where the only viable market for Proteas are the discriminating ones half way around the world. In this case less than the best is not good enough and the motto should always be, "If it won't travel don't plant it".

10:10 VARIETY — FINAL CHOICE — ENVIRONMENT

The matching of a variant/clone of any variety to the environment is important. If you don't get it right the resulting crop will be lower in volume, quality and value than it should be. Lack of qualified information makes it difficult to verify what the performance of a particular variant or selected clone would be in a given location. There are some proven facts that can be used as guide lines to selecting plants for a particular climate and an observant grower can define with some accuracy what the performance of a plant is likely to be by what the leaf form is. This is not infallible but is accurate enough to give an indication of whether a plant should be considered or test planted in a plantation. In general terms the following outlines what could be expected of varieties and variants of varieties that could be used for cut flower production. The frost tolerance is given for a five hour sub-zero duration. In locations where frosts lie for much longer periods than this the tolerance will be less, particularly in regard to flower damage.

10:11 PROTEAS. The bearded forms.

Without exception the blue and blue grey leaved plants will give the best results particularly in high light areas. Many of these however do not have the same clear colours in the flowers as do the green leaved forms of the same varieties. This group are usually frost hardy to -5°C as adult bushes, flowers to

-3°C. Flowers always travel well but foliage can be a problem if there is active sap movement in the plants at harvest or until the plant reaches maturity at four to five years. If this group are planted in low light areas or where there are high humidity/temperature periods, over th c 105 (th.f160). some fungal problems can be expected.

Closely following the blue and blue grey ones are the pale green or slightly bronzed forms provided they have a red edging to the leaf. These will give a good performance in high light areas provided they have adequate soil moisture right through from spring to late autumn. This group mostly have flowers of clear colours and it will be found that those with slightly crinkled leaves generally have brighter flowers. The group is frost hardy to -5°C as adult bushes except those with crinkly leaves which will only take -3°C Flowers of all these will start to damage at -3°C Flowers of this group are inconsistent in their post harvest and travelling performance. From seedling stock only about one in fifteen would be of real merit as a cut flower and 40% will give very poor travelling and post-harvest value. However there are some outstanding named cut flower clones in this group. Fungal problems are normally minimal in this group provided there is adequate air movement.

Unless they are producing in low humidity areas the green leaf forms do not produce flowers that give good post harvest value. Even in favoured areas their flowers are usually only fresh for a week or so. High humidity/temperature conditions cause fungal problems in flowers and leaves. Frost tolerance is variable with -4°C being the cut off point for cropping in most varieties. Provided light levels are not excessively high these forms establish easily in most locations. They must be regarded as being more suited to supplying local or mass markets rather than the "top-shelf".

10:12 PROTEA *Cynaroides*

There are a number of well defined variants of Pr. cynaroides with most having acceptable flower forms although some do have stems too short for the more discerning markets. There is some variance in the climatic conditions they will produce a satisfactory crop in. Those with broad rounded leaves (Outiniqua) will not produce a satisfactory crop with a combination of high light and high temperatures plus dry air and ground during the summer, as these conditions cause the buds to semi-abort or alternatively affect the vase life. They will however produce reasonably well provided there is adequate soil moisture. The varieties with the long narrow leaves will take high light, high temperatures and dry air provided there is plenty of soil moisture through midsummer to autumn. Some variants such as the Tzitzikammamas have their leaves set on edge and these will take more exposure than those with the leaves set flat as the East Cape form has. The forms with a bright red edging to their leaves are more resistant to dry autumns. Although the plants of most Pr.cynaroides variants will tolerate -6°C the flower buds will start to damage at -3°C with most being destroyed at -4°C. Fungal invasion is not a problem with Pr cynaroides except for the spotting on the leaves which is inconsistent from one year to another which indicates that it is influenced by climatic variables from year to year. Long periods of low light combined with high humidity/temperatures will cause leaf tissue breakdown and subsequent fungal invasion in all variants.

10:13 PROTEA Magnifica

Although all variants have very similar leaf forms there have been marked differences observed in how each particular one performs in different plantation environments. The principal problem is fungal invasion of the soft growth tips and it has been found that if the average day humidity, irrespective of the temperature through spring/summer, is above 50% it is impossible to grow the Ceres or Koo variants. The Cedarberg and Overberg variants will tolerate higher humidity but if it reaches th/c 95, (th/f 140) and above they also will have problems particularly in areas where there is low air movement and/or long cloudy periods in the summer. Once established the plants of all variants are frost hardy to -5°C and in some locations to -6.5°C Buds will damage on all at -5°C.

10:14 LEUCOSPERMUMS

To be successful as a commercial crop all Leucospermums must have good air movement in all seasons and a humidity/temperature rate of below th/c 95 (th/f 140).

Varieties that have broad green slightly hairy leaves have poor resistance to fungi and should not be attempted unless there are conditions matching those noted above. These varieties are mostly frost hardy to only -4°C for plants with flower buds often being damaged at -3°C. They will however take one extra minus degree all round once they are five or more years old. These varieties will take high light levels provided there is adequate soil moisture and afternoon temperatures aren't excessive and coincide with low air movement. Many commercial plantations are made up of this group with Lsp. cordifolium being the dominant one.

Varieties with narrow green and grey green leaves (lineare and hybrids) are more resistant to fungi than the broad green hairy ones. They are frost hardy from year three to -4°C but this seems to be the limit for all Leucospermum flower buds. This group need constant soil moisture to grow a high quality flower crop as if they get dry during summer they sometimes abort their flower buds. There are some excellent clones that have been developed in this group.

Grey and blue grey leaf forms have not been developed to any extent as commercial cut flowers. This group which includes Lsp. reflexum and catherinae will stand very high light levels and dry late summer conditions. High humidity/temperatures in the late spring often cause fungal invasion in the growth tips which will destroy the flower bearing part of the stem. This group is hardy to -6°C as adult bushes but flower buds will damage at -4°C. They are not successful in wet soil types.

10:15 LEUCODENDRONS

The red, bronze, glaucus blue (sometimes hairy), dull grey edged red and silver forms will all take high light levels during all seasons. All of these will have fungal problems if they are in very low light areas or become crowded in the plantation. The red leaf/bract forms grow and produce well in most locations provided there is adequate soil moisture during their growth run. With the strong growing ones (Safari Sunset, Silvan Red etc.) the spring growth may run for up to a hundred days. Those with silver leaves (argentum, uliginosum etc.) and hairy glaucus blue leaves (nervosum etc.) must have air movement at all times. Those with smooth glaucus blue leaves (discolour, procerum etc.) will stand very high temperatures but must have perfect drainage at all seasons or they will get Phytophthora.

The green leaf forms, most of which have yellow bracts, will tolerate high light provided there is adequate soil moisture and air movement during high temperature periods. The very green ones will not take long periods of low light owing to tissue break down and fungal invasion. The spring flowering varieties of this group have problems with fungal invasion of the bracts if wet or humid conditions occur during their harvest period.

When considering leucadendrons it must be borne in mind that at the very best only half of the total number of seedlings planted will produce a saleable crop. The reason for this is that it is rare for both the male and female forms of a variety to produce a saleable commodity. In almost all varieties it is the female that is the saleable one. Male bracts of most varieties get heavy spotting of the guard leaves which is caused by the pollen falling off the central "pom" as they are colouring up. There are almost no male forms of any variety that are in the top bracket of cut flower clones.

All Leucadendrons have a frost tolerance of around -3°C at two years rising by one degree per year to -6°C at year five. This however is the cut off point for commercial cropping and some bracts will be damaged at -4.5°C.

10:16 SELECTION — SUMMARY

Which variants or clones of a variety that are suited to the particular market that will be supplied and the environment of the location where they will be grown will depend on how their demands fit the conditions that are either present or can be provided by artificial means. The principal points to observe are:
Plants must be matched to the **light levels** that prevail (j/lu).
Plants must be able to tolerate the seasonal **temperature / humidity** levels (th/C).
Plants and flower buds must be able to tolerate the **frost levels** (f/f).
Plants must be able to tolerate the seasonal **rainfall patterns** or water must be provided in low precipitation areas.
Plants must be able to cope with the seasonal **air movement** patterns.
The flowers must be able to withstand transit from the production area to the end user and in all instances give value for money.

* SECTION ELEVEN *

Plantation Establishment

11:1 OVERVIEW

The configuration of plantations varies greatly in varieties planted, the layout, the terrain that they are planted on, whether there is irrigation installed and so on. The varieties planted should have been influenced by the environment of the location and the market that it is intended to supply. The method of planting and general layout will depend on the contour. Whether irrigation is installed will depend on the rainfall pattern. This section outlines some general procedures of setting up a plantation and identifies some hidden pitfalls.

11:2 LAYOUT

Irrespective of the contour, the design of the plantation should always take into consideration the efficiency at which the crop will be able to be harvested while at the same time ensuring that the plants do not impede good air drainage. In the life of the plantation there will be many tons of material harvested, all of which will have to be carried by some means, firstly to a collection point and then to the place of sorting and packing.

On steep land where it is not possible to get a tractor, layout should be arranged wherever possible so that all harvesting is done down hill to a collection point. On flat land where there is easy access with machinery, rows should be arranged so that the harvested material does not have to be carried excessive distances to a collection point, bearing in mind that when the plants of some varieties reach maturity the plantation can be so dense that it is not possible to walk cross-row.

In areas where there tends to be an absence of adequate air movement that will keep summer temperatures down, and winter frosts above danger levels, dense stands of tall Proteas or hedge rows running cross wind will cause local heat and frost pockets. In some areas where Proteaceae crops are being grown, the margin between the normal local frost level and one that would cause damage to the flowers/buds, is only one or two degrees Celsius. As this is the difference that there will be in most locations if night air movement can be encouraged rather than stopped, it is important to arrange the pattern of rows to encourage good air circulation rather than restrict it. By doing this the rows will also probably run in the same direction as the prevailing winds which will minimise wind-rock.

11:3 PLANT SPACINGS

On flat land where it is possible to use machinery to maintain control over weed

growth it is usual to plant in rows. The width between rows is controlled by the width of the machinery that will be used and is a sum of the ultimate width of the plants plus the width of the machinery. On expensive land where it is necessary to utilise it efficiently, most planting of Proteas and the larger types of Leucospermums is done at three meter rows by one and a half meters between plants, (10 feet X 5 feet) and for the smaller Leucospermums and most Leucadendrons two and a half meter rows and one meter between plants. On some land where space is not a problem I have seen plantations at twice these spacings. On the other hand I have seen some successful plantations of Leucospermum and Leucadendron at one and a half meter rows and 70cm between plants, (4'6" x 2'3"). In these instances all maintenance is done by hand and the plants are pruned hard each year.

When deciding on spacings it is advisable to ensure that the eventual density of foliage does not become so thick that it eliminates air movement and by so doing creates humidity and heat traps. Under such conditions fungi invasion is a certainty and it is virtually impossible to control it, firstly because you can not eliminate the cause without removing some plants and secondly it becomes impossible to get adequate cover with fungicides.

Some plantations are planted in double staggered rows in a "back to back" lay-out. Whilst this method does utilizes the land better than the single row lay-out, it does create some problems in adequate fungi and pest control over the entire crop once the plants reach maturity.

On steep hillsides spacings are usually a little closer and often have to be varied to suit the terrain. Being a little closer on a hillside is acceptable as the tiered effect gives more air space to each plant. Where irrigation is being installed on hillsides the rows always run across and follow the contour.

11:4 PRE-PLANTING SITE PREPARATION

When land is brought into production from a natural state it is usually cleared either mechanically or by hand and the texture of the soil is not altered to any degree nor are there normally any chemicals used to kill the existing vegetation. On the other hand if the land has previously been used for pastoral or horticultural uses, it is normal practice to control the existing herbage by spraying off with one of the many chemicals available. The roots of Proteaceae plants are very sensitive to most chemicals that have any residue or translocation effects. These must never be used either before or after planting within the area of the root zone or where the roots will penetrate within two years of planting. Although the effects of the chemicals are often slow to show in the plants, they will eventually destroy Proteaceae plants in most soil types if they are used within reach of the roots. It may take two, three or even four years but they will eventually affect them. [Ref. 13:8 for further information on chemical weed control]. If it is necessary to control existing herbage the use of Gramoxone (Paraquat) or Fusilade are safe for grass control and Versatile will eliminate most of the broad leaf weeds. If possible it is best to spray off the row lines up to six months ahead of planting. This enables most of the secondary seedling weeds and grasses to be controlled before planting.

11:5 PLANT SIZE

The size of plants is often a subject of some discussion with some growers advocating large two year old plants and others using small plants of about six months. Whilst the size of the plants will have a bearing on the overall establishment of the plantation and the time it takes to come into production, much of the success of the planting out will be pre-determined by the procedures used during the production of the plants in the nursery and the final handling and hardening-off of the plants immediately prior to this operation.

Plants should be a minimum of nine months and a maximum of eighteen months old. Plants younger than this do not have the resilience to absorb the adverse weather conditions they will encounter following final setting and with plants older than eighteen months the root system is starting to lose its vigour unless that vigour has been maintained by moving the plants up successively into larger container sizes during their time in the nursery.

Provided they can be adequately looked after following setting out, and they have been well prepared in the nursery and grown in mediums that are compatible to the soil type of the plantation, plants of between nine and fifteen months old from a 100mm. (4") pot or of eighteen months old in 150mm. (6") pot, give excellent results. Plants of this size are at the point of their development that enables them to make a rapid growth of a strong primary root system which is the basis of their future production capabilities. Plants of this size must be provided with adequate soil moisture during their development and NEVER have weed growths creating a humidity trap around them. If they are well maintained, they will develop a balanced structure both above and below the ground in harmony with their surroundings and problems from wind-rock are usually minimised.

Where plants of 60cm. (24") tall and over are used, root development is not matched to the vegetative structure above the ground and problems associated with dehydration and wind-rock are frequently experienced. These have lasting effects on the plants performance.

Plants of six months old can be planted out but losses from exposure and weed competition are usually high unless they are planted and maintained in cultivated strips for the first year or through weed matting [ref.11:8 & Appendix Three].

11:6 WHEN TO PLANT

The climatic conditions that are experienced during the winter and spring will influence which are the best months to set the plants out in the plantation as there is little point in setting out young plants in the autumn if they are going to be damaged by frost during the winter. However there are periods when plants

make major primary root development and this should be taken into account when planning the planting of a plantation. All Proteaceae, irrespective of whether they are in their native habitat or under cultivation, follow their natural rhythms of growth and although they don't all do the same thing at the same time they do all have their periods when they are growing roots, or they are growing above ground, or they are resting and growing nothing. It is virtually impossible to break their seasonal rhythmic pattern of growth and rest periods.

All of the varieties that are used as commercial crops follow much the same pattern with primary root development starting from early winter and peaking by late winter. These primary roots then go into a rest period of about sixty days during which time the plants make a vegetative growth, ie. their spring flush. At the conclusion of the spring vegetative growth the primary roots will recommence development which continues for another ninety days. After that they will rest until the cycle starts again in early winter. It is this late spring summer root growth which penetrates deeply searching for moisture levels in the subsoils and in their first year this is the critical period of development. A healthy plant which has been grown in a medium which is compatible with its final planting site is capable of root penetration to a depth and lateral spread of 45cm. (18") in ninety days. However this depends on when they are planted as they either go immediately into a primary root growth or they go into a phase when they grow proteoid roots, depending on their particular stage of development and season. When they do the latter they often fail to make their next scheduled primary root development especially if they have been cutting grown. If you are to capitalize on the two periods when there is a rapid development of primary roots the two best times to plant are just entering winter and again around the spring equinox.

Proteoid roots develop from early winter to reach a peak by early spring and then die away by midsummer. In a field situation they will be virtually non-existent from about the longest day through to early winter. As proteoid roots play no part in supporting the plants through periods of high transpiration. (dry weather etc.), the rhythm of their development and decline is of no consequence in the timing of planting unless the plants have been container grown in a medium that encourages the development of proteoid but not primary roots. If this is the case then there is a problem in supporting the plants until they can be encouraged to put down their primary root system.

To observe the establishment and behavioral pattern of plants that were set out at different seasons, five plants each of five commercial varieties were planted out every thirty days from mid-autumn through to late spring. No artificial water was applied at any time for a full year as moisture levels were always above 50 centibars. The climate through this period was, dry autumn moist winter with -4°C (27°F) maximum frost, moist early spring becoming dry by late spring with 28°C (83°F) temperatures, wet month after longest day, dry late summer and autumn with temperatures up to 31°C (88°F).

Results showed that those planted mid-autumn to early winter (3 months) all rapidly developed a strong primary root system. The batch planted in the first month withstood the winter frosts but the other two batches suffered damage. Plants set out midwinter to late winter (2 months) suffered frost damage and did not develop primary roots but did develop proteoids. Owing to their poor performance these plants were considered to be non-viable by late spring. Plants set out in early spring, thirty days prior to the commencement of vegetative growth, did develop some primary roots and then made their vegetative growth flush with their subsequent over-all development considered satisfactory in all ways. Those planted a month later just as they were starting their vegetative growth initially made poor root development and with the exception of the two winter batches, were the least successful in survival and subsequent development. The final batch which were planted after they had made their spring vegetative growth, rapidly established a strong primary root system. These had the best survival and over-all development of all batches.

A brief summary of the above indicates that the following should be taken into account when planning the planting time of a plantation:-

In areas where there are frosts of -4°C and more, pre-winter planting does carry risks.

Winter planting has no advantages over spring planting.

To get optimum results spring planting must be timed so as to avoid the period when the plants are in active vegetative growth.

Provided sufficient soil moisture is available or alternatively can be provided, late spring planting gives excellent results with a minimum of risk from frost damage.

In areas where frosts are not a problem best results should be from mid-autumn, early spring and late spring planting.

11:7 PLANTING METHODS

There are many methods of planting and the procedures followed are usually adopted to suit the site. Holes may be dug by hand, bored with an auger or planting may be done in cultivated strips. If holes are bored with an auger it is important to break up the glazing affect that this causes on the sides and bottom of the holes as the roots have difficulty passing through this surface. Where strips are cultivated it does create a new surge of weeds to germinate but does make for easy planting and early maintenance.

Holes should be a minimum of three times the volume of the container that the plant comes from. Where the land has been in pasture the top spit of turf should be cut up and put in the bottom of the hole. This creates an area that is open and airy and also retains moisture well. All Proteaceae plants benefit from this and rapidly develop a primary root mass that will pass right through this and continue down towards the sub-soils. In some areas such as on the island of Hawaii when planting is being carried out in lava flows, larger holes are dug and

are then back filled with a local "mountain dirt", a very old decomposed type of volcanic lava. In soils made up from materials as outlined in 10:2 it should not be necessary to add any other materials to the holes before planting. If it is necessary it is probable that the soil structure is not suited to the commercial growing of Proteaceae. Never incorporate peat in the holes as it will "lock up" the root system and prevent it from developing as it should (see figure 49).

Plants should be set in the ground slightly lower than they were in the container, with the soil being back filled and only lightly firmed, not pounded down hard. Plants must have air in the soil or the roots won't develop as they should. If it is considered that they need immediate watering after planting, this indicates that the soil was too dry before planting was done and it should have been moistened prior to planting. Heavy watering after planting will expel the air from the soil and will have the same affect as pounding the soil down too hard. If at all possible watering should be with-held for at least four or five days as if the plants are made to hunt for moisture they will continue to do so throughout their life. Ideally the soil where they are being planted should be slightly damper than that of the container mass. This will stimulate the roots into immediate growth and within three days from planting many of the roots will be showing one to two mm. (1/16") of new growth. It is possible to get plants "hooked" on water and it is difficult to wean them off it. A well prepared plant, ie. in the right container mix and properly hardened off, should be able to survive and develop at a soil moisture level of 50 centibars from the moment it is planted. [Ref. Section 12 for information on irrigation and soil moisture measurements.]

Unless there is some definite reason for applying insecticides, fungicides, fertilizers etc. no chemicals should be incorporated in or near the hole as Proteaceae roots, both primary and proteoid are very sensitive to chemicals and may be damaged. If chemicals do have to be used they should be applied and worked into the soil at least a week before planting is carried out.

11:8 PLANTING THROUGH WEED MATTING

This method has now been widely adopted in New Zealand where most plantations are established on flat or near flat pasture land. There are two basic methods of planting, that of laying the matting and then planting the plants through holes cut in it and the other method of planting as for a normal row lay-out and then either laying a narrow strip of matting both sides of the row over locking on a line with the plants or laying wider matting folded in half alongside the row, then cutting slits to draw the plant through and complete by pegging down. The pro's and con's of using weed matting are dealt with in Appendix Three.

11:9 CARE — FIRST HUNDRED DAYS

If the plants were container grown in a medium that was compatible with the soil of the plantation site and were well conditioned before planting, they should need little attention for the first three months other than keeping sufficient soil moisture available, possibly restraining from wind-rock, protected from pests (including rabbits — they love proteas), diseases and weed growth and some initial training of future shape.

Extensive research has been carried out to determine what moisture levels should be maintained. There is considerable variation between minimum requirements of different varieties but it has been ascertained that at day shade temperatures of 30°C (82°F) humidity at 40% to 50% and a five knot wind, no varieties of South African Proteaceae suffer permanent damage in their first year at a minimum moisture level of 50 centibars in the top 30cm of soil. Some however will show temporary signs of dehydration. Under higher transpiration conditions some will suffer permanent damage. Although some varieties will survive at 80 centibars, the 50 centibar level of soil moisture under the conditions outlined above is the maximum dryness they should be subjected to. Tests have indicated that a minimum level of 40 centibars is necessary to keep the plant in a condition that it will maintain satisfactory health and vegetative growth. With Telopea it will be found that they will need more moisture (30 to 40 centibars minimum) to be maintained in a turgid condition.

There are some locations where plants will need protection from wind-rock. In extreme cases this may involve restraining them by tying in some manner. If small plants have been used the problem is minimised as the plants then grow into the situation developing a root system that will support their growth above the ground. On flat land where planting is done in three meter rows, good control of ground wind (0 to 40cm level) can be achieved by letting the grass grow up tall between the rows, only maintaining a small strip either side of the row. This has been found to be most effective in the first year after planting with all species and in a very windy location where it was tried no plants showed any signs of wind damage.

A watch should be kept to guard against the invasion of diseases and pests. Unless pests were present on the plants or in the soil at the time of planting there should be few problems except from those that are highly mobile, ie. rabbits, hares, gophers, birds, flying insects and those insects that develop rapidly on a seasonal basis. The same does not apply to fungal invasion as this can occur at any time when conditions favour its development. For this reason an inspection should be made at least every two weeks and prompt action taken if any problems from fungi are detected.

Keeping plants clear of weed growth is important during this period as excessive growth around the plants harbours pests, encourages fungal invasion and robs the plants of soil moisture. In this the use of weed matting can be of assistance but the use of herbicides carries great risks [ref.13:8].

The initial shaping of plants should have been carried out during the nursery production stage. Basically a plant should be encouraged to form the shape it will eventually achieve as a producing plant. If it is a Protea neriifolia and meant to be on a trunk it should have one, if it is meant to proliferate from a central

root mass such as Protea cynaroides it should be allowed to do so or if it is meant to grow from a central trunk and "rest on its elbows" like Leucospermum cordifolium it should do so. Double stems from near ground level on varieties that normally grow on trunks must be avoided as almost invariably it will cause the plant to split in half later in life. Keeping this in mind plants should initially be encouraged to develop their shapes by removing unwanted branches and where necessary pinching out the tips to promote lateral branching. When pruning plants of this age it is important that the amount of foliage that is removed at any one time is kept to a maximum of 25% of the total leaf mass and that branches are not cut off when the plants are in very active growth. The removal of branches during very active growth periods will cause a high sap loss through the cuts with the result that there will be die-back on that portion of the plant.

11:10 FROST DAMAGE — WHAT TO DO

It is always possible that a plantation will experience frost damage. The degree of damage to the plants will be governed by the frost factor (f/f) as outlined in 10:6 and the age of the plants. Plants of less than three years old will be at a much greater risk than older ones although the crop of flowers and foliage of all aged plants will be damaged at about the same frost factor.

When plants do get frosted, the damage is usually much more extensive in the last growths than any other parts of the bush. It is in these damaged growths that problems can begin. If a branch that has been obviously frosted is taken and split lengthwise with a knife it will be seen that there is a dark stain running down the central pith of the stem and it is usual that this stain will be the full length of the last growth run right down to the growth joint. If tissue damage is this extensive it is a good practice to remove those growths right back to that last growth joint as if this is not done, decay often sets in and runs down the pith of the stem where it may or may not stop at the growth joint. If they are left on they will sometimes heal over of their own accord but when growth begins the following spring they then collapse and die along with the new spring growths.

Fungal infection is a great danger following frost damage, not only in the central pith of the stems but also on the damaged foliage. Because of this it is a good precaution even where plants have only been superficially affected to clip off the obviously damaged growth and then spray with Captan, Ronilan and similar chemicals. This will seal off the damaged tissue and allow the plants to callus over the wounds. This treatment should be carried out within three days of the damage to the plants.

Frosts of greater than -6°C will damage old wood on many varieties. This is usually in the form of splitting the bark on branches that are more than a year old and the bark has turned from green to grey. There is little that can be done to save plants so affected as the damage is usually much more extensive than is apparent.

11:11 FROST PROTECTION

Protection is very difficult to carry out effectively in a plantation situation. The best protection is to choose the right site, select the hardiest clones and plant to encourage air movement rather than to restrict it. Some plantations use smoke pots, wind machines or overhead irrigation to raise temperatures and these are effective within certain limitations. There are anti-freeze chemicals available which can be sprayed onto foliage which are to some degree effective. These chemicals have a maximum effective life of about a month or until there has been 10mm. (half an inch) of rain. A side effect of one that has been tried was that it caused unacceptable spotting of some foliage but it did protect to a -2°C to -3°C level.

In a nursery where plants are more concentrated it is possible to control frosts effectively. The most common way is to protect the plants by stretching various types of cloth over the holding beds. This is quite effective provided it is at the correct height above the foliage canopy. Tests indicate that for frosts of up to -6°C, the best level is 120cm. (4 foot) above the leaf area. Lower than this and the frost will pass through it and if it is much higher than this the frost will re-form under the cloth. Readings taken during frosts of up to -6°C consistently show that there is a 2°C differential between the area that is covered at 120cm and an area that has no covering. At frost greater than this the deferential diminishes as the intensity of the cold is sufficient to penetrate evenly everywhere.

Protection can also be carried out by the use of overhead irrigation and wind machines. The use of irrigation does carry some risk of root damage caused by excessive amounts of water in the root zone.

SECTION TWELVE

Irrigation

12:1 OVERVIEW

In their natural environment most Proteaceae will survive in very dry conditions. To do this they go into a state of inertia and are able to maintain life for long periods with very little moisture available in the soil. This is also true in plantations provided the plants have been able to establish a satisfactory primary root structure.

In the first two years following planting, much of the plants' initial root development and demands for soil moisture are related to the container mediums they were grown in during the nursery production phase. Their record of establishment under dry conditions without irrigation in most soil types is not good with plants that have been nursery produced in peat or bark fibre based compounds. An exception to this would be when the plants are planted in peat type soils with which they would then be compatible.

12:2 PLANT TOLERANCE TO DRY CONDITIONS

Under New Zealand conditions I have seldom seen plants suffer unduly from dry conditions when the plants have been grown in the nursery in a media compatible to the planting site, provided the final planting was well-done and timed to coincide with favorable conditions for root development. However under severely dry conditions (60 centibars and above) they may go into a state of inertia during their first summer and remain in that condition until there is again adequate soil moisture to promote growth. If plants are allowed to remain in this state for long periods (several weeks or more), some permanent damage can occur through the dehydration of the cambial layer. This will show in the outer layer of bark which will take on the appearance of crepe paper. The damage is normally restricted to the parts of the plant where the bark is green or grey/green at or near ground level like that found on plants under two years old. Most healthy older plants are incredibly resistant to permanent damage through dry soil conditions.

When a plant does go into a state of inertia due to stress from a lack of soil moisture, it will take at least 72 hours following the application of water for a full reversal to take place and for the plant to become fully turgid again. This can be observed when plants in a nursery accidentally become very dry through a malfunction of a watering system and plants, especially those less than 18 months old begin showing stress in the last run of growth which will wilt during the heat of the day. If the plants are left un-watered these growths will dehydrate to such an extent that the leaves will burn up and the stem will wither to the base of the last growth. A healthy plant will then usually go into its state of inertia and suffer little more permanent damage unless it is left for a period of several weeks in this state.

If the plant is watered when the last run of growth is severely dehydrated, ie. just before leaf burn becomes obvious, (which with most varieties is at around 70 centibars), watering will arrest any further deterioration. However under normal sunny summer conditions (day temperatures 25° - 30°C), they will continue to show wilt during the heat of the day for the first two days following the application of water.

In a field situation the same symptoms of dehydration may be seen in plants particularly in the first year after planting, especially if it has been done too late in the spring to capitalize on their natural primary root development period or if plants with a vegetative canopy larger than the roots can support have been planted. If a reading is taken with a tensiometer at 25cm. (9") when the first signs of wilting are obvious, it will show a soil suction of 65 to 75 centibars but may vary a little depending on the soil grain size. At this reading you can neither see nor feel moisture in loam type soils and it is at this moisture level that most turf and weeds will perish, especially in sandy silica type soils which tend to retain heat more than soils derived from other materials. Provided they have developed a good primary root system plants of three to four years old (planted out one to two years) will tolerate up to 80 centibars at day temperatures of 30°C (shade reading), but this appears to be the uppermost limit for commercial varieties. If however the plant has been grown during the nursery phase in a medium not compatible with the plantation soils, it will usually have suffered such severe root damage by the time it reaches this stage that it will continue to completely dehydrate and die.

A partial exception to this is when plants have been grown in a peat based medium and have been planted out in the autumn from a container not larger than 400cc (1/2 pint). In this case provided there has been sufficient soil moisture available throughout the winter, they may have established enough primary roots to sustain themselves from permanent damage. However without irrigation available these are at a greater risk than those planted out from soil based mediums.

Whilst it is not advocated that Proteaceae plants should be subjected to such stress, it does demonstrate that provided they have been grown in the correct mediums for the soil types into which they are to be planted and they are set out during the optimum season, they are very resistant to death from a lack of soil moisture. However under such conditions a plant of any age would be unproductive either for cut flowers or as a garden plant.

12:3 CYCLE OF MOISTURE REQUIREMENTS FOR FLOWER PRODUCTION

It is a fact that not all varieties need the same amount of soil moisture to give good service in a garden or to produce top quality flowers in a plantation. This is

not only true of the differences that exist between varieties but also there are differences between variants within the same varieties. There is also the point that in their growth cycles all Proteaceae are rhythm plants, particularly in their seasonal moisture requirements, with the differences between varieties being relative to the conditions that exist in the specific area in South Africa from which they originally came.

Some are from summer rainfall areas but many of the varieties we use in our cut flower plantations and gardens are from the areas that experience a wet cool late winter and spring with increasing dryness and temperatures through midsummer with a prolonged dry period during the autumn to early winter. These varieties are adapted to this pattern through evolution and when it is interrupted whether by heavy warm midsummer rains or excessive irrigation during their normal dry rest period, they react adversely with serious root disorders which often cause death.

Heavy warm rains from tropical storms which at times drift south to drench New Zealand for several successive days during January to March, at constant temperatures of +25°C are the major cause of what are often regarded as "mysterious deaths" in plantations and gardens. The principal reason for these deaths in a field or garden situation is usually Phytophthora Cinnamomi but the onset of severe infections by other fungi is often a contributing factor. Much the same result can be expected from irrigation if excessive amounts of water is applied to plants during their dry period.

12:4 PROBLEMS CAUSED BY SOIL MOISTURE IRREGULARITIES

In cut flower production there are two principal problems that a shortage of soil moisture will cause. These are, shorter than normal flowering stems which is the result of a moisture shortage towards the end of the spring growth run; and the other is bud scorch, which is usually caused by moisture shortages in the late autumn period. It should be noted that bud scorch can be a genetic problem which may be aggravated by various climatic conditions and may not necessarily be the result of inadequate levels of soil moisture.

To crop successfully on a regular basis, plants, particularly Proteas, need soil moisture available to them at a level sufficient to maintain their growth patterns in the spring to midsummer period. If this growth flush is checked by inadequate moisture particularly towards the end of the run, it will cause the stems to stop elongating to their ultimate length although they will set buds.

On the other hand, constant irrigation without regard to the natural rhythm of the plants' annual pattern of development results in a series of growth flushes developing which bypass the flower buds that have set on the terminals of the earlier spring growths. This is a problem in many Proteas and is greatly aggravated by over-watering plants during their normal dry rest period. In excessive cases of this I have seen three growth flushes develop by late autumn past the flower bud which had set on the ends of the first spring growths. This makes the harvesting and trimming of the flowers labour intensive and costly. Even clones that have been selected for their resistance to this problem will develop one or two growths past the flower bud with all year round irrigation.

Another common result when excessive amounts of soil moisture are made available to a plant in the period when it should be on a declining supply is that they tend to produce a pendulous type of terminal growth. This is particularly evident in Protea neriifolia, obtusifolia, some repens forms and compacta when they are kept supplied with high levels of soil moisture during the very late part of their spring/summer growth run. In nature this is the period when they would be starting into their drier season and their terminals would harden off and set flower buds. When excessive irrigation is applied during this period the tips of the current flush of growth tend to over-develop their terminals with the result that they droop. This causes the stem to twist as it turns upwards again. In some instances it is not unusual to see two or even three such twists as the plant goes through successive surges of growth. Whilst this is of no consequence to the home gardener it is to the commercial cut flower producer as such stems have little value.

12:5 METHOD OF APPLYING WATER AND ITS EFFECTS

There are very few areas where Proteaceae are grown as a commercial crop that have sufficient rainfall in the correct rhythm pattern to produce a high quality commercial crop every year without the application of some supplementary water. How that water is applied and in what quantities will have a considerable bearing on the quality of the annual crop and the general health and productive life of the plant.

In cut flower plantations irrigation water is almost invariably applied by the trickle method, using emitters or drippers which apply it to the soil at surface level. The rate that water is applied varies between plantations and locations with almost every operator having their own programme as to the frequency and amount that is applied. The average where regular irrigation is carried out seems to be around 8 to 10 lt (2 gals.) on adult plants each time at five to seven day intervals on a year round basis with little regard to the season of the year or growth pattern.

The result of this practice is that the plants develop a surface root system and become reliant on a constant supply of moisture in the soil near surface level which causes them to go into a state of stress if for any reason water is not available in sufficient quantities in that upper soil level. As a result they have poor or no resistance to dry soil conditions and if they are dug up there is minimal evidence of a deep primary root system.

12:6 DEEP IRRIGATION

Research has been carried out to test the effects of applying water to a number of clones in other than the conventional surface irrigation method. The principal departure from the norm was to apply water to the plants at a depth of 45cm.

(18") below the soil surface. This was achieved by inserting a clay pipe on end into the ground about 25cm (10") from the plant. Water was applied by trickle irrigation into these pipes where it fell to the bottom and was then available to the plant at that depth instead of on the surface. This trial was run over a period from spring planting through a full year, a second summer and on through to the following winter. Unfortunately the trial was interrupted during the first winter when a frost of greater magnitude than normal damaged or destroyed some plants and it had to be terminated after the second winter when a frost of -8.5°C was experienced.

The row of plants where the deep irrigation was used was correlate against a control row using no irrigation, and two other rows, one using surface irrigation and the other one surface irrigation with weed matting. Five plants each of fourteen cut flower varieties were used under each method for the trial. Six litres of water were applied once a week from planting until late autumn of the first year and no irrigation for the second summer.

Through the first summer those with deep irrigation were noticeably slower in making vegetative growth than the two with surface irrigation with the spring run being only 70% of the surface-irrigated rows. However this was about double that of the row that was not irrigated. With the autumn growth, those with deep irrigation compensated for their earlier shortfall and by winter were comparable with those having the surface irrigation. Survival rate to midwinter was 97% with all those irrigated and 90% with those not irrigated.

At midwinter (first year) a frost of -6.5C. was experienced. Plants in the control row and the one that had been deep irrigated suffered little permanent damage. Those that had surface irrigation without weed matting suffered damage to some extent in most varieties. Those that had been irrigated with weed matting suffered severe damage to all varieties and many subsequently died. The exception was two Leucadendron varieties, var. "Safari Sunset" and a salignum clone which suffered no damage. The reason for the frost damage to the two surface irrigated rows was because these had continued to grow late into the autumn where-as those with deep irrigation and the control rows had made their growth and hardened off before winter.

In the second summer no irrigation was carried out but observations were made on a monthly basis on plant health. By midsummer the two rows that had been surface irrigated the previous year were showing stress from a shortage of soil moisture and had not matched the growth of the control or the one that had been deep irrigated. By early autumn those that had been deep irrigated were well ahead of all others in growth development and survival (still 97%) and this trend continued through to winter when the trial was terminated.

When the trial was terminated a number of plants were dug up to inspect the root development and this revealed that those in the control row had developed a primary system from the base of the plant which was distributed evenly to a depth of 65cm. The plants that had been deep irrigated had some strong primary roots going straight down to the 45cm depth where they then proliferated into a greater number and continued to penetrate to more than 65cm. Those that had been surface irrigated had their greatest mass of primary roots within the top 30cm. These roots had radiated out from the base of the plant at 30 degrees and deeper to the soil surface. There was evidence that during the second summer they had turned downward seeking the moisture at lower levels however there was little development below 45cm. All plants had proteoid roots present when they were dug up in midwinter with little difference between each row.

Although these trials were never taken to their ultimate end, that of observing the plants performance when in production, it did demonstrate that irrigation and the method of application does influence the type of root structure that a plant will develop and its vegetative growth rhythm at least in its first year. Further trials are needed under various climatic conditions and soil types to determine which is the best method for each particular variety under any given climatic condition and soil type.

12:7 SUMMARY

For a commercial operation producing cut flowers, irrigation is a necessity in many locations where Proteaceae are being grown. In areas such as Hawaii, California, Australia, Zimbabwe and other places where there is not regular rainfall it would not be possible to grow consistently saleable crops without it.

The amount and frequency that water needs to be applied to produce a saleable crop varies greatly and is influenced by the variety being grown, the soil structure, the pattern of the annual rainfall in relation to the plants requirements and the rate of dehydration caused by temperature and air movement.

Year round irrigation without regard to the plants natural rhythm of demand does cause problems in some varieties by producing bent stems, by-passing of the flower heads, immature growths that will suffer frost damage in the winter and root disorders. On the other hand, because Pr.cynaroides grows naturally in damp sands it benefits from all year round access to moisture.

The application of water to the soil surface encourages plants to be surface rooting. This makes them less secure in the ground and lowers their resistance to un-scheduled moisture shortage because of a lack of a deep primary root system. Water of poor quality will affect the function of the proteoid roots causing nutrient disorders and it is wasteful of water as much of it evaporates before the plant has access to it.

The application of water below the soil surface encourages a strong primary root system which makes the plants more resistant to periods of high dehydration, poor quality water does not affect the very sensitive proteoid roots to such an extent and evaporation is reduced greatly, in some soil types as much as 60%.

SECTION THIRTEEN

Maintenance — Development Years Through To Harvest

13:1 OVERVIEW

This section deals with the maintenance of the plants during their development from the time they became established following planting. It outlines how to maintain them during this period and how to manipulate them to make them produce a saleable crop.

Much of the success of the plantation will have been pre-determined by:

a. how suitable the soil and climate of the site are to the growing of Proteaceae as a commercial crop.
b. the matching of the correct variants or clones of a variety to the environment of the plantation.
c. whether the flowers from those varieties have a viable market in the accessible markets.

If the target market is the "top shelf" area of trade, the task of producing a product that is acceptable to the consumer will be much more difficult and less rewarding in plantations where seedling based stock has been used. In some cases much of the product from this type of stock will not be profitable unless there is viable access to the mass market type of trade. If selected clones [ref. Section 15] or variants of a variety that are matched to the soil/climate have been used, much of the work needed to produce a profitable crop will have been eliminated as plants will have been selected because of their ability to produce a bountiful saleable crop. The flower, which is the end result of production, is at its peak condition at the moment of harvest and no amount of post-harvest manipulation can improve it. Inattention to any one or more of the above points (a. b. c.) will make the production of a profitable crop more difficult or impossible.

13:2 PLANT MAINTENANCE — DEVELOPMENT YEARS

Maintenance care during the development years is a continuation of that outlined in 11:9. In areas that need irrigation attention should be paid to giving the plant sufficient water to maintain growth during the seasons when they should be growing and reducing the amount when they should be resting. This is particularly important in the growth period prior to the first harvest when they are growing the stems that will later carry the flowers.

To have plants that will consistently produce a saleable crop it is necessary to carry out a continual shaping programme during the first two years to produce as they grow through the seasons and readers should refer to Section 16 for further information.

13:4 TRAINING. PRUNING AND FIRST HARVEST — DEVELOPMENT YEARS

If one to two year old plants are used to establish the plantation. most Proteas and Leucospermums will take two years to develop to a point of a first possible small harvest and a further two years to reach full productive maturity. With some varieties it is best not to harvest at all until the third year as it has been found that with plants less than four years old, the removal of more than 25% of foliage at any one season does slow down their structural development which will affect their cropping ability in later years.

With Leucadendrons a first harvest is usually possible at the end of the second year and full or near full production can be expected by the third year. Leucadendrons should not have more than 40% of the foliage removed at any one season until they reach maturity which in most varieties is at three years after planting. From then on higher rates of foliage can be harvested.

Telopea and Proteas grandiceps and magnifica will take at least three years to reach a stage of maturity that will enable a first harvest to be made without adversely affecting their further development and many will take up to five or more years to reach full production.

13:5 WEED CONTROL — DEVELOPMENT YEARS

The control of weeds to acceptable levels is important during this period as excessive competition will create two basic problems. that of inducing fungi invasion during warm damp conditions and that of robbing the plant of accessible soil moisture and available nutrients.

There are many methods of weed control ranging from hand weeding. the use of weed matting, mowing and chemical control. All methods have their advantages and disadvantages and the final choice often depends on the terrain. cost factor and availability of labour. The practice of carrying out a "scorched earth" policy (bare ground adjacent to the plant), is not always in the best interests of the plant as it does expose the soil surface level to excessive heat and fluctuating moisture levels in the area where the feeder proteoid roots form. When the soil surface is bare, temperatures can reach well above 40°C in the top 50mm. (2"). and this will destroy sensitive root tissue. In nature the roots are never exposed in this manner, they are always covered by grasses, litter etc.

13:6 HAND WEEDING ASSISTED BY "SAFE" CHEMICALS

Weeding by hand or hand held tools is probably the safest method especially when the plants are small. The time factor of labour involved is not great when worked out on a per plant basis. Time sheets kept over a two year period on a small test plantation containing 350 plants planted on flat ground in three meter

rows by one and a half meter spacings gave the following results:- In the first year plants were maintained by a combination of hand weeding (four times) and chemical control (Versatile & Fusilade. three times) plus mowing between the rows as necessary and cross-row between the plants (three times). The time taken per plant was 65 seconds for the hand weeding and chemical application. and 55 seconds for mowing giving a total of 130 seconds per plant for the first year. The second year was a repeat of the system with two hand weeding and two sprays (40 seconds per plant) and mowing (35 seconds per plant). giving a total of 75 seconds and a grand total aggregate of around 3.5 minutes per plant for two years. This method does not give a bare ground control and is safe provided only these two or similar chemicals are used.

13:7 WEED MATTING

This method is now widely used by some growers with varying results which depend largely on the varieties being grown. the local rainfall and frost levels. On a cost basis it is often more expensive than hand weeding as hand maintenance for a four year period would amount to approximately three minutes per plant. The reason for this low time factor is that the mowing has to be done whether it is hand weeded or weed matting is used and the cost of three minutes labour would not compensate for the cost of the material and the laying of it. In many instances however the extra growth factor and the fact that plants can come into production a year sooner will more than make up the difference in costs. [Ref. to Append⸱ Three for information on comparison trials.]

13:8 CHEMICAL WEED CONTROL

There are many chemicals available to control weed growth in crops. These range from Paraquat (Gramoxone) a desiccant which causes defoliation of plant growth. right through to some very selective compounds that appear to only visibly affect specific families of weeds. The fact that they **do not visibly** affect a Proteaceae plant, at least in the first year, does not mean to say that it has no effect, nor that it never will have an effect at all. Almost all weed control chemicals used repeatedly over a long period will have some compounding effect.

The use of any weed control chemical, if used within the root zone of any Proteaceae plant must be regarded as putting the plant at some risk. The level of risk varies with the variety of plant, the chemical, the time of year it is used, the soil type, rainfall and/or irrigation, (if used), and the accuracy of the rate of the active chemical that is applied per area treated and where it is placed.

Two chemicals that have been used widely in Proteaceae plantations are Round Up and Simizine. Both of these at full strength are "total kill" to weed growth. When Round Up has been used at full strength in plantations where there are weeds with thick fleshy roots such as, kikuya and couch grass, clovers, docks, Californian thistle, yarrow etc. some problems have occurred through the trans-location of the chemical from the weed roots to the plant roots which can cause ill thrift and sometimes death. This risk diminishes if the weeds being controlled are only shallow rooting or only half strength is used but if proteoid roots are present and active near the soil surface at the time of application, some risk still exists. If Simazine is used within the root zone of Proteaceae similar results can be expected especially if it is active in the soil during the period when proteoid roots are present and active. Soil structure greatly influences the penetration of this chemical with coarse sandy/porous types being affected to much deeper levels than fine silts and heavy clays. In these there appears to be little penetration beyond surface levels unless excessive quantities are applied over a long period.

There have been findings of several chemical weed control trials in Proteaceae published over the past few years. These have dealt with these two and other chemicals commonly used in plantation management and have to some degree exonerated them from being a danger to plants. When assessing these recorded results it must be borne in mind that these trials have only been run for periods ranging from less than a year and up to about two years. In my experience no chemical can be declared as safe until it has been used for at least three years in succession under normal plantation practices as they often take up to at least a full years growth cycle to show any toxicity and up to two or more years to build up to danger levels in the plants or soil. I have seen many thousands of plants so affected in plantations over the past six years, usually at year three or four from the date of first application of these chemicals.

If chemical weed control is to be carried out, local information should be sought as to "safe"? compounds to use on that particular soil type and the rates it may be used at. Accuracy in application is essential as the difference between weed control and toxicity to plants may be very fine.

First indications of toxicity are a paling of the leaves, sometimes accompanied by slight variegation and in many varieties an out of character flushing of pink/red on the edges of the leaves particularly on those more exposed to the sun. This is followed by general ill thrift and a stunting of the growth and in the case of leucadendrons, forming bracts earlier than seasonally normal. If the stem of an affected plant is cut or broken it will be found that the wood has a yellow colouring rather than white/green, the core will be a dark brown colour and the general texture of the whole stem will be corky with the bark looking and feeling dehydrated. There is usually no recovery possible of plants so affected.

13:9 NITROGEN - ITS ROLE AND EFFECT ON PLANT GROWTH

Of the three principal elements needed for plant growth, nitrogen influences the growths that a plant makes season by season more than phosphate or potash do. Whilst the soils in many plantations initially do contain sufficient nutrients to produce a crop there is evidence to show that after a number of years many plants begin to "run out of steam" as they take on a lack-luster look

and start producing short stems. This is evident in high density plantations of Ld. cv "Safari Sunset" when after about five years without added fertilizers they start to produce shorter stems with small heads. This is especially so if they are on land that either leaches quickly or initially has a very low nutrient level. Similar deficiencies are evident in Proteas and Leucospermums on the island of Hawaii where plants are growing in pure lava which has virtually no ability to lock nutrients and the plants therefore rely on twice yearly added fertility to keep them producing.

All Proteaceae have a need of nitrogen to maintain their growth development. In what form and in which season it is available to the plant has quite significant effects on the type of growth it encourages. It must never be applied in the nitrate form as this is quite toxic to all varieties, particularly Proteas and if it is available in excessively high amounts (over about 70ppm) it will cause severe damage and above 150ppm death. Nitrogen in the ammonia form such as Sulphate of Ammonia has proved quite safe if prudently applied and levels of 50ppm of ammonium nitrate in the period leading into the spring growth are acceptable.

Depending on the time of year that nitrogen is available it will have a marked affect on the type of growth that the plant will make. Proteaceae use their proteoid roots to store and then provide the plants with the nutrient to produce vegetative growth. If left to their own rhythm they will store nitrogen during the winter when the proteoid roots are active and then use it up during the spring growth flush. In their natural environment proteoid roots are not normally present or active to any degree from spring through to early winter so the plants only have one chance to store and then use the minimal amount of fertility available. Remember that the soils they grow in are usually very low in nutrients and the only availability of it is from decaying litter. Under cultivation however where it is normal that summer autumn soil moisture levels are kept above those that would prevail in nature, the plants will continue to take up nutrient as under these conditions they do maintain a low level of proteoid roots through the summer. It has also been established that primary roots are capable of taking up and supplying the plant with nutrients. This has been proven where plants have been seriously affected when planted on land that had an excess of phosphate in a subsoil layer starting at one meter (40"), well below the level of any proteoid roots. If nitrogen is available to plants under cultivation in the summer/autumn, they have the ability to "main line" it through their primary roots straight into their system with marked effects on their vegetative growths.

If nitrogen is available to the plant in the late winter/early spring it will help to promote a strong terminal vegetative growth during the early part of the summer. If however it is readily available in late spring, it will promote a soft pendulous type of terminal growth a month or so after midsummer. This is particularly evident in Leucospermums, the later growing Protea neriifolia forms and Leucadendrons which make strong midsummer growths. If it is available in the late summer it will stimulate multiple lateral growths from behind the set flower buds on Proteas and multiple random growths on most Leucadendrons during their mid to late autumn growths. These late growths on all varieties are very prone to frost damage. The only time that nitrogen can be applied when it will not adversely affect the crop is in the late winter when it will assist in the development of strong terminals during the main spring growth which will then set buds.

13:10 THE YEAR BEFORE THE FIRST HARVEST

During the year leading up to their first harvest, the plants will change from a juvenile type of growth that has developed the structure of the plant, to a mature type that will produce flowering stems. To ensure that a high percentage of these flowering stems grow to be a marketable product will take a certain amount of control and manipulation as without it, many of them may be short or alternatively they may be long and bent with many by-passes. Even if the plants have originated from selected stock, poor cultivation practices will still give poor product and poor returns.

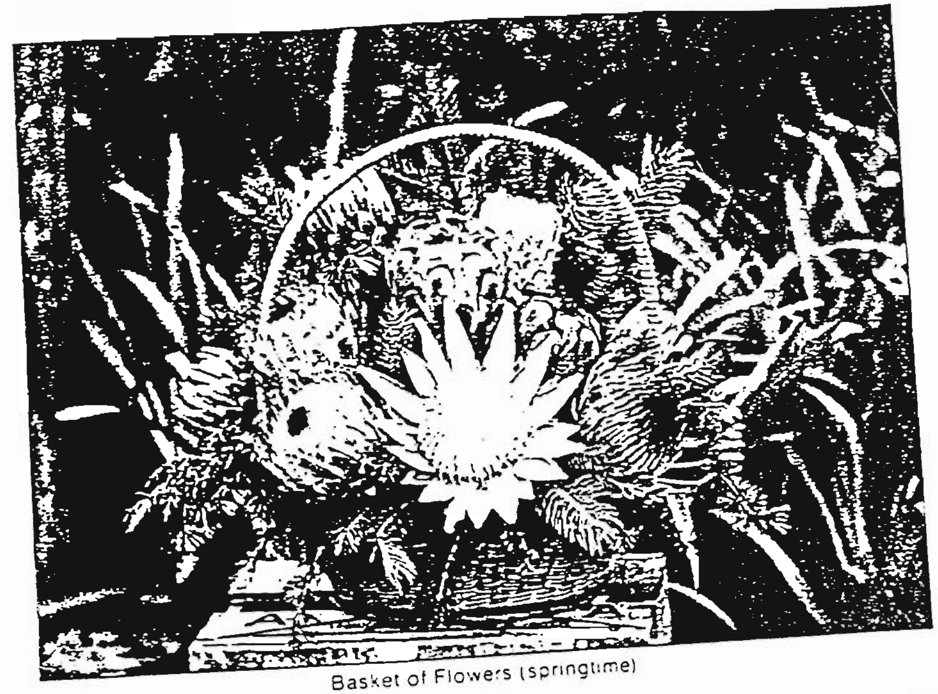
The principal aspects that will influence the development of the best possible flowering stems in this and each successive year thereafter are: how much and when nitrogen and soil moisture are available to the plant in relation to their natural rhythm of growth. The application of water and the effects of soil moisture on the plants growth habits has been dealt with in Section 12 and the role of nitrogen in 13:9 above. Besides attention to these it is necessary to carry out a certain amount of training and care of the plants.

Throughout the productive years of the plants it is necessary to be aware of and control as appropriate in relation to the market being supplied, fungi and pests invasion. How clean a flowering stem and its flower is from fungi and pests will greatly influence its post-harvest vase performance and subsequently the long term profitability of the crop.

With some varieties it may be necessary to thin out a crop to encourage a better type of final product. It is not likely that any thinning will be needed in the first harvest year but in subsequent years a certain amount of pruning and thinning may be necessary to develop the greatest potential of the crop.

The pruning and thinning practices of growers vary tremendously and depend on the varieties being grown, the local climate, how the crop is harvested, over what period the crop is harvested and the age of the plant. In many instances the normal harvesting of the crop from mature plants will do much of the necessary pruning. It is not possible to lay down any hard and fast guidelines on pruning but there are certain basic practices which should be followed.

The removal of more than 65% of the total foliage of a mature plant in any one season will usually result in it being less vigorous the following year causing it to have fewer flowering terminal growths and/or may cause it to go into a state of shock through a lack of sufficient foliage to support it. Varieties that are har-



Basket of Flowers (springtime)

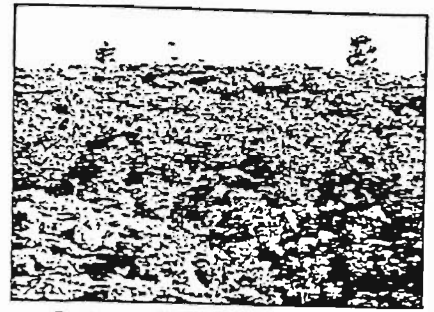
The most southern protea in the world. Stewart Island, New Zealand. 47° South.

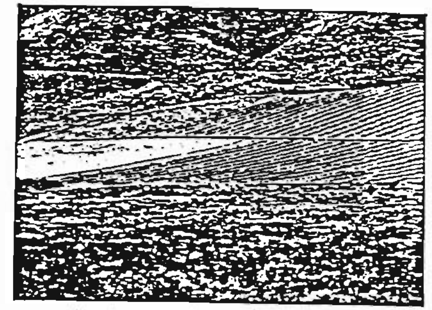

Pr. hybrid cv."Candy Floss"


Pr. neriifolia cv. "King Mink"

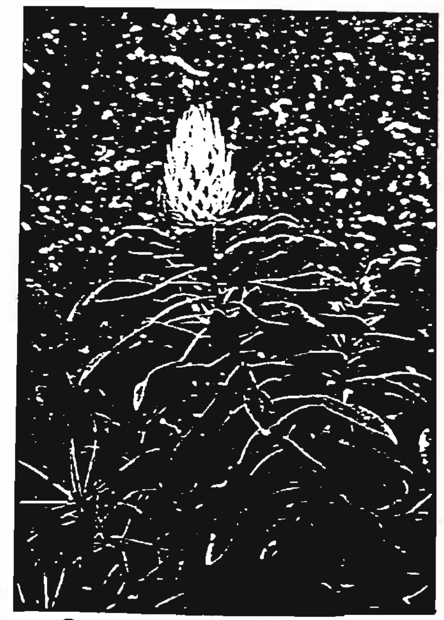

Pr. hybrid cv. "Pink Fantasy"


Pr. hybrid cv. "Fantasia"


Protea neriifolia growing naturally near Caledon, South Africa.


Proteas under cultivation near Kleinmond, South Africa.


Proteas in grassland in New Zealand.


Protea cynaroides growing in lava on Is. Hawaii.

Ld. orientale cv. "Fionaflora"

vested or pruned close to the active spring growth are more at risk than those harvested and pruned progressively through the winter.

Some clones of Protea are bi-annual croppers, producing a large crop one year and a much smaller one the following year. This is particularly so in those that produce very long stems as these are usually the result of two years growth on each stem before the flower bud sets. With most Leucadendrons excessive and late spring pruning will result in a greatly increased number of growths initiating of which only a relatively small percentage will develop to produce a full bract the following year. Thinning these out will increase the number which will reach maturity. Late spring pruning of any plants increases the risk of fungal invasion through the wounds and in Proteas often results in die-back which can be quite severe on some varieties if there is a very active sap flow.

13:11 CARE AND MAINTENANCE — SUBSEQUENT PRODUCTIVE YEARS

By the time plants have reached the age of their first production they will have become well-established in their site, have formed their ultimate structural shape and become acclimatised to the rhythm of the local weather pattern of rainfall, temperature, light and air movement. If the plants were well chosen in relation to the soil and climate of the plantation, survival to this point will probably be in excess of 85%.

The continued survival and productivity of the plant will depend on two aspects, that of maintenance and manipulation and that of the life expectancy of the species and varieties that have been planted. The maintenance and manipulation of the plants is a continuation of those practices carried out during the development years. As the plants age they may need more water during some seasons to develop their larger canopy to its full potential as a commercial crop and as they use up the resources present in the soil they will need added fertility in the form of NPK and often some trace elements such as iron, zinc, magnesium etc. As these needs vary greatly from place to place local practices should be followed. It is possible to "read" many deficiencies in the leaves of the plants and this is outlined in Section 16.

The productive expectancy of plants varies greatly but in general terms Leucadendron production wanes in stem length and numbers after about five to seven years. Proteas should produce well until they are twelve years old and will then tend to become short stemmed. Leucospermums are at their peak until they are about ten but depending on the clone and climate can be productive until they are twelve or even fifteen years old and Telopea are known to still be productive after thirty years. There are exceptions to all of these with varieties that have a lignotuber giving much longer service.

An annual pruning following harvest is necessary to help in restructuring the plant for the successive years and to remove any branches which may break off back to the main stem. With some varieties, particularly those with the hairy leaves, it is necessary to carry out some foliage thinning especially near ground level to assist in air movement. The foliage of varieties such as Lsp. cordifolium and Pr. magnifica become so dense at this level that in areas where there is high humidity and/or warm summer rains there will be problems with fungi.

As an experiment we once removed all the lower branches of some eight year old Lsp. cordifolium cv."Harry Chittick" so that they were on trunks for the first 30cm to 40cm and we left some still growing to the ground naturally. Those that were trimmed to a clear space between the soil surface and foliage improved greatly in health and have since had fewer fungal problems where as those that were left untrimmed were infected with various fungi and were subsequently removed. This has also been done on an experimental basis with Proteas with the same results.

In areas where there is high humidity and temperature with levels of th/c95 (th/f140) and more, attention should be given to encouraging air movement at ground level particularly with varieties that have soft hairy leaves. There is evidence that dense foliage at the lower levels act as a link for fungi invasion into the plants from the soil and grasses. Many of the fungi that affect Proteaceae are hosted by grasses.

The continued successful production of a viable crop is a combination of having selected the right plantation site, the right plants for that site (and the market), common sense in the maintenance of the plantation and a lot of work. The rest is easy.

SECTION FOURTEEN

Pre-Harvest — Harvest — Post-Harvest Procedures

14:1 OVERVIEW

Whilst much of the vase life of a flower is controlled by the genetic make-up of the plant that produces it, the methods and procedures followed leading up to harvesting and the immediate post-harvest handling of the crop will also play a significant role in the over all result.

There are some varieties of Proteaceae particularly Proteas that will only give three or four days vase life. No matter how they are handled their degeneration can not be delayed. It is also a fact that there are big variables in the vase life of different clones of a single variety. If we are to take Pr. neriifolia as an example, some clones will withstand seven days in transit and still give two or more weeks vase life while others will not even survive three days travel or vase life without degenerating to an un-usable state. The importance of selecting and planting stock that is known to be capable of producing a viable flower was outlined in Section 10 and is summarized in Section 15. If an error of judgment has been made in the clones/variants selected and planted the problem of poor flower types will now become evident. A flower is at its peak of perfection at the time of harvest and from that moment on it will degenerate. Good pre-harvest preparation and post-harvest procedures will slow down the degeneration and enable flowers from good genetic material to give a satisfactory vase life. It will however do little to help flowers from poor genetic material other than perhaps prolong the vase life one extra day.

14:2 PRE-HARVEST PROCEDURES

There are three principal pre-harvest causes of leaf blackening and rapid flower degeneration:

i. undetected dehydration within the plant at the time of harvest,

ii. the plant experiencing a sudden surge of sap, (caused by the plant being dry and then suddenly receiving water or alternatively a sudden rise of temperature in the very early spring),

iii. the effects of chemical reaction from the application of insecticides.

Of the three main species, Proteas are by far the most likely to be affected by any of the above. It is very difficult to detect dehydration within a mature Protea plant at the time of harvest. Extensive observations on a number of selected clones indicate that there is only a fine line between a deficiency in soil moisture level that would cause the problem and that which would not. These

investigations have also shown that each clone has different tolerance levels to all of the above causes.

When a flower is harvested from a mature plant that is under stress from dehydration, the flower and foliage are already partially dehydrated although it is not possible to see or detect this in any way. When the stem is severed from the plant the flower and foliage are already short of moisture within the cells and in some cases flowers and foliage will go black within minutes even if they are placed in water immediately. This is because when a Proteaceae plant goes into a state of shock through dehydration it will take up to 72 hours for a full reversal to take place. A flowering stem responds in exactly the same way. It is just not capable of taking up water quickly enough even if it is available.

The second cause, that of a sudden rush of sap within a plant is normally only a problem of short duration but occasionally extends over several weeks and is confined to the autumn to early winter period although a similar phenomena sometimes occurs in the late winter when an un-seasonally warm week is experienced. In this case the surge of sap flow is caused by an out-of-season rise in temperature and not through the sudden availability of water.

It has been established that when a plant has been under stress from dehydration caused by a lack of adequate soil moisture and it is then supplied with water, it will become fully turgid again within 72 hours. As a result of the period of stress from dehydration it goes into a state of bud initiation which it may or may not continue to develop into full growths. When this happens the flowers, foliage and growth buds all become highly stimulated and go through a chemical change which when the flowers/foliage are harvested cause them to blacken. This problem has often been observed in non-irrigated plantations when following a dry period there is significant rainfall which stimulates an out-of-season sap flow in the plants. If flowers are harvested from about the third to the seventh day following rain, they and the foliage will often go black. This explains why blackening occurs when previously that particular clone has been clear of the problem. This syndrome usually disappears after about a week but if the plant is so stimulated that it goes into a vegetative growth run it will continue for some time. Outward signs of this will probably be in the form of by-pass growths from behind the flower heads or in a lesser degree as slightly enlarged terminal tips which are usually an emerald green colour. In such instances the problem will continue for several weeks until the sap flow slows down again and growth ceases. Because of these two causes of blackening, it is necessary to ensure that the plants have sufficient constant soil moisture to eliminate the possibility of this occurring during the harvest period. Good irrigation practices minimise the risk of these problems occurring.

The third cause, that of chemical reaction from insecticides is probably caused by the emulsifying agents rather than the active ingredient as the same result has been experienced when an excessive amounts of wetting agent has been used just prior to the harvest of cuttings. The effects can be quite severe if the

chemicals are applied within three days of harvest especially if it is bright sunny summer weather.

A final pre-harvest check should be made to ensure that the material is as free of fungi and pests as is practical. Once the flowers and foliage are harvested and placed in a confined area in close proximity to each other, it is a haven for the rapid development of fungi, which transmits from one to the other by contact or air-borne spores. In the case of insects, particularly those that cause the dehydration of plant tissue, (mites, thrips etc.) these will greatly affect the vase life of the flowers. Pack- house control will do nothing to improve the situation as the harm has already been done.

14:3 HARVESTING

Flowers are best if harvested in the mornings when it is cooler and before the effects of the rising temperature and the suns rays have increased the transpiration rate within the plant. For the best possible vase life they should be recut and placed in water as soon as possible following harvest.

Research and observations show that the degeneration of material is accelerated at temperatures above 20°C and very greatly so at 25°C and over. The acceptable time lag from the moment of harvest to being placed in water is on a graduated scale in accord with the temperature at the time of harvest. Below 12°C there will be very few problems but it should still be placed in water as soon as practical. From 12°C to 20°C the maximum time should not exceed 45 minutes, from 20°C to 25°C 30 minutes and for 25°C to 30°C an absolute maximum of 15 minutes. All times should be shortened appreciably when there are conditions of high dehydration such as hot dry winds. When temperatures are 30°C and over, especially if coupled to humidity of less than 30%, inconsistent vase life of flowers will be experienced even if the material does appear to be in good condition at the time of harvest and it is placed in water within minutes of harvest. It is under such conditions that clones that have been selected as having superior vase life will show their ability to perform.

When harvesting it is usual practice to cut so as to give the longest possible stem length without causing structural damage to the plant. It is important to cause the minimum of tissue damage when handling material as broken and bruised foliage will give off ethylene gas which is very detrimental to flowers. Cut material should never ever be left lying in the sun even for a few minutes as many varieties can not tolerate the suns rays on the back of their leaves, a few minutes can cause some to dehydrate and go black. Cut material should not be heaped up or when placed in buckets of water it should not be jammed in tight. This is because once harvested, all material will go through a period when its temperature will rise, (usually about 2°C within two to three hours of harvest), and if it is left tight even if it is in buckets of water and not controlled by refrigeration it will continue to heat up which causes it to degenerate more rapidly.

Harvesting is an operation which should be carried out during periods when there is the least dehydration. when the flower is at its optimum condition in relation to the market it will be sold in and handled in such a way that causes the least possible damage to the flower or foliage. Remember the flower is at it most perfect state at the moment of harvest. the plant has done its part. the rest is in the hands of the grower.

14:4 POST-HARVEST PROCEDURES

This is the final act in the chain from the initiation of the plant right through its development to producing a flower which has just been harvested. Good post-harvest handling will ensure that the flower gives its best possible value to the end consumer. poor or a total lack of post- harvest handling can destroy the flower well before its due time.

There have been a number of papers written on post-harvest handling of flowers in general and a certain amount of work has been done and written on the handling of Proteaceae in particular. Unfortunately some of this work has been carried out with material harvested from seedling stock and because of the highly variable product that seedlings produce the findings are not necessarily conclusive for that particular variety. To eliminate the possibilities of discrepancies. all research work I have done has been carried out on material from identified clones.

It has been established that dehydration is the greatest factor influencing the degeneration of the flower. While there are other factors such as exposure to ethylene gas, chemical reaction to sprays etc. dehydration is still the main problem. There are many things that can cause it such as those outlined above in the pre-harvest file, but following harvest the principal causes are high temperatures and/or very dry air which is not necessarily hot air. Cold air can be very dry and can cause severe dehydration in flowers.

For effective post-harvest handling of Proteaceae a chiller is a necessity. The standing of flowers in water is not sufficient on its own to ensure that they will give the best possible results. With Leucadendrons, which in actual fact are foliage and not flowers, it is possible to process many varieties through the winter months with acceptable results without refrigeration but with Proteas, Leucospermums and Telopea it is virtually impossible to do full justice to them without refrigeration of some kind.

The quality of water is important as poor water with a high pH. or carrying water borne fungi can cause rapid break down of plant tissue causing blackening of the leaves and flowers. Water with a high pH. from a mains supply which has been chlorinated can be disastrous to Protea flowers and is probably the reason why occasionally a shipment goes wrong as some mains supplies can vary somewhat in pH. and chlorine content. As water is the common denominator in post-harvest procedures it is also the vehicle by which contamination can be passed from one batch to another and for this reason it is important that fresh water is always used for each batch that comes into the pack-house and that the containers are cleaned frequently.

How the material is handled once it arrives in the pack-house does vary from one grower to another and the system used is usually designed to fit in with the pack-house practices. Some growers stand their flowers in buckets of water then immediately place them in the chiller. while others may strip the leaves before standing in water and placing them in the chiller. Some will use other variables. The important thing is that the field heat and that which generates within the plant tissue following harvest must be brought down to around 4C. as rapidly as possible. Once it has reached this temperature dehydration and degeneration slow down to near zero and the aging process is almost halted.

The re-cutting of the stems just prior to standing them in water ensures that they have a fresh start. The capillaries on some varieties seal off very quickly in the air. there-by effectively stopping the stem from drawing up water as it should. A recut will minimise this problem.

The use of preservatives. (as distinct from the use of sugar for pulsing). does not appear to give any consistent results and it is doubtful if they have a great deal of influence on vase life. As all Proteaceae are woody plants it is much more difficult to get preservatives into them than say carnations. chrysanthemum etc. which are soft stemmed. With Proteaceae the uptake of water which would be the vehicle by which preservatives would translocate into the stems. is strongly influenced by the maturity of the flowering stem and also the environment conditions of temperature and relative humidity in which they stand in the water.

During tests on the flowers of many varieties it has been shown that the inclusion of the fungicide Thiram and to a lesser degree Captan in the water will improve the traveling performance of some flowers. In particular Pr. cynaroides responded well as also did Lsp. reflexum. In one case. stems of Ld. cv. "Red Gem" were treated and remained usable as a fresh cut flower for FOUR YEARS!

The use of a 2% sugar solution as a pulsing medium has been tested on a number of varieties. Its greatest use is in restoring Leucospermum flowers if they dehydrate during transit. If the stems are recut just as they are stood in the solution it will restore the flowers to a fully turgid state and usually heightens the colour. When using this solution it is important not to splash or spill it on any part of the stem other than the base as sugar on the leaves invariably promotes the rapid development of fungi wherever it contacts the foliage.

Exposure to ethylene gas especially in high concentrations will do great damage to flowers of any kind. Common sources of ethylene are from cut and bruised foliage and torn stems caused during the stripping of leaves or the removal of by-passes, petrol and diesel exhaust fumes, smoke from tobacco and ripening fruit. Precautions to avoid the exposure of flowers to these sources should be taken at all times.

Good post-harvest procedures are really just good common sense.

SECTION FIFTEEN

Clone Selection for Cut Flower Production

15:1 OVERVIEW

The present standing and future of Proteaceae as an internationally recognised cut flower is and will continue to be closely linked to the ability of the growers to supply a consistently high quality product, that is of uniform type and form, to the international floricultural markets. The ability of growers to do this, irrespective of where the plantation is situated, is a direct result of what they plant and no amount of careful attention during production and post-harvest treatment of the crop will make a very good flower out of poor genetic material.

There are distinct markets for Proteaceae flowers with the oldest and most established one being the mass utility outlets such as those which have been selling them for over twenty years in Europe (which up until now has principally been supplied by material harvested from natural stands in South Africa). The others are the developing world wide "top shelf" design florists and retail outlets. These are very discerning markets which expect top line material every time, not just sometimes. It is a fact that much of the material that has been offered to them in the past few years has done little to gain their confidence as it has been more suited to the mass utility area of trade.

If growers intend to supply and are expecting the financial returns from the "top shelf" markets, then they must plant clones that will consistently produce a product that is acceptable in those markets. It is a proven fact that the careful selection of the right clones, grown in a specific climate suited to those clones, will result in the production of top quality material. The points that must be considered to do this have been dealt with in Section Ten. On the other hand if seedling based material or vegetatively propagated plants from unproven stock is used to plant plantations, the resultant crops will be much the same type and quality as that "harvested wild". Growers of this type of flower will not be able to capitalise on the higher priced markets and attempts to market this inferior material in the astute areas will continue undermining the confidence of the design and up-market florists in Proteas.

This section summarizes the result of eight years of personal involvement in the screening and selection of Proteaceae varieties in the search for clones suited to cut flower production. This work is and will continue to be an on-going programme and what is published here is intended as a guide to protea growers on what to look for and how to go about the initial screening of plants to identify those that have merit. Because of their constant contact with the plants, growers are the ones who have the greatest capability to make these initial observations and selections. Every reader of this book has the ability to find a real "gem".

15:2 THE SETTING OF SELECTION PARAMETERS

The criteria I set following investigations into the prospective markets of Europe and North America in 1979 was:-"IF IT WON'T TRAVEL IT IS NO USE PLANTING IT".

With no internationally established bench mark of standards and no blue print to work to, it was necessary to determine a number of factors before any progress could be made in selecting clones for cut flower production. Twenty years of handling Proteaceae plants, had shown that not only was each clone different within a variety but also that each particular clone could give quite variable performances when grown in the diverse climates found throughout New Zealand. As it was considered probable that these differences would also show in the flowers' post-harvest performance, it was decided that clones being reviewed should not only be screened for the vase life of their flowers but that a comprehensive programme be adopted to cover all aspects from plantation establishment through to the vase life of the flower following transit from New Zealand to New York. An extension to this was to have plants of each clone under review established in various locations throughout New Zealand for observation.

Initially the selection process was divided into two areas of investigation, that of a general observation of the plant and the flower it produced, and secondly the post-harvest performance of that flower. Minimum parameters were set which were related to what a flower would experience from the bush to the end consumer and what that consumer would expect of it.

In the material sense these covered:

a. stem length and straightness of stem,
b. leaf configuration especially those near the base of the flower,
c. the flower's ability to mature and open following harvest (very important in Leucospermums and Pr. cynaroides),
d. flower colour and its ability to retain its lustre after five days in darkness, (in a carton),
e. flower conformity (shape and size).

In the post-harvest area it evaluated not only vase life but also the flower's ability to travel and still give satisfactory value to the end user. Early experiments had shown that a flower that had a good vase life was not necessarily a good traveller.

The check sheets since developed and published with this Section are the result of seven years of testing, screening and evaluation. They were developed for New Zealand locations to record plant and flower performance in relation to given climatic conditions. The final assessment, (sheet 4) gives two ratings. that of the flower only. and secondly the overall score of plant and flower related to the climatic conditions it has been produced in. The parts per hundreds (%) allocated to each specific section of the overall review are in relation to my assessment of their overall importance. The importance of these sections would vary from country to country depending on how long a flower takes to get to a market. climatic variations etc.

15:3 PRE-TESTING EVALUATION OF PLANT AND FLOWER

Over the past eight years a number of aspects have been noted which influence the production capabilities of the plant and the vase life ratings of the end product. By taking these into account it is now possible for an experienced person to pre-assess the probability of any particular plant producing a viable crop in a given climate. This saves a lot of unnecessary work and can speed up the trial period and final assessment. The following is a summary of the main points recorded in relation to the plants genetic make up.

1. Foliage should be free from serious fungal invasion and disorders. This has been found to be the most important aspect in initial evaluation as in all species and varieties. if a plant does not have "clean foliage" it is rare for it to have top quality flowers or bracts that will give satisfactory travelling ability and vase life.
2. Stems should be long and straight with the flower well set. and without too many leaves near the head. There should be and a minimum of by-passing.
3. Leaf colour (in Pr. neriifolia in particular and in others to some degree). those that have blue leaves or a reddish edge to a green leaf have a superior ability to travel and give a better vase life than those with green leaves. They will also perform much better where there are high light levels.
4. Bud scorch of Proteas that is associated with high light levels should be noted. Some clones suffer serious bud damage when light levels exceed 80,000 j/lu, [ref. 2:3]. This damage affects the transit and vase life performance of the flower. Where this is a problem, the clone should be tested in an area that experiences summer afternoon cloud cover as it may perform very well under such conditions.
5. Frost hardiness should be noted of plant and flower. Some plants will tolerate -5°C but will have their buds/flowers damaged at -2°C.
6. Differing seasonal rainfall patterns from one location to another will influence a plant in relation to health and seasonal growth structure. Problems caused by this are usually related to fungal invasion and if this is a problem during the flowering season it will influence the post-harvest performance of flowers and leaves. In growth structure, excessive rainfall during the plants rest period often causes by-passing and/or pendulous growths, even in a clone that has been selected for its upright stance.

7. Impact resistance of leucospermum heads from becoming detached from the stem during handling and transit should be measured. Lsp glabrum and its hybrids have given problems.
8. Flowering season related to market demand. This is important where freight may exceed the value at low demand periods.
9. Male leucadendrons generally do not travel satisfactorily at their fully mature stage. They should be saleable before that stage of maturity.
10. Telopea evaluation. Over the past four years I have carried out preliminary screening on the flowers of some sixty clones of Telopea flowers. During this work several aspects have been identified which when applied give a near infallible instant evaluation of a clones travelling and vase life expectations. These findings have been correlated against the performance of these sixty odd clones and have been found to be constant in every instance to date. These are:-

i. The more intense red the flower is, the poorer is its performance. This is particularly so when the intense colour runs right to the ends of the flower styles.

ii. The higher the dome is. the poorer the vase life performance is.

iii. If the ends of the flower styles are tending to be pink rather than white. their vase life performance is always good.

iv. The flowers that have the best vase life are those that have a defined pink end to the styles.

v. If the flower has a combination of being crimson (not mauve) with a rounded dome that has defined pink ends to the styles it will travel well and then give good vase life. I have one with this combination which lasts for thirty four days in a vase.

15:4 PRODUCTION OF MATERIAL FOR SCREENING AND EVALUATION

The following points should be considered when making provision for a supply of material for evaluation.

1. Plantation grown plants must be used for all testing. Flowers harvested and tested from plants in gardens etc. may give misleading results.
2. A number of plants of each clone under test should be used for harvesting material from for testing. A single plant can give misleading results.
3. Controlled irrigation in relation to seasonal growth patterns can play a significant role in the stem length achieved in some clones. Those with marginal length stems (less than 45cm) should not be discarded until grown with irrigation.
4. If nitrogen is available to the plant especially during the spring growth it will lengthen stem length. On the other hand if it is available in mid-summer it may also cause severe problems with bent stems and by-passing in the midsummer - autumn growths.

15:5 FLOWER EVALUATION

There are many aspects which may influence the post-harvest performance of a flower/foliage. The condition of the plant, the climatic conditions prevailing just prior to and at the time of harvest, the production techniques used in the weeks prior to harvest and the handling of the material in the first fifteen to thirty minutes after harvest have all been found to influence the post-harvest performance of the flower. If these are not taken into account when harvesting, testing and assessing, some misleading results can be recorded in the flower's ability to travel and subsequent vase life. Because of this, persons carrying out this work should standardize their pre- and post-harvest procedures and use the same format with every clone every time. These procedures should be of a practical nature that can easily be duplicated under pack-house conditions. It is only by doing this that reliable data will be gathered which can then be used in a practical situation.

In pre-harvest procedures the following should be noted:-

i. Age of plant. Proteas and Leucospermums should be at least four years old before being used for observations. By this time they will have adopted their adult cropping pattern. Leucadendrons should be three years old. Growers should not condemn a promising plant or plants of a clone for poor performance in their particular climate until it has flowered for three years as flowers from young plants often give poor travelling performance and improve as the plants get older. The reason for this is that plants of less than three or four years old are almost continuously vegetatively active which may give results similar to those experienced when an adult plant experiences a surge of sap flow. [Ref 14:2 & iii. below].

ii. Material under stress from dehydration must not be used for testing. It should be noted that dehydration can be caused not only from dry ground conditions but also by dry winds (hot or cold) and frost.

iii. If a plant has been dehydrated owing to dry ground conditions and is then watered either by irrigation or rain, the material must not be harvested for testing for a least six days. The sudden rush of sap within the plant is one of the main reasons why a clone that has not previously given leaf and flower blacking problems suddenly goes wrong in transit.

iv. Some insecticides if applied within four days of harvest may affect the post harvest performance. Problems have only been observed where they have been in emulsion forms or when spreaders have been used. It is probable that it is the emulsifying agent rather than the insecticide that is the cause. Spraying a week prior to harvest will minimise the possibility of inconsistent results from this.

In the post harvest procedures the following should be noted:-.

v. Time of day of harvest. For consistent results only harvest early in the day especially when temperatures are going to exceed 18°C. Accelerated degeneration has been observed above this temperature.

vi. A time span not exceeding thirty minutes from harvest to water should be adhered to. Even if this time factor is achieved the combination of temperature above 18°C and material cut from a plant under stress from dehydration will often give inconsistent results. Trials have shown that most material degenerates rapidly, often beyond recovery, after 45 minutes at +18°C.

vii. Stripping of leaves. In some clones this results in damage to the flower stem which causes poor vase life owing to the production of ethylene gas and the invasion of fungi. This has been the reason for discarding some promising clones under observation. When a clone is being tested and this is a problem, cutting the leaves will reduce the stem damage but may not be cost efficient in production.

viii. Removal of by-pass growths will cause the same problems as stripping leaves. By-passes should be removed in the field at least a week prior to harvest.

ix. Flower preservatives. Trials with these have not shown any consistent results. However the use of certain fungicides in the holding water has shown benefits to some clones. It is thought that the influence of both preservatives and fungicides is closely linked to the flower/foliage ability to take up the solution in the immediate post harvest period. If flowers/foliage are stood in water at room temperature their uptake will be considerably more than if they are in a chiller unless the chiller humidity is very low.

x. Density that material is packed in the carton has a bearing on its survival and eventual vase life. Cartons under trial must be packed at the same density as they would be in normal transit.

xi. Each clone should be tested three times during the flowering period, early, flush and late. Varying results will be obtained especially in some Pr. neriifolia clones over these periods.

xii. Vase life must be tested after simulated travel or actual transit. Some clones that have been investigated have had a good static vase life and a poor record of transit. Some have had a good transit record followed by a poor vase life when re-exposed to the air.

15:6 TESTING SUMMARY

The only way to get reliable results is to grow the crop for testing in a production environment, harvest the flowers from mature plants that are not under stress, preferably early in the day and place in water within 30 minutes of harvest. The material must suffer the minimum of damage during processing, be packed at normal density in cartons and then tested for travelling performance. Only after it survives this, should it be tested for vase life. Static vase life means nothing if a product has to travel for three or more days.

15:7 CLIMATIC INFLUENCES

Observations made and data accumulated during the development of the selection programme show quite clearly that climatic variations have a great bearing on whether or not a particular clone may consistently produce a marketable and profitable crop in any specific climate.

This has been highlighted in New Zealand with Ld. cv."Safari Sunset" (the almost indestructible plant), which in some climates is highly productive, long-lived and profitable whereas in other locations it has been found to be a horticultural disaster.

The climatic factors influencing production and profitability do vary between species and varieties but in the main cover the same general areas.

a. rainfall — the seasonal variations rather than the actual amount.
b. air movement — influences plant health especially those with hairy leaves. It is also important in high light/temperature areas.
c. minimum temperature — below minus 3°C puts great restrictions on what flowers can be viably produced. Most plants will survive -5°C.
d. maximum temperature tolerance — is closely related to a combination of temperature x air movement x light intensity.
e. light intensity — is a complex ingredient of seasonal climatic variation. It influences most cutflower varieties in both plant health and flower quality. Seasonal light rhythms are believed to be the main factor influencing production and flower quality especially in Protea.

15:8 FUTURE SELECTION PROGRAMMES

It is at this point our investigations move from pure clonal selection matched to a particular climate, to a combination of selection X climate plus plantation management. To further the investigations into these fields it is intended to install a climate monitoring station linked to a computer to record accurate data on light radiation, humidity, air movement, rainfall, air and ground temperatures while at the same time making detailed observations on some 15 to 20 selected clones in a field plantation. The basis of these observations will be on the effects of irrigation, the application of nutrients, plant management and their relationship to the local seasonal climate. These field trials will be long term covering the period from plantation establishment through to the post harvest performance and profitability of the crop for a period of at least four to six years.

Ideally several such trials should be set up in various climatic locations/ countries, all using the same format of data collecting and all growing identical clones. Information gained in such trials would be invaluable and would be the key to consistent successful cultivation of Proteaceae.

As we move further into understanding what influences Proteaceae it will be possible to manipulate them to produce a more valuable crop. This manipulation falls into two areas, initially that of the careful selection of cutting material from the stock plants of the selected clones [ref. 17:4] and secondly the educated uses of irrigation and fertilizer application at specific growth periods, (not just when they look as if they need it), seasonal control of light, temperature, air movement, and in the case of some clones of some species, specific pruning techniques.

Success will only be achieved if the plantation has been established with selected clones with known performance factors covering not only the flower but also the climate that it is grown in. In the past some clones have been selected for a single factor such as colour, time of flowering, because it is a nice looking flower on the bush or even in some cases because of a pretty picture in a book with no thoughts as to whether it will be a viable producer for the grower and or a flower which is acceptable to the end consumer.

The ultimate target for research in selection and the matching of those selections to a particular climate will be to populate our plantations with plants that will produce to specific pre-determined levels of quality, stem length, flower type, travelling ability, vase life, productivity and profitability.

SHEET ONE — INSTRUCTIONS FOR EVALUATION

To achieve uniform assessments it is important for each individual researcher to follow an identical pattern for investigation on each and every clone under review for a given climatic location. The following are the procedures adopted in screening and evaluation to gather information for recording data on sheets, two, three and four.

Seedling plants are only to be used where a new subject is under initial investigation. Cutting grown plants are to be used in all instances for final evaluation. Protea and Leucospermum plants should be four years old before use as the source of material for final testing and Leucadendrons should be three years old. All plants must be grown in a production plantation environment. Material must only be harvested from plants in a fully turgid condition. Material must be harvested at the same time of day each time testing is being carried out. It is preferable that harvesting is carried out in the early morning. Material must be recut and placed in water within 30 minutes of harvest. Material under test must be handled and treated in accordance with good pack-house practices with the minimum of tissue damage and kept as cool as possible during handling. All material shall be chilled for a minimum of 12 hours to 4°C before packing into cartons for transit testing. **Material shall be packed at normal density** in the cartons for transit testing, (either simulated or real). Use small cartons for small quantities. Do not make up space with paper packing. **Vase life** must be assessed after transit. **Flower life** is judged ended when degeneration is obvious when viewed from 2 metres at 32ft/c. which is equivalent to the average light in the living area of most homes. **Frost tolerance** of plant and flower should be monitored over a period of at least one full calendar year, two if possible. **Light tolerance** of plant and flower should be monitored over at least one full year, not just summer months. **Flower buds** may not be present during summer but could be exposed to high light factors in other seasons.

Minimum stem length has been set at 45cm. Transit period has been set at five days. Minimum acceptable vase life has been set at 15 days. There are many factors such as colour, flower lustre, flower shape, leaf configuration etc which are impossible to measure. These must be assessed with the view that the flower must be competitive with similar products in the market. For this reason it is essential that the researcher has a knowledge of what is being traded in the market place.

SHEET TWO

PROTEACEAE.
SELECTION FOR CUTFLOWERS

Species .... Variety ....

Clone/cultivair .... Origin ....

ASSESSMENTS MADE AT:

Location ....

....

Latitude ....

Longitude ....

Altitude ....

Annual rainfall ....

PLANT SPECIFICATIONS:

Growth habit ....

Mature height ....

Mature width ....

Leaf colour ....

FLOWER SPECIFICATIONS

Flowering period. J F M A M J J A S O N D

Flower colour .... Flower size ....

Flower weight with 45 cm stem .... gms ....

Average stem length .... cm .... inches ....

SHEET THREE

PLANTS FIELD PERFORMANCE

Has the plant shown any phosphate toxidity problems? Yes No

Has the plant shown any establishment problems? Yes No

If yes to above state —

....

Tolerance to -3C after 3 years (/10) after 5 years (/10)

Tolerance to light above 60,000 units per day (see note page 1 ch/sh) (/10)

Tolerance to +28C in full summer sun (/10)

Tolerance to less than 25mm rain per month in summer (nil irrigation)

January (/10) February (/10) March (/10) April (/10)

Tolerance to over 400mm rain per quarter (nil irrigation)

Spring (/10) Summer (/10) Autumn (/10) Winter (/10)

Effects of over 400m rain per quarter. State —

....

Effects of less than 25mm rain per summer month, nil irrigation. State —

....

Response to irrigation. State —

....

Resistance to:

botrytis	(	/10)
dresular	(	/10)
phytophthora c.	(	/10)
other fungii	(	/10)

Are there any particular fungal problems with this clone. State —

....

....

SHEET FOUR

FLOWERS FIELD PERFORMANCE

Tolerance to -3C frost (/10) to -5C frost (/10)

Maximum frost buds will tolerate with damage? (degrees °C

Bud tolerance to light over 60,00 units per day. (/10)

Tolerance to rain (/10). Effects state —

....

Is by passing a problem? State —

....

Leucospermums only. Impact resistance of heads. (/10)

Are there any problems associated in the production of this flower. State —

....

FLOWERS PERFORMANCE AS A CUTFLOWER

Ability to mature following harvest.	(	/10)
Ability to withstand five days in transit.	(	/10)
Vase life following 5 days in transit.	(	days)
Domestic vase life nil transit.	(	days)

PRODUCTION DATA

At year 3 (**salable stems)**

At year 4 (**salable stems) assessed on (cm length)**

At maturity (**salabe stems)**

OVERALL RATINGS

Flower post harvest and physical rating

	Part/100	Rating
Ability to mature following harvest.	*10	....
Ability to withstand five days transit.	*30	....
Vase life following transit.	*20	....
Stem length.	*20	....
General presentation to end consumer.	**5	....
Flowering period related to market demand.	*15	....
	Flower rating	.... %

Combined plant production and flower rating

	Part/100	
Flowers ability to travel.	*20	....
Vase life following travel.	*10	....
Stem length.	*10	....
Flowering period related to market demand.	*10	....
Flowers general appearance to consumer.	*05	....
Flowers tolerance to -3C.	*05	....
Flowers tolerance to +28C and full sun.	*05	....
Flower/plant tolerance + 60,000 light unit/day.	*05	....
Plant resistance to fungal invasion.	*10	....
Plants general health.	*10	....
Plants production ability.	*10	....
		....
	Overall rating, plant and flower.	.... %

Problems — Reasons — Remedies

This section is designed as a quick reference check list. It will help you to determine what are the reasons for problems which will be encountered from time to time. It must be regarded as a first check only and where serious problems occur expert advice should be sought.

The listing of problems is divided into sections and are filed under the heading where they are most likely to occur. A system of referrals [ref.**] the same as that used throughout the book is used to direct the reader to the file containing the information on the subject under review. In most instances this will tell how to avoid or remedy the problem. If there is not a referral a suggested cure is listed.

16:1 VEGETATIVE PROPAGATION

16.1.1 Cutting material goes black within hours of harvest.

Material was harvested when:

i. It was under stress from dehydration [ref. 3:7].
ii. Air temperatures were above 28°C and the material then rose to +30°C [ref. 4:2 & 4:3]
iii. The stock plant had a dry root zone and had then received water or rain within 72 hours prior to the material being harvested [ref. 3:3]
iv. Material was too immature to handle [ref. 3:7 to 3:12]
v. Stock plant had been treated with sprays containing excessive quantities of wetting agent or insecticides [ref. 3:1]

16.1.2 Cuttings go black within 36 hours of setting.

i. A carry over of the reasons above
ii. Hormone strength was too high [ref. 2:15]
iii. Excessive amount of alcohol was used when mixing hormone [ref. 2:15] (in the hormone not the grower)
iv. Too much time lag from hormone treatment to setting [ref.5:7]
v. Insufficient overhead watering in relation to the maturity of the material and atmospheric conditions (low humidity etc.).

vi. Direct sunlight was permitted to shine on the material at some point of handling [ref. 4:3]

16.1.3 Cuttings gradually take on a dehydrated appearance one to two weeks following setting.

i. Insufficient overhead water being applied for prevailing conditions of temperature and air movement. If the problem is only near the perimeter of the propagation area check for wind drift.
ii. Too much light for variety [ref. 6:3]

16.1.4 Leaf tissue begins to deteriorate ten days following setting particularly with grey and hairy leaf varieties. fungicides are not effective in control.

i. Insufficient light for variety being handled [ref. 6:3]
ii. Difficult to control fungi [ref.9:12 to 9:19]
iii. Result of stem damage from too much hormone [ref. 2:15]

16.1.5 Some cuttings rot below medium surface between fifth and twentieth days.

i. Material was too soft at harvest [ref. 3.7 to 3:12]
ii. Medium is not draining sufficiently [ref. 2:14]
iii. Delayed result from hormone damage [ref. 2:15]
iv. Fungi was present in the material at harvest [ref. 3.3]

16.1.6 Cuttings take on a water stained appearance, firstly in the leaves and later in the stems. Often first shows in the centre of a tray or bed of cuttings. Can occur at any time during rooting but is more likely 15 to 20 days after setting or during cloudy weather.

i. Cuttings have been set too close to each other causing insufficient light and air movement within the canopy of leaves in the tray/bed [ref. 5:4]
ii. Insufficient light in the propagation area for the varieties affected. It will affect grey and hairy-leaf varieties first then the red foliage leucadendrons [ref. 6:3 & 9:19]
Note;- This should not be confused with similar symptoms that show on leaves following frost. Unless very severe this will disappear of its own accord by the fourth day.

16.1.7 Cuttings callous heavily but will not root even after an extended period.

i. Some varieties are prone to this problem especially Proteas.
ii. Material was too mature when harvested and set [ref. 3:7]
iii. Hormone was too strong and although it did not destroy the cuttings tissue it caused scar tissue to form [ref. 2:5]
iv. Bottom heat was applied too soon after setting or it was set too high [ref. 2:10]

16.1.8 Cuttings will not root. Base of cutting does not callous or change in any way from the day it is set except take on an appearance like crepe paper.

i. Material was too immature at harvest and a heel was not retained at the base [ref. 5:8 to 5:10]
ii. Hormone strength was too low for particular variety [ref.2:15]
iii. Cuttings were allowed to dehydrate on the bench during preparation [ref. 5:6 & 5:7]
iv. Cuttings were inserted into dry medium causing them to dehydrate at the base [ref. 5:1]

16.1.9 Cuttings start vegetative growth but do not root and eventually abort and become inert.

i. Material was harvested and set too late in spring [ref.3:7 to 3:12]
ii. Material had initiated growth too far after seasonal manipulation [ref. 3:4]
iii. With leucadendrons it can be caused by dipping dehydrated cuttings into hormone which burns the base and stimulates vegetative growth [ref. 2:15 & 5:7]

16.1.10 Entire batch of cuttings go yellow by about the fifth day then start dropping their leaves and die.

i. Medium or water supply contaminated with herbicide or hormone.
ii. Water contaminated with high salts, [ref 4:2.]
iii. Water has very high phosphate content, [ref 4:2]
iv. Material was harvested from plants infected with <u>Rhizoctonia</u> or <u>Fusarium</u> [ref. 9.11].
v. Material was put under great stress following harvest from heat and dry [ref. section 4].

16:2 PLANTATION HEALTH

Much can be read of plant health by observation of the leaves. Whilst this is in no way a positive identification of plant deficiencies or excesses, it can be used as a field guide to determining the probable reasons for a plants condition.

In carrying out observations of this kind it should be borne in mind that a particular leaf pattern or condition may be the result of more than one cause. This is because almost all Proteaceae are photo-sensitive and a particular chemical condition often also affects their light tolerance as a side effect.

The following is an outline of leaf conditions that are likely to be encountered in the cultivation of Proteaceae and should be regarded as a guideline to determining the cause. Positive identification takes laboratory analysis.

16.2.1 Leaves have a horny texture, usually crinkled with high colour on edges and pale on the upper surfaces exposed to the sunlight. Advanced symptoms are dead tissue around the edges of the leaves and general dehydration of foliage and flowers.

i. Too much sunlight for the variety planted.
ii. Probably aggravated by high pH. and phosphate levels.

Remedy. Avoid planting varieties that are sensitive to high light levels where they will face the sun all day. These varieties should always be planted on slopes facing away from the sun.

16.2.2 Leaves pale between leaf ribs with ribs highlighted green. Leaf shows chlorosis towards the tip and in some cases tip burn.

i. Lack of magnesium.
ii. If there is tip burn there is also a deficiency of iron.

Remedy. Apply magnesium (epsom salts), 1000 ppm. and iron (iron chelate), 500 ppm. as a drench spray. Repeat as necessary.

Note: This problem is usually of a seasonal nature linked to the spring growth period.

16.2.3 Leaves pale between ribs with burning at the tips progressing to severe tip burn and a mottling effect of the foliage.

i. High phosphate levels present probably aggravated by,
ii. High pH. and or dry soil conditions.

Remedy. It is difficult to bring the phosphate level down. Apply sulphate of ammonia as a drench at 2000 ppm and also as a ground dressing. Keeping the soil moisture up during dry conditions will often help.

16.2.4 Leaves begin a pale blotching as light and temperatures rise during progress into summer. Leaves eventually go almost white and roll back at the edges and show burn along the edges. There may be a slight pinkish appearance on some varieties.

i. Very high nitrate nitrogen levels. Proteas in particular will be affected.

Remedy. This is difficult to control. Fortunately it is usually only of a few months duration and is caused by the breaking down of humus at high temperatures such as under weed matting [ref. Appendix Three]. Heavy flushing with irrigation does help to reduce it but will not help the plants much that are affected. A delay of six months from the laying of matting or the rotary hoeing of herbage into the ground to planting will reduce the risk of this problem.

16.2.5 Leaves are small and show tip burn during hot weather, otherwise O.K.

i. Shortage of potash.

Remedy. Usually a short duration problem. Keep moisture levels up for the remainder of the summer. Apply potash prudently in the following early spring to avoid a recurrence the following year. High levels of potash will cause chlorosis.

16.2.6 Plant has rosette leaves with growth tips sometimes arranged in a whorl. Leaves may have a "bird beak" (twisted) tip.

i. Principal cause is zinc deficiency, probably associated with iron and magnesium shortages.

Remedy. Apply sulphate of zinc at 500 ppm. as a drench several times. Pay attention to iron and magnesium also, see 16.2.3.

16.2.7 Foliage of plant is paler than it should be but leaves do not show veining as for magnesium deficiency. Growths are shorter than expected.

i. Shortage of nitrogen, usually shows following spring growth after about the third or fourth year from planting if no supplementary supplies have been applied.

Remedy. Apply sulphate of ammonia either as a dressing or through irrigation. Refer to 13:4 for information on the role of nitrogen in plant growth.

16.2.8 A cream coloured variegation shows on lower leaves and progresses up the plant, intensifying as it progresses. For a start it may only affect one side of the plant.

i. Almost certainly the result of a herbicide containing Symizine being used within the root zone of the plant.

ii. In low doses it may only show as a faint margined yellowing of leaves that were developing at the time of being affected or the leaves may be slightly stunted and margined.

Remedy. Refrain from using this type of chemical within the root zone of plants. [ref. 13:8]. Plants will usually survive one or two annual accidents but no more.

16.2.9 Plants take on a slightly stunted and lacklustre appearance. The margins of leaves will often take on a dark appearance and Leucadendrons set bracts earlier than usual. Foliage may take on a slightly pink appearance and stems become slightly dehydrated and brittle.

i. Plants are affected by Round Up either by direct contact (if the symptoms develop rapidly) or by translocation through the roots from the fleshy roots of sprayed weeds if the progress of symptoms of poisoning are slow to develop.

Remedy. There is nothing that can be done to improve the plant. Once affected the plant will either eventually die or may malinger on as an unproductive plant for several years.

Avoid using this or any other chemical that translocates in the root zone of plants especially if there are any weeds with fleshy roots present. [ref 13:8].

16.2.10 New growths all over the plant goes slightly pink edged silver and foliage is small and slightly twisted. Last few cm. of terminals may be twisted.

i. Plant has been affected by hormone drift, possibly from a great distance away. Proteaceae are very sensitive when making their spring growths.

Remedy. Check chemical store for leaking containers as these chemicals are volatile and the vapors can drift to affect plants. If symptoms are only on the lower foliage of large plants or all over only small plants, the problem may have originated from the use of weed control prills/granules. Some of these give off gas when first applied.

16.2.11 Foliage of new growths show burning then go grey after a few days and is confined to one side of the plant.

i. Almost certain to be salt burn from dry winds. May occur up to 40km (25 miles) inland. Usually follows a strong wind which is not followed by rain.

Remedy. Move further inland! Trim off foliage that is showing severe burn as it may later be host to fungi.

16.2.12 Sudden appearance of random black patches on the younger leaves and temporary tip wilt during the heat of the day.

i. Plant has been temporarily short of soil moisture and/or over heated through the lack of air movement [ref.10:5 & 10:6].

Remedy. Increase soil moisture, [ref. 12:2] and air movement.

16:2:13 Plant fails to establish well. Shows stress from dehydration and light even at low levels of exposure. Plant often fails second summer.

i. Plant has poor primary root development caused by the container medium being incompatible with the plantation soil type. [ref 8:5 to 8:7].

ii. Plant root system is affected by nematodes [9:21].

iii. Plant has suffered some physical root damage from ground insect populations [9:22].

Note:- The condition may be compounded by more than a single cause.

16.3 DISEASES

This section deals with symptoms of diseases. Early detection of diseases is often difficult to detect as the first symptoms are sometimes similar to those caused by deficiencies and excesses of minerals.

16.3.1 Plant shows general yellowing of the lower foliage and stems with tip wilt in the upper part of the plant.

i. Plant is almost certainly affected by Phytophthora Cinnamomi. [ref.9:10].

Remedy. There is none, remove the plant, it is a danger to replant in the same site.

16.3.2 Part of a mature plant suddenly goes yellow and drops some leaves and later shows tip dieback. Rest of plant is O.K.

i. Plant is affected by a form of Phytophthora. The disease has almost certainly entered following some physical damage or pruning wound.

Remedy. Avoid large wounds especially to the main stems. Cut out infection and treat with fungicides.

16.3.3 The lower leaves show sudden yellowing and become brown. there is no tip wilt. Roots are still healthy.

i. Plant is infected with Rhizoctonia or Fusarium or possibly both. [ref. 9:11].

ii. Problem is usually only seen in plants under two years old but sometimes carries through to the plantation from earlier propagation practices.

Remedy. There is no cure. once infected the plant will eventually die from within. Good drainage and attention to air movement and adequate light at ground level during propagation will minimise the incidence if infection. The problem originates at ground surface level. not below.

16.3.4 Whole plant goes yellow during wet periods and improves during dry weather.

i. Rising water table during wet periods.

ii. Low level infection of Phytophthora Cinnamomi in a plant that is semi resistant to it.

Remedy. Improve drainage. Treat with Ridomil or Alliette. ref. 9:10.

16.3.5 Soft terminal growths show a grey mould which rapidly spreads to progressively infect much of the plant. Usually occurs during wet humid conditions.

i. Plant is infected with Botrytis or some similar fungi. [ref.9:13].

Remedy. Improve air movement, spray with Captan or similar chemical.

16.3.6 Leaves of Leucospermums get a tan spot which develops a purple margin and progresses to a large lesion with dead tissue in the middle. It will infect all leaves and can spread to other species of Proteaceae.

i. Plants are infected with Drechslera. Infection usually develops in early autumn and continues into winter. [ref.9:15].

Remedy. There is virtually no total cure. Control by constant application of fungicides [ref 9:15]. Note: the practice of using young plants in nursery production beds as a source of cutting material does carry some risks in its spread as it is difficult to detect this fungi visually in the early stages of infection.

16.3.7 Leaves become almost covered by pale orange pin head size spots starting down low and progressing up the stems. usually on Leucospermums but sometimes on others.

i. This is Septoria which is often accompanied by other fungi. [ref. 9:17]. Develops about the same time as Drechslera and the two are often seen together.

Remedy. The damage to current growth can not be eradicated. Preventative control by chemicals.

16.3.8 Young plants. especially those with hairy leaves develop decay in the terminal tips and or young soft leaves. There is a rapid development down the leaf or main stem and plant dies. Infected leaves have a very dark margin on the stem side of the infection.

i. This is Pestalotia and is always associated with low light levels and moist conditions [ref. 9:14]. It is often encountered during the winter in both propagation and plantation situations.

Remedy. Increase light and air movement [ref.8:2 & 8:4]. Treat with chemicals as per 9:14.

16.3.9 Leaves develop a silvery appearance all over. This may affect the whole plant or only one ot two branches.

i. Plant is infected with Silver blight. [ref. 9:16].

Remedy. Once well established it is almost impossible to eradicate. Remove affected branches or plants. Avoid large cuts to plants especially late spring. If possible remove known host plants.

16.3.10 Large water soaked spots appear on leaves which affect surrounding foliage.

i. This initiates as a physical disorder but may become invaded by fungi as yet unidentified. It is always induced by low light and high moisture levels. It is usually confined to the propagation phase but can occur in plantations. [ref 9:19].

Remedy. Increase light and air movement which will help to decrease moisture levels. Don't crowd plants unnecessarily.

16.4 PESTS

Early detection of pest infestation will make control much easier. A close watch should be kept during periods when it is known that there can be a rapid build up in populations.

16.4.1 Plant takes on a patchy silver appearance and upper surface of lower leaves and get a black smut on them.
Note:- not to be confused with 16.3.9 — silver blight.

i. Plant is infected with thrips, mites, red spider. These are very small and 10X magnification is needed to detect.

Remedy. Treat as required. 9:26].

16.4.2 Leaves of plants have numerous holes in them, especially at the tips of Leucadendrons.

i. There have been leaf roller caterpillars present in the terminal of new seasons growths. These are there well before growth begins. [ref 9:25].

Remedy. Prevent invasion by early and regular spraying with systemic insecticides. Spray or remove host trees.

16.4.3 White, black or brown scales on the under sides of the leaves. Usually first show during late summer to peak by early winter.

Remedy. Control as per 9:27. Remove known host plants.

16.5 PRODUCTION

Early identification of the reasons for less than expected performance of plants in producing good quality material is important. Procedures must be carried out up to a year ahead to correct problems.

16.5.1 Flowering stems are shorter than they should be for that particular clone.

i. Plant was short of soil moisture in the latter part of its vegetative growth run, ref. 12:3

ii. Existing nutrient levels too low to sustain growth. [ref 13:9].
iii. There were too many stems initiated for the plant to sustain [ref. 13:10].

16.5.2 Flowering stems are bent or growth is pendant.

i. Poor stock was planted. ref. Section 15.
ii. Plant was supplied with an excess of nitrogen. [ref. 13.9].
iii. Plant was supplied with an excess of soil moisture in relation to its seasonal growth pattern. [ref. 12.4].

16.5.3 Flower buds suffer scorch.

i. Too much light for that particular variety/clone in relation to plantation site. [ref. Section 10].
ii. Plant was temporally short of soil moisture [ref. 12:4].
iii. Plant was exposed to unusual weather conditions. hot wind. very high temperature for short period. frost. [ref. Section 10].
v. Possible salt burn. It can occur well inland following a big wind which is not followed by rain.

16.5.4 Flower buds abort.

i. Bud was exposed to very high temperatures or a frost [ref. 10:6].
ii. Terminal tip carrying bud has been infected by Botrytis or a similar fungi. [ref. 9:13].
iii. Physical damage caused by impact or by insects. caterpillars etc. [ref. 9:23 & 9:24].

16.5.5 Plants won't set buds as they should.

i. Lack of sufficient light. Plants are probably being shaded too much by hedges or have been planted too close to each other.
ii. **With young plants, soil is too rich and causes the plants to grow vegetative rather than flowering wood.**
iii. **Some varieties take up to five years to flower, [ref.13:4].**

16.5.6 **Flower heads develop numerous bypass growths.**

i. **Plants have gone through a dry period and then received excess water to their seasonal requirements, [ref. 12:3].**
ii. **Nitrogen has been supplied to plants during their normal rest period in the summer, [ref. 13:9].**
iii. **Poor genetic material has been planted, [ref. Section 15].**

16.5.7 Plants are seriously damaged by frost.

i. Plantation site not suited to Proteaceae.
ii. Plants were irrigated too much in the autumn which stimulated a late growth. [ref. 12.4 & 12.7].
iii. Plants were supplied with nitrogen during the summer, [ref. 13:9].
iv. Hedge rows have become excessively high or thick and are restricting air movement. thereby creating "frost pockets". [ref. 10:6].

16:6 POST HARVEST

By the time a flower has been harvested and gone through its post harvest treatment there is little else which can be done to improve their performance. Where problems are encountered the causes should be identified and corrected.

16.6.1 Flowers and foliage goes black within hours of harvest.

i. Plants were under stress from dehydration, [ref. 14:2].
ii. Flowers and foliage had been frosted recently.
iii. Day temperature was too high for that variety to be handled, [ref. 14:3 & 14:4].

16.6.2 Foliage and flowers go black within two or three days following harvest.

i. Poor stock was planted, [ref. Section 15].
ii. Material was left too long from harvest to being put into water and cooling, [ref. 14:3].
iii. Material was poorly handled and suffered crushing and bruising, [ref. 14:3].
iv. Material has been exposed to ethylene gas, [ref. 14:4].
v. Can be caused by heavy infestation of thrips and mites in the flower head and on the foliage [ref.9.26].

SECTION SEVENTEEN

Facts and Fancies

17:1 OVERVIEW

In thirty years of involvement with any occupation you will from time to time have thoughts of the past and future. As well as this you will come across various situations and events for which it is difficult to pinpoint the reasons. This section notes some thoughts. experiences and observations I have made that have not been dealt with in other sections of this book.

17:2 MICRO-PROPAGATION — (TISSUE CULTURE).

(Fact and fancy).

Although there have been a number of projects run in various research and commercial laboratories to investigate micro-propagation of Proteaceae. to date there has been little success apart from with Telopea in New Zealand. With these there has been some success in multiplication but very little progress has been made in defining a system to transfer from the flask to a successful plant at least on a commercial basis.

It is known that work is progressing in several labs. and eventually a system will be worked out that will have some success. Meantime it is back to the knife. cuttings and trays of medium.

17:3 THE ROLE OF MICRO-ORGANISMS IN PROTEACEAE.

(Fancy or fact)?

There are many indications that micro-organisms play a prominent part in all phases of Proteaceae production. right from propagation through to the end product. To pinpoint it and identify which they are and how they interact with plant development and health. is something that I may never see. I recently spoke of this to a scientist friend. He told me that you could look down the tube of a microscope for three years and still not be any the wiser as to which ones are beneficial and what role they play in better plant propagation, development and health. During the course of propagating, handling plants and observing them growing in many locations both within New Zealand and other countries, I have seen a number of facets that support the theory that micro-organisms do play a significant role. This assessment is supported by a growing world wide interest on the role of micro-organisms in plant health.

In a field situation one particular parallel has been observed in many locations. This is that Proteaceae always establish and grow very well in land where there is or has been upland fern (bracken) and/or the dry land grass-like rushes (Juncus) growing. This observation has been irrespective of which country it was seen in with the best production plantations always being in "bracken country". It can of course be argued that this parallel is because Proteaceae and these plants all like well drained soil, the same pH., similar climatic conditions and nutrient levels.

In the propagation phase, there are indications of "friendly greebies" influencing the initiation of rooting of a number of varieties. It is thought that the presence or absence of micro-organisms in the rooting medium may play a significant role in whether and how well cuttings root.

Many years ago an old nurseryman told me that if I wanted to be successful growing South African ericas that I must get some "erica dirt" from under a growing plant and mix it with the potting medium. About the same time I was told by a successful gardener that if you want to grow a Telopea, that you had to find one growing and get some dirt from around it and put it in the hole where you were going to plant your new plant. These suggestions do have a lot of merit in them as it is really inoculating the soil with micro-organisms, a practice that is common in forestry when land is being put to the use of growing seedling trees for the first time.

During propagation there are several things that have been noticed that occur on a fairly regular basis. When propagating varieties with a lignotuber, it has been noted that they often develop a mass of tiny white dots which are usually accompanied by a white/grey mildew appearance on the part of the stem below medium surface just before they produce visible roots. If a seed of prairie grass accidentally gets in amongst the cuttings and germinates and is not removed, the cuttings closest to it will always root quicker than those not within the grass root zone. The same will happen if barley germinates and grows amongst the cuttings. If cuttings of an easy fast rooting variety and some of a slow difficult one are set into the same tray, the cuttings of the slow difficult one adjacent to the easy ones will almost always root well before those that are further away. The same thing can happen if difficult ones are put around the perimeter of a pot and a few easy to root ones are put in the middle of the same pot. Whilst the possible influence of auxins can not be ruled out, there is evidence that it is either these or micro-organisms which cause these things to occur.

In the growing-on phase, tests are being run to investigate the possible effects of micro-organisms on plant health and growth. It had been noted on a number of occasions that when plants (following their first tubing up) were stood out in the growing-on area with some on a bed of sawdust, some on sand and some left standing in their tubes in wooden trays, those that had been stood down onto the sawdust out-performed their counterparts in growth and health. It was also noted that those that were stood on sawdust developed their primary roots much quicker at least until they reached through the base of the tube when they then slowed down. As there are significant levels of micro-organisms present during the degeneration process of matter such as sawdust it was assumed that these may be influencing the plants' development and health.

A trial has since been implemented and is still under observation. In this trial, seedlings of Protea magnifica (Cedarberg variant) have been used as the test plants. The variety was chosen because it does sometimes give problems above and below the ground owing to periods of high humidity in my location. The plants have been moved on from the 5cm tube stage in a standard soil based mix to a more advanced plant in a 10cm. (4") pot using three different media.

The media are:-

i. Loam top soil 50% + pumice 50%.
ii. Loam top soil 33% + pumice 33% + one year old sawdust 33%.
iii. Loam top soil 33% + pumice 33% + fresh sawdust 33%.

The sawdust used is Pinus radiata which is readily available and always of a consistent type and texture.

Fifty plants were transferred from 5cm. tubes to 10cm. pots into each of the media one month after the longest day and were then stood in wooden trays to eliminate any possibility of them being influenced by other materials, ie. sawdust, sand, soils etc. in the growing on beds. As it was intended that nothing should influence the plants other than the medias, no fertilizers were incorporated at potting or used subsequently. All plants have been maintained with a regular application of fungicide matched to the climatic demands.

After 150 days the following is the current situation:-

Media i. Deaths 16%, health of surviving plants is average but there has been some fungal infection on a further 38% at some stage. Growth of surviving plants has been average. Root development is satisfactory with a good primary system established.

Media ii. Deaths nil%, health of surviving plants is good with only superficial fungal invasion (12% of plants affected). Growth has been satisfactory but plants have a slight "hungry" look. This is no doubt due to a shortage of nitrogen which will have been depleted by the breaking down process of the sawdust. Root development is similar to that of i.

Media iii. Deaths nil%, health of plants is excellent with no fungal invasion on any plants at any time. Growth has been satisfactory but these also have a "hungry" appearance. Root development is similar to i. and ii.

Whilst it is still much too early to make positive assessments on whether it is indeed the result of micro-organisms being generated by the breaking down of the sawdust which is influencing the health of these plants, the results to date can not be ignored. Extensive testing on a number of varieties to gather more information and improve procedures will be carried out in the future.

Taking into consideration the observations and facts that have been outlined in this file, it seems probable that many of the problems encountered in the propagation and production of Proteaceae may be able to be controlled or minimised by the encouragement of micro-organisms in our mediums and plantation sites. However this may still be a number of years away.

17:4 GROWTH HABIT — IS IT INFLUENCED BY SELECTION OF MATERIAL? (Fact).

Proteaceae come in all shapes, sizes and growth habits. Even within a single variety, seedling plants of some varieties vary greatly. If we take a batch of seedling Protea neriifolia as an example, it will be seen that they will vary in their growth habit even if the seed is all collected from one stand of plants growing wild in South Africa with some being upright and some pendulous.

When a single plant is selected from a host of seedlings because it has superior characteristics suited to cut flower production, one of the reasons for selecting it will be because it has an upright growth habit and produces long straight stems in that particular climate. In theory every plant produced from that parent plant by vegetative means should be exactly the same with the same upright growth habit and long straight stems provided it is grown in that same climate or one very similar. This however is not always so and there is now evidence to show that the type of material and where it comes from the parent plant does influence the growth characteristics of the resulting plants (but not the flowers) and in extreme cases if the wrong material has been used an upright plant may produce progeny with predominantly pendulous growths.

Although this must have been a fact since Proteaceae were first propagated vegetatively, it would have been of little consequence as long as the plants were only for landscape use. However as the cut flower trade has developed and "Proteas" are now gaining a foothold in the "top shelf" area where there are ever increasing demands for long straight stems, it is now of considerable importance to ensure that desirable characteristics that a clone has been chosen for are retained so that the grower can produce long straight stems.

For many years I observed that even although plants had been vegetatively propagated from a single stock plant there were variations in growth habit between plants of the same batch but not in the flowers or bracts. This was particularly evident in one particular clone of Pr. neriifolia and in a wide range of Leucadendron varieties. Initially this was thought to be the result of nutritional excesses in the containers as this will cause pendulous growths [ref. 13:9]. However this is always of a temporary seasonal nature where-as when these plants were planted in plantations the growth habits of each plant remained constant with some being upright and some pendulous. Because of this it was obvious that growth habit was being influenced by the type of material that had been used as cuttings. This same phenomenon is common in the propagation of conifers and to some extent in camellias.

Selective harvesting of cutting material was begun six years ago on some clones. Only upright terminal or laterals from upright terminals were harvested and set to root. Weak bent low level laterals were not used. With each successive generation the same type of material has been used and in the case of

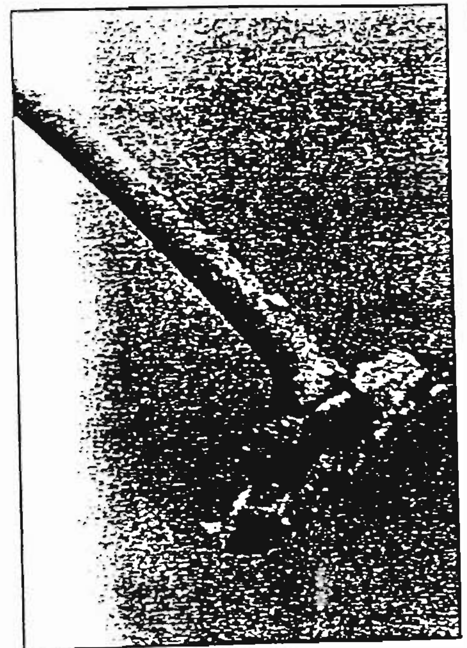


Fig. 62

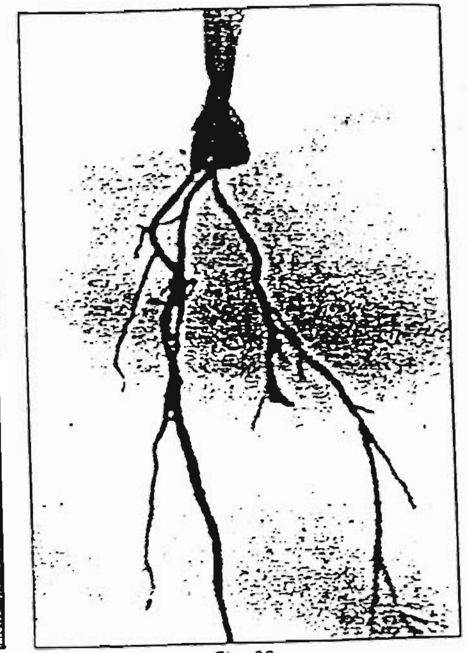


Fig. 63

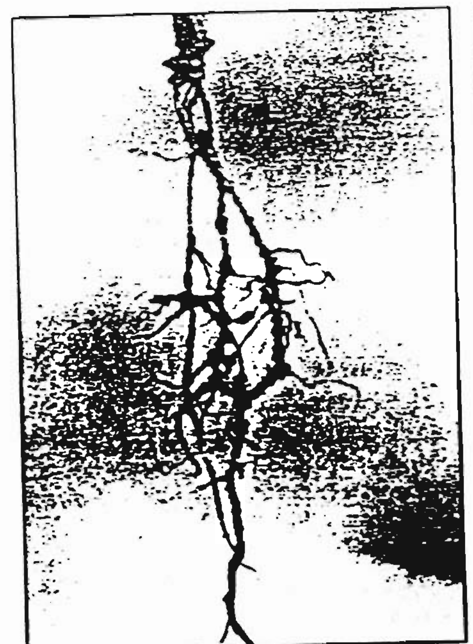


Fig. 64

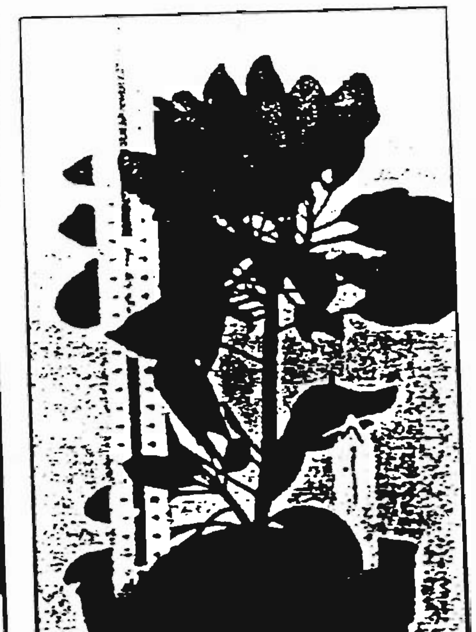


Fig. 65

some Leucadendrons under trial only from those plants that had shown a marked improvement from the previous generation.

After four generations there has been a marked change in the growth habit of these varieties with one Leucadendron in particular changing from a low weeping form to an upright stance. The practice of selective harvesting has been applied to all of our propagation for the past two years with the result that there is now a noticeable uniformity in growth habit of each variety that was not evident before. When applying this practice it should be borne in mind. that if the plant is of a prostrate form and it is supposed to be that form. then low prostrate material should be used in propagation. but if it is upright with long straight stems then material should only be harvested from long upright stems. Irrespective of these precautions there will always be the occasional departure from the intended form.

It is probable that every variety of every species can be influenced in this manner in varying degrees by careful selection. initially of the parent plant. then of the material that is harvested from that plant and finally from the subsequent generations. It is known that the growth habit can be influenced and there is some evidence to show that by only using the strongest growths as cutting material from successive generations. it may also be possible to produce a plant that consistently has longer stems than the original parent. Further work is needed to verify this and determine which varieties will respond.

17:5 A.B.C. PROPAGATION. (Fact and Fancy)

What is A.B.C propagation?

It is:-

Asexual (without sex — [vegetative]).

Biogenesis (the derivation of living things from living things).

Culture (the state of being cultivated).

In practice it is a term that I have applied to the proliferation of plants by vegetative means which are a departure from normal propagation practices. ie. the use of parts of plants rather than a full cutting.

In the absence of any consistent success in the micro-propagation of Proteaceae, there is a great need to be able to bulk-up stocks of selected clones by much quicker means than that of normal cuttings. In an attempt to achieve quicker multiplication, it was decided to begin investigations into propagation by using various approaches to bud culture. This involves severing the growth bud and its accompanying leaf from the stem and setting it to root (figure 62). If successful this gives a potential of producing a new plant from every leaf on a parent plant, many times that of conventional stem propagation. Whilst this is by no means new as it has been done for many years with Rhododendrons and is known to have been carried out in Australia and New Zealand with Telopea, problems often occur following rooting in getting the bud to initiate growth. It can remain dormant for many months and in Proteaceae are often permanently inert.

A start was made to research this three years ago by running preliminary experiments to determine whether it was possible to root tissue other than stems of a number of Proteaceae varieties. ie. leaves and buds. The reason for setting leaves was to determine if it was possible to initiate rooting even although they would never grow and produce a plant as it was thought that if roots could be produced on leaves it would warrant further research to try to break the bud dormancy problems being experienced. All of the early experiments were carried out in a standard outdoor propagation area under automatic mist and set in a standard propagation medium.

The first experiments were instigated in the spring using buds that were initiating in the natural course of their spring growth and mature leaves of the previous years growth. These were not successful nor was current years material set to root four months later in midsummer. A third test was run using summer grown material. set to root at the beginning of winter. From this. initiation of roots on leaves without any stem tissue was achieved in Pr. neriifolia (figure 63) and cynaroides. Leucospermum cordifolium and cuneiforme. Leucadendron salignum (figure 64) and Serruria florida. Leaf buds of Pr. cynaroides and Telopea speciosissima were also set many of which rooted to some degree.

Problems encountered were:-

The spring batch all turned black within fourteen days of setting. This was due to the fact that growth had already commenced and with the sap flowing it was impossible to sustain them.

With the midsummer batch. although some did survive for a number of weeks and did callous. they eventually all became infected with fungi due to the high temperatures and the amount of water that had to be applied to prevent dehydration. Because almost 50% of a bud cutting surface area is cut surface. more water than normal is necessary to prevent dehydration. Fungal infection mostly entered through the cut surfaces.

With the early winter batch few problems were encountered apart from the fact that it was difficult to hold the leaves and leaf buds in the medium as only a small amount of wind caused them to shake loose. Most of the leaves calloused but only a few actually produced roots. The exception was Pr.cynaroides which all rooted. Of the leaf buds set almost all did eventually root but the eye of the bud either died or was permanently dormant. None of this batch actually came into vegetative growth.

The following year. the terminal tips on some Pr. cynaroides and T. speciosissima plants were removed in late autumn. This caused the top three to five buds on each growth to initiate. These were then taken and set to root again in early winter. Almost all of these rooted by spring in an outdoor situation and of those that did root some 30% came into vegetative growth in the spring with a further 20% by midsummer. The remaining 50% remained alive but were permanently dormant for a further year and were eventually discarded. The resultant plant from one bud that did initiate grow is pictured eighteen months later in Figure 65.

Since that time work has continued using variations of manipulating material to encourage bud initiation as well as varying the conditions they are set in. Some marked improvements in results are being achieved and at this time it is known that the principle is workable at least with some varieties although not yet on a fully commercial scale. It also seems probable that some others will be able to be propagated in a similar manner and technical work is continuing in this field. The work is being documented and will be published when some conclusive results are achieved.

17:6 ALLERGIES TO OTHER SPECIES OF PLANTS. (Fact)

Proteaceae have likes and dislikes. It is unfortunate that when they show a dislike for some particular thing it has often already been fatal to the plant.

The most significant of these is their aversion to being within the root zone of certain conifers. There are three principal families of these that they take exception to: Pinus, Cupressus and to a lesser degree Thuja. Of these, Cupressus are particularly toxic to them and it is seldom that Proteaceae will survive if they are near any of these trees. If the conifers are living the decline of the plant will be gradual, but if the tree felled then any Proteaceae plant within the root zone is almost certain to die within six months. As the Cupressus roots start to decay a highly toxic condition occurs within the soil and this may last for up to two or more years. With Pinus a similar situation exists and the effects of this may be seen in South Africa where pines are encroaching through stands of Proteaceae. In landscape use, if a Proteaceae plant is doing poorly in a garden the problem can often be traced to the fact that it is growing within the root zone of an ornamental Pinus, Cupressus or Thuja. On the other hand the oldest Protea that I have is a cynaroides which is three meters high (10 feet), 34 years old and is growing quite happily up through a Juniper Squamata Meyerii of the same age and it still produces its twenty odd flowers each spring.

17:7 TO WHAT AGE WILL A PROTEA LIVE? (Fact)

The oldest plant that I have seen was a Protea compacta growing near Sale in Victoria, Australia. When seen in 1978 this tree was known to be 74 years old and was some 10 meters high and 13 meters wide (30X40 feet) and still flowering. I have a Protea cynaroides 34 years old, a Leucospermum of 30 and a Pr. neriifolia of 25. I know of a small plantation in the Banks Peninsular region of New Zealand where most of the plants are around 25 years old and there are a few Leucospermum conocarpodendron in the western part of the North Island that are over 30. There are plantations in the Mt. Dandenong area of Victoria that were around 25 years old when I saw them in 1978. It is believed that some plants of Pr. laurifolia growing in their natural environment in South Africa are more than 70 years old.

It is probable that all of these long lived plants originated from seed. However the Pr. neriifolia which I have that is now 25 was grown from a cutting and this is the oldest cutting grown plant that I know of.

There is some conjecture whether cutting-grown plants have the same life expectancy as their seedling counterparts. No definite answer can be given to this but provided the cutting grown plant has been properly cared for during its production from initiation to final planting, there is no reason why that should not be the same as a seedling. However there are a number of things that can happen to a cutting during this period which would shorten its life expectancy. These are outlined throughout the sections on vegetative propagation.

17:8 THE PRESENT — WHERE ARE WE? (Fact)

Proteaceae are now well established as a landscape plant in a number of areas throughout the world where conditions are suited to their cultivation. It is also true that there have been very large numbers planted for cut flower production over the past few years and there are indications that this trend will continue for some time. At what level plantings continue depends greatly on whether the plantations now being established are profitable to those investing in them. To be profitable, the production must be acceptable to the end consumer at a price that they are prepared to pay. The consumer always has the final say. Therefore, for a plantation to be successful, that price must be at a level that is viable to the producer.

Proteas have now been known in the European floricultural market for over twenty-five years, and almost as long in some North American regions. Of recent times they are being discovered by Japan and to a lesser degree in some other regions. In the beginning, the main bulk of the European market was supplied from natural stands in South Africa with these flowers being predominantly traded in the mass market with only a small percentage going through to the "top shelf" type of presentation. Whilst this mass market trade is still predominant for a great proportion of the African production into Europe, it is now being supplemented from plantations that have been planted both in Africa and other parts of the world which enable growers to supply a more reliable type of product on a near year round basis which was not possible when "harvesting wild".

The mass market trade of Proteaceae floral material is well established in Europe and to some degree in North America and will continue indefinitely provided growers adjust their production and presentation from time to time to meet the changing demands of the market place in fashion and quality. These markets will no doubt remain an excellent steady market for those countries so geographically situated that they have access to cost-efficient airfreight and a production cost structure that enables them to supply at the price that the market will pay.

There is a growing awareness of Proteaceae flowers and foliage in the more discerning "top shelf" markets of Europe, Japan, North America and to a lesser degree in the Middle East. At present the limiting factor in supplying these more lucrative markets is a lack of a constant supply of sufficiently high quality product which these consumers demand. Japan has and always will demand very high quality material and the demands for that same high quality and presentation is increasing in the "top shelf" markets of Europe and North America as the overall presentation of all types of flowers improves and competition in the market place becomes greater.

At the present time very little of the world's Proteaceae production measures up to the quality that is demanded by these high priced markets and sadly in other than with Leucospermums, little has yet been achieved internationally in selecting, propagating and planting those clones that are in existence but are still waiting to be discovered. Certainly large numbers of seedling grown plants have been planted in the hope that the production from them can be sold into the "top shelf " markets but results can and have been disappointing with the material from many plantations proving to be unacceptable in other than the lower priced markets. A seedling plant will produce exactly the same flowers and foliage when growing in a plantation as it would if it were growing in the wild and there is no difference between a flower of poor genetic quality that is harvested from a plantation and a flower with poor genetic quality harvested from the wild, other than the fact that the one from the wild has cost nothing to produce and can be sold for a much lower price than its cultivated counterpart. Consistent supply of quality means everything for the discerning markets and I believe that this is the market where cultivated Proteas belong. Every effort should be made by propagators and growers to achieve this level of excellence. There is always sufficient second run material available from even the best selected clones for the mass markets without deliberately setting out to produce it by planting anything that looks like a "Protea".

17:9 THE FUTURE — THE FINAL ANALYSIS — A FINAL PLEA

It is possible to produce top quality flowers and foliage in almost any area where Proteaceae will grow. However it is not always possible to produce every variety to that level in any one place and the importance of selecting the right plants for a given climatic location was outlined in Section Ten.

In supplying the "top shelf" market there are two problems facing the international Protea industry. First, that of determining what will grow to the necessary levels of quality in a given climate, and second, having sufficient numbers of plants of a known performance to populate the plantations. To solve either one of these we currently lack the skilled human resources and the international co-ordination that is necessary to do the research to resolve the problems (including micro-propagation) and then educate those people involved in propagation and production in the techniques needed to assure success. To date there has been a certain amount of research carried out into some aspects, but this (including my own efforts) has been done in isolation rather than as an over-all approach.

In the last ten years I have read every piece of information on Proteaceae production that has been available to me. The papers read cover many aspects from propagation, through production to post-harvest handling. In all of these it

is very rare that the researcher has specifically identified the subject under review other than to state that it was say a Pr. neriifolia or a Lsp. cordifolium etc. Whilst in the past this may have been sufficient as we now move further into the selection of superior clones and the professional production of these crops with the associated financial commitment by growers, future research must be more defined and specific. As I have moved from a very basic core of knowledge of these plants thirty-four year ago to a reasonably proficient operation to-day, I have increasingly noted that in a truly professional sense it is just not possible to generalize about any variety of this genus of plants.

To say that Pr. neriifolia has post-harvest problems with leaf blackening is not always correct, nor is it always true to say that Pr. repens is much easier to root than Pr. neriifolia or that Pr. neriifolia is much more susceptible to Phytophthora than say Pr. eximia. There are Pr. neriifolia clones that are virtually totally resistant to leaf blackening, that are much easier and quicker to root than some Pr. repens and that are just as resistant to Phytophthora as some Pr. eximia are. When growers are making what at times are considerable financial commitments they are increasingly demanding much more accurate information than that which has previously been available. It is up to those of us involved in the development of these crops to see that this information is forthcoming.

The answer seems to lie in planned research on a world wide basis with each researcher, whether they be a grower or scientist, all working within the same parameters, wherever possible with the same clones, recording their findings and climatic conditions to the same format and finally pooling their knowledge for the benefit of all "Protea Growers". It's a nice thought, can we make it happen?

Proteas in Gardens and Landscape

18:1 OVERVIEW

This section is devoted to the culture of Proteaceae in home garden and landscape. There are a number of differences between these and production plantations. Ten years ago I believed that if a certain variety could be grown in a home garden in a particular climate and location then it would be possible to successfully grow a commercial crop of that variety in that area. This is not so as most gardens have micro-climates created by trees, buildings and contour. In addition to this each plant tends to get more personal attention and because of this it is often possible to grow varieties in a garden that are not successful in a plantation environment. The following files outline the siting, cultivation, care and uses of Proteaceae in non-commercial uses. In doing so it summarises the contents of the previous seventeen sections of that applying to the home grower. Where applicable, references to other sections are made. For ease of reference in this section the family of Proteaceae is referred to as Protea. Where a particular species is being discussed it is quoted as Leucadendron etc. This method of reference only applies to this section, all other sections use the formal format of reference.

18:2 CONSIDERATIONS IN SITE SELECTION

There are four basic principals to apply when selecting sites to plant Proteas. It must have good soil drainage, good air drainage, the correct light levels for the varieties being planted and finally it must not be unduly crowded by other plants.

Most sandy, sandy loam, gravel, decomposed granite and conglomerates of volcanic origin are satisfactory for Proteas. Those that are not suited are heavy clays, fine wet silts and any area where the water table ever comes within a metre of the surface (40 inches). Whilst it is possible to grow under adverse soil conditions by mounding up the sites, it is seldom that Proteas ever live to maturity in such locations. If the land has an incline of one in twenty or more it will help with surface drainage but a high water table even for short periods is very damaging to the root system. [Ref to 10:2 for a full outline on soils and drainage.]

Air drainage is essential for several reasons. Where Proteas grow naturally in South Africa it is a constant companion to them and by keeping the leaves dried off as the temperatures rise each day it helps to keep fungal invasion to low levels. It stops the leaf area from overheating during very hot periods and it also helps in keeping frosts to lower levels. In general the varieties with hairy leaves must have a more constant air movement than those with the smooth leaves. Many garden situations have small areas where there are humidity traps caused by buildings or large trees stopping adequate air movement and it is difficult to maintain healthy plants in such places. The greatest problem that this will cause is fungal invasion.

Proteas are very sensitive to high levels of light radiation especially until they are four years old and this is one of the reasons why they fail in some areas. Those with blue, blue grey, or hairy leaves will take more light than their smooth green leaved counterparts. Generally all varieties are much better if they are sited so that they are facing away from the afternoon sun. [Ref to 1:2 and 10:3 for further information]. The temptation to protect them from afternoon radiation by siting them close in on the east side of a large tree should be avoided.

Whilst Proteas do grow in nature in dense stands they do this with their own kind and are not found intermingled with other genera of trees. The same applies in gardens, they don't mind being crowded by their own types but they do resent being crowded by other trees, especially many of the conifers [ref 17:6]. It has also been noted that they resent being in strong competition with deciduous trees. A final point to remember when choosing a site to plant a Protea is that some of them do get BIG and they certainly need more than the three to five feet that is often allocated to them in a home garden.

A brief summary of siting is:-

- Soil must be free draining
- Air movement must be adequate to maintain health.
- Frost levels should not exceed -5°C, preferably only -3°C
- Rainfall should be adequate to sustain the plant or water should be available.
- Sloping ground is better than flat ground. Avoid local depressions as drainage of water and air are often poor and it is usually a "frost pocket".
- Ground facing away from the sun especially in the afternoon is much preferred to that facing sun all day.

18:3 WHEN TO PLANT

The usual seasons of planting are autumn and spring. Extensive trials show quite clearly that plants don't establish as well if they are planted out when or just immediately prior to it being in very active vegetative growth. Proteas are rhythm plants and go through phases of growth cycles when they are, growing vegetatively, growing roots or they are growing nothing and resting. They don't grow roots and leaves at the same time and it is almost impossible to break them from their rest period which is usually in the mid to late summer. To establish well, plants must be at the phase when they are about to make primary root growth. The period when they do this is from early autumn to mid winter and again following the spring vegetative growth flush until about the longest day. The plant should be developing primary not proteoid roots when it is planted. The presence or development of proteoid roots does little in the establishment of the plant as they provide food, not a sustaining supply of moisture to the plant. The best times to plant as far as root development is concerned is entering winter and again following the spring vegetative growth flush. There is also a small time slot just as spring is breaking, several weeks before the spring flush.

These are the best times to plant but with care they can be planted at other times. Avoid exposing a plant unnecessarily to adverse winter conditions. You are better to wait until spring. [Ref. 11:6 for further information].

18:4 COMPATIBILITY OF CONTAINER MEDIUMS

Many plants fail by the second or third summer after planting. This is more so in certain soil types and when plants are not regularly irrigated. While there may be multiple reasons for these failures, the one that constantly shows as being the principal contributing factor is incompatibility between the container medium that the plant has been grown in during the nursery production phase, and the soil type of its final site. The problem is wide-spread and in some soil and climate combinations losses are known to be as high as 70% by the end of the second summer. [Ref. 8:5 to 8:7 and Appendix One for further information]. Proteas are the most affected by this syndrome followed by Leucospermums and then Leucadendrons. If establishment and survival to maturity are not up to expectations there must be some principal cause and this is the most likely.

18:5 SIZE AND AGE OF PLANT

With Proteas the best size plant to plant is the smallest one that you can adequately look after, both in the physical sense of keeping it clear of weeds, diseases, pests, (including cats, dogs and humans) and climatically so that it can establish without being unduly affected by frost, dry or very wet conditions, high light, temperatures and winds.

It has been found that one year old plants with a good primary root system give the most consistent results in survival and development. Plants of this age are past their juvenile phase and are at the stage of development where they are ready and able to establish a strong primary root system which will be followed by a well-balanced structure above the ground. Plants that are more than two years old tend to have this in the reverse with a leaf and branch structure that cannot be supported by an underdeveloped root system.

For general home garden uses, plants younger than six months old should not be attempted unless they are in a cultivated situation and can be well cared for at all times. These very young plants don't have the resistance to adverse conditions of heat, frost, light, dry and fungal invasion that the year old ones have. Plants that are put into their final site at the year old stage almost invariably have a better survival rate, out grow and out live any other aged plant.

18:6 SITE PREPARATION AND PLANTING

If the soil type and structure are suited to the growing of Proteas there is little need to do much other than to dig a hole and put the plant in it. In doing so the hole should be a minimum of three times and preferably five times the volume of the container that the plant is in. If there is turf on the ground this can be cut up and placed in the bottom of the hole as Protea plants love to get their primary roots into it. Plants should always be planted slightly deeper than they were in the container. They should never ever be left planted high as the base core of the roots will dry out and the plant will fail. This is a very vulnerable part of any Protea plant. The soil should be only packed around the roots firmly and not pounded down hard as the roots must have oxygen to develop properly. For the same reason they should not be watered heavily and if there is adequate soil moisture they often do not need watering for weeks or months after planting.

If they do need watering as soon as they are planted.

i. the soil was too dry to be planting into.
ii. the climatic conditions are causing excessive dehydration and planting should be delayed.
iii. the plant was poorly prepared and is too "soft" to plant.
iv. the plant has been grown in the wrong container medium.

In a soil type or structure that is marginal for the growing of Proteas it may be necessary to take steps to improve drainage or to open up the texture of the soil. Improving drainage on sloping ground is much easier to accomplish than it is on flat land. On flat land little can be done except to raise the soil level into mounds or ridges to create a drier patch. On sloping land it is possible to dig drainage away from the planting site. Soil can be opened up by the addition of porous rock material, humus etc. Don't use peat moss as although the plants will initially establish they usually fail in the second or third year. Soil types that are marginal will give marginal results.

18:7 MAINTENANCE WATERING

Once established most varieties only need very low levels of soil moisture to survive but to grow and flower satisfactorily they do need access to water. In many instances Proteas are given too much water when they are resting and this can cause diseases in the root system, out of character growth patterns and expose them to the risk of severe frost damage. Their soil moisture requirements are in a pattern of seasonal rhythm and readers should refer to Section Twelve for a full understanding. The one cardinal rule when applying water is that when they do need water, give them plenty and then let them rest, don't irritate them by splashing a little around on the surface every day.

18:8 SHAPING, STAKING AND TYING

Most Proteas are very rapid growers and it is during their first two years following planting out that they should be trained to full-fill their ultimate shape. All young Protea plants have one thing in common in their growths. Until they start setting flowers or bracts each terminal growth will run, then rest, then run again from the terminal and will not branch laterally until the first flowers set. With many varieties if this is left unchecked the plants tend to become very leggy and or outgrow the strength of the lower branches which either break or become pendulous.

Shaping is carried out by removing the terminal tips on those varieties that need to be developed into a bush rather than an open upright tree. When shaping always keep in mind what the ultimate shape should be. If it is intended to be on a trunk shape it that way, if it should be rounded and resting on its lower branches let it do so and if it should be prostrate leave it that way.

In windy locations those that are to be on trunks may need restraining from wind-rock by staking and tying. Don't use wooden stakes that have recently been treated with wood preservative as the chemical will probably kill the plants. When tying use two ties as this is many times more effective than a single tie. Much of the necessity to stake and tie plants will be eliminated if small plants are planted and they are shaped right from the start. Such plants grow in balance to their environment. The use of large rocks placed on the soil surface close to the plants helps to stabilize the soil and roots as well as acting as a mulch that will retain moisture during dry periods.

18:9 CULTIVATION AND WEED CONTROL

Protea plants do not like heavy cultivation or chemical weed control within their root zone especially during the period when the proteoid roots are active. Proteoid roots which are present and active from mid-autumn through to late spring are very sensitive to damage from disturbance or chemicals and either of these will cause serious disorders or the death of the plant. For this reason only hand or very shallow (1cm = 1/2 inch) cultivation should be carried out during this period. The use of any herbicide or hormone must be regarded as putting the plant at some risk. [Ref. 13:5 to 13:8 for more information on weed control].

18:10 FERTILIZERS AND PH LEVELS

The pH level of the soil is a significant factor affecting the plants' health and performance. Almost all varieties prefer soil that has a pH of 5.0 or less and in practice if it were possible to get and hold the pH level down as low as 4.0 there would be very few problems in plant performance or health. When the pH is down to this level it locks up the phosphate which is so damaging to most varieties. There is also some evidence to show that very low pH levels either increase the plants' resistance to soil-borne fungi or creates an environment through the fostering of high populations of micro-organisms so that fungi such as Phytophthora are no longer active in the soil.

In other than very poor soils the addition of fertilizers is usually not necessary at least within the first two or three years after planting. Much of a plants needs

and excesses of nutrients can be read from the leaves and a guide to these is listed in 16:2. It is probable that nitrogen will be the element that will be required to maintain satisfactory growth. [Ref. to 13:9 for further information].

18:11 DISEASES AND PESTS

The diversity of these is so great that it is impossible to list the problems and the controls of those problems here. Best control is prevention and when siting plants always keep an eye to encouraging air movement to minimise fungal invasion and avoid planting close to known host plants of pests. A full general outline is given in Section 9 on diseases and pests and in 16:3 and 16:4 may be found a quick reference to the most common problems.

18:12 FROST TOLERANCE AND DAMAGE

In many areas the amount of frost that is experienced is the controlling factor of whether Proteas can be grown successfully. It is possible to grow many varieties in a garden environment that would be impossible in a plantation in the same location. This is because gardens are full of little micro-climates: because of the influences of buildings or large trees, gardens have pockets where the minimum temperature is two to three degrees above that which would be experienced out in a plantation, well away from trees and buildings.

Once again it is air movement which will make the difference in marginal situations as this slows down the freezing process of the plant tissue. Never plant in sheltered pockets as on a calm cold night these can be three degrees colder than the rest of the garden. There is a fine line between survival and disaster. Most varieties will take -3°C with no problems, some -4°C, a few -5°C but very few -6°C or more. [Ref. 10:6 for further information].

When plants do get severely damaged by frost it is imperative that the damaged tissue is cut away as if it is left on, decay will continue to travel down the inner pith of the branches and can cause damage well beyond the original frosted area. It is also advisable to apply a fungicide such as Captan as some fungi can become established in the damaged leaf tissue.

18:13 THE END USES OF PLANT AND FLOWERS

Usually plants are initially chosen to enhance the garden. As a by-product almost every South African Proteaceae variety also produces a flower or foliage that can be used in the home or for recreational activities such as Floral Art and Ikebana.

The harvesting of flowers and foliage will do much of the necessary trimming and pruning that is necessary to keep the plants compact and tidy. Provided not more than 50% of the leaf area is harvested in any one year the removal of flowers will benefit the plants by encouraging them to produce new growths. Some varieties will only give three or four days vase life while others will last for three or more weeks. Whilst these variables are the result of differing genetic make-up. the vase life of any material is strongly influenced by the handling at and immediately following harvest.

Dehydration is the greatest contributing factor in the degeneration of plant material and every precaution should be taken to avoid this. Harvesting in the early morning will assist greatly and the placing of the cut material in water in a cool place preferably within minutes of harvest will usually ensure a satisfactory vase life for the home user. To get the very best from your flowers and foliage refer to Section Fourteen for further information on the pre- and post-harvest handling of material.

APPENDIX ONE

Compatibility of Mediums in the Production of Proteaceae

ABSTRACT

It is a widely accepted fact. that in the transition of Proteaceae plants from the nursery production phase to successful field plantation or home garden establishment. there can be marked inconsistences showing in:-

a. percentage of final survival of plants to the number set out.
b. health and subsequent development of surviving plants.

It has been my long held view that contact with certain materials that are sometimes used during the nursery production phase of Proteaceae plants. influences their survival rate and development once they have been planted in their final site.

It has been observed over a period of 30 years that this problem is particularly evident when mediums containing peat and more recently pinebark have been used during the nursery production phase.

It should be noted that this problem was virtually unknown in New Zealand until the early 1980s but has become a frequent occurrence in commercial plantings and home gardens since that time. Up until six years ago. almost all Proteaceae were nursery grown under an "open ground" system of production and in most instances were not in contact with materials other than soils during production. In the last six years there has been a widespread shift to container production of all genera of nursery stock including Proteaceae and a very high percentage is now produced in soil-less container mediums.

Because of the widespread problems being experienced during establishment of Proteaceae plants in some locations in commercial plantations and home gardens it was considered to be of economic importance to determine if. which. and to what extent any medium is incompatible to these plants in the transition from the nursery to the final setting.

To determine this. a trial was implemented in 1983 using five different varieties of Proteaceae in five different mediums under controlled conditions to assess the affects by comparison of medias on:-

a. the survival rate under normal field establishment procedures.
b. general health with particular observation of the root system.

The plants were container grown for one year in a standard nursery production environment. using the five different mediums. and were then planted out in a

field production site under standard establishment procedures for observation and comparison in survival and health performance.

After two summers in the field plantation site. there were disturbing indications of a correlation between medium and failure to survive in the field. Plants grown in the peat and pinebark mediums had markedly inferior survival and development of plants grown in the soil based medium.

The findings are based on the soil type present in the field used and are consistent with earlier observations as well as a number of reports from commercial cutflower growers and home gardeners in various locations throughout New Zealand.

It should be noted that these trials were designed to determine the survival and performance of plants following setting in their final production site and were not intended to measure growth rates during the nursery container phase.

TRIAL PARAMETERS AND PROCEDURES

Varieties of plants used and reasons.

Leucadendron Safari Sunset. Has economic importance as a cut flower. It should not however be regarded as a bench mark for all Leucadendrons as results with this clone are not consistent with all varieties.

Telopea Speciosissima (ex seed) Used because of its economic importance as a cut flower and also because it is an Australian Proteaceae which may have given differing results to those from South Africa. Seedlings were used because at that time it was the principal method of stocking plantations.

Leucospermum cordifolium cv."Harry Chittick". Has economic importance and is one of the best proven clones of Leucospermums in the cutflower trade.

Protea neriifolia cv."Big Mink". Is an average type neriifolia which is not affected by frost. Neriifolia types have strong economic importance as a mainstay cutflower in international trade.

Protea magnifica, Cedarberg variant, (ex seed). Has economic importance as a cutflower. This variety is known to be difficult to establish in some areas. Seedlings were used because it is the principal source of stocking plantations.

Base materials used in mediums.

Pine bark: commercial grade as used extensively in the New Zealand nursery trade.

Peat: first grade Hauraki peat.

Pumice: standard horticultural grade.

Loam: local alluvial brown loam topsoil.

Mushroom litter: ex Wanganui mushroom factory. Decomposed for one year.

Composition of mediums used and reasons.

A. 50% pinebark / 50% pumice
An approximation of a widely used medium in New Zealand.

B. 50% peat / 50% pumice.
An approximation of a widely used medium including some Government Departments.

C. 42% loam / 42% pumice / 16% peat
Used as a comparison bench mark to measure differences between standard peat pumice (B. above) and loam pumice (D. below)

D. 50% loam / 50% pumice
Used by Riverlea Nurseries and some other Proteaceae producers in New Zealand with long term experience.

E. 33% loam / 33% pumice / 33% decomposed mushroom litter.
Used as a comparison. A similar mix has been offered by at least one potting medium producer as a "Protea mix".

Trial period. Trial to run for two summers after planting out or until 50% deaths had occurred in a least two mediums.

Containers used. 5cm square liners at the growing-on stage. 400 cc square hard plastic pots at the holding stage. 2lt square hard plastic pots at nursery production stage.

Nursery production site. Standard production beds with overhead watering. As temperatures of -6°C can be experienced during the winter plants were covered on demand by 48% cloth as a frost protection.

Sequence of production. (nursery phase). Even grades of plants were selected from 5cm GOL liners during September - November 1983.

As they became available they were potted on into 400cc pots using a holding medium of 50% sand and 50% perlite. This medium was used as a holding material for two reasons:-

(i) it is inert and would have no influence on the plants but would encourage root development.

(ii) it was intended to bare root the plant prior to their final potting and this medium was known to shake free from the roots without causing damage.

On the 20 January 1984 eleven plants of each variety were potted on into 2lt pots into each of the five mediums and set in standard productions beds.

From 20/1/84 to 29/9/84 plants were left untouched except for hand weeding and protection from frosts when necessary.

During this period all plants made satisfactory growth above ground level with the exception of those in medium E. (mushroom litter).

It was noted that the plants in medium B. and to a lesser degree those in E. did suffer some superficial damage at -6°C even under protection, whereas those in A., C., and D. did not.

Field establishment phase.
Field planting was carried out on the 29 9 84. Site was a well drained sandy loam, (not the same origin as the material used in mediums C. and D.). Soil moisture was adequate for establishment without irrigation. Plants were planted in hand dug holes. Average day temperature was 16°C with maximum of 20°C Roots both primary and proteoid were well developed in all mediums with the exception of E. (mushroom littler). In this development was poor with the exception of Safari Sunset which was marginal. It was noted that proteoid root development in all varieties was more pronounced in medium B. (peat/pumice) than any of the others. The best ten plants of each variety in each medium were planted. The remaining plants were destroyed as no replacements were to be made.

Maintenance during establishment.
Site was kept mown between rows and hand weeded within rows. No chemical weeding was done at any stage from planting until termination of the trial on the 28/2/86. No irrigation was used at any time from planting on the 29.9 84 to termination on 28/2.86. This is normal procedure in this location and climate.

Field observations during trial period.
After 90 days the trial using medium E. (mushroom litter) was abandoned owing to almost total losses of plants with the exception of L. cv."Safari Sunset". Intermittent observations were made on the remaining plants as follows:

25/10/84	All plants O.K.	
15/4/85	Medium A. (pinebark)	88% alive, health fair.
	Medium B. (peat)	92% alive, health fair.
	Medium C. (15% peat)	92% alive, health fair to good.
	Medium D. (loam)	100% alive, health fair to good.
21 8/85	Medium A.	78% alive, health fair to poor
	Medium B.	72% alive, health fair.
	Medium C.	86% alive, health good.
	Medium D.	100% alive, health good.
1/10/85	All surviving plants were cut back to promote branching. No change on records for 21/8/85.	
13/12/85	Medium A.	60% alive, health fair to good.
	Medium B.	60% alive, health fair.
	Medium C.	76% alive, health fair to poor.
	Medium D.	94% alive, health good.
28/2/86	Medium A.	42% alive, health fair to poor.
	Medium B.	48% alive, health fair.
	Medium C.	70% alive, health fair to poor.
	Medium D.	92% alive, health good.

As losses exceeding 50% in two mediums had been recorded the trial was

terminated on the 28/2/86. Measurements of stem diameters and root weights were recorded on the 1/3/86.

Summary of observations made during the field development phase.

A. Pinebark.

Plants had a tendency to fall over and needed staking. This was not because of a light stem but a weakness in the root system at ground level. Proteas showed dehydration stress in summer unless there was regular rainfall. High losses were recorded entering the second summer stress period.

B. Peat.

After initial establishment all varieties showed stress at high temperatures even with adequate soil moisture. Health showed some improvement as temperatures fell in the autumn but the problem reappeared early the following summer. All varieties showed chlorosis in the leaves by December 1985 (one year after planting), which became severe by February 1986. Leucospermums and P. magnifica suffered frost damage whereas they did not in other mediums. High losses were recorded entering the second summer stress period.

C. 15% Peat.

Plants established well and showed few losses in first summer. Health was good through to spring (12 months after planting) but deteriorated after that. From November 1985 to termination all varieties showed chlorosis of the leaves which was severe by termination (28.2.86).

D. Loam.

Initial growth above ground was slower than other mediums but stronger. Plants did not show stress from dehydration or develop chlorosis in the leaves. Establishment was considered excellent with the exception of P. Big Mink which was below expectations.

TERMINAL ASSESSMENT PROCEDURES

Each variety in each medium was assessed on four factors:-

(i) diameter of stem at first root level.
(ii) maximum length of roots (except fine hair roots).
(iii) gross weight of roots cut off at first root level.
(iv) percentage still alive at termination.

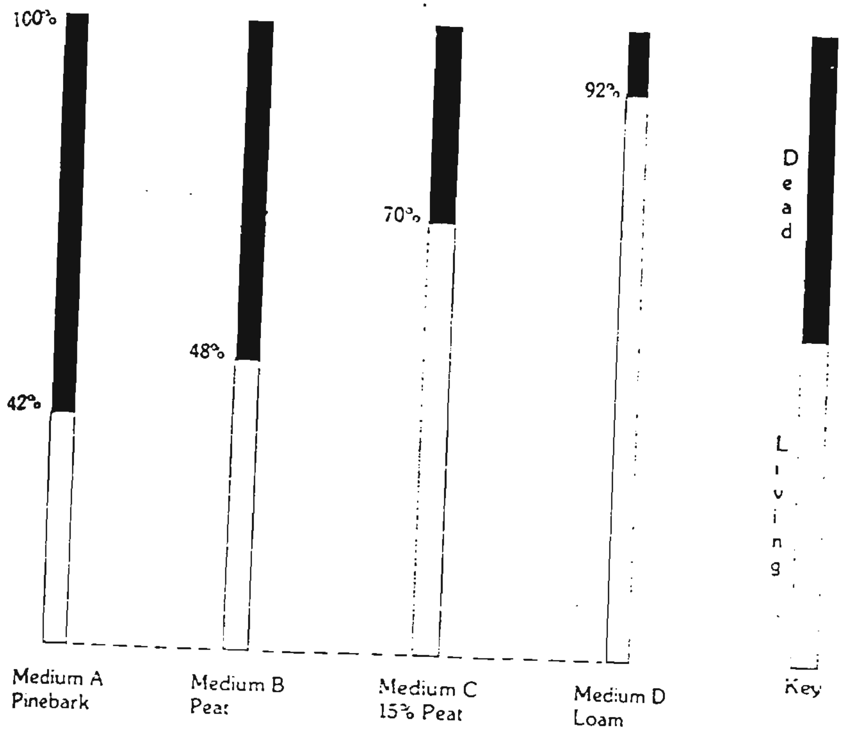
Each varieties performance below ground level was assessed by digging up and measuring:

a. the two most average surviving plants of each variety
b. the best surviving plant of each variety in each medium.

All plants were dug 30cm from the base of the plant and 30cm deep.

Weight was measured wet immediately after digging.

The graph shows the percentage still alive at termination.



Graph showing percentage of living plants in each medium at the termination of the trial 28 February 1986.

CONCLUSIONS

The results recorded show that in every instance with each variety tested, those which had been nursery grown in mediums that contained peat or pinebark had a poor performance rating when compared with those grown in soil-based medium. The medium containing 15% peat showed results approximately average between the 50% peat medium (B.) and the 50% loam medium (D.) indicating that the effect peat has on Proteaceae plants is in relationship to the percentage incorporated in the mix.

Continuing observations indicate that if plants have been nursery grown in a soil-less medium to a container size **not exceeding** 500ml (1/2 pint) and then planted in their final site and provided with irrigation on a regular basis, the problem is to some degree minimised at least in some soil types.

APPENDIX TWO

Delayed Propagation Technique

ABSTRACT

In the vegetative propagation of Proteaceae by cuttings rooted under automatic mist, there is often inconsistency even within a single clone in:-

a. the percentage that root.
b. the vigour of the root system of those that do root.

Preliminary investigations into these inconsistencies indicated that they were due to the variable condition of the material when it was harvested from the stock plant particularly in respect to:-

i. the level of dehydration within the material at harvest.
ii. the amount of dehydration that continued after harvest.
iii. the general physical condition of the harvested material.

Early tests showed that percentages rooted and the type of roots produced could be improved by delaying the final preparation and setting of the harvested material for periods of up to several days following harvest provided it was held under specific conditions.

The conditions that the material must be held under are:-

1. 100% moisture on the leaves at all times
2. it must not be heaped up deeply but must be spread out not more than two or three cuttings deep.
3. direct sunlight must never shine on it after harvest
4. light levels must be maintained at between 2500 and 3500 foot candles during daylight hours
5. some gentle air movement should be present at least during daylight hours.

To determine if or what time lapse from harvest to setting gave the best results a trial was run in January to March 1986.

TRIAL PROCEDURE

Variety used and reason.
Leucospermum cordifolium cv. "Riverlea".
Has economic value as a cut flower. Is known to be inconsistent in rooting.

Methods used.
At 6.30 am on the 15th January 1986, 340 cuttings were harvested from one stock plant. The cuttings were damp with dew, the temperature was 12°C.

Cuttings were immediately divided four ways into lots of 85 and placed under automatic mist as outlined above.

At 10.30am on days 1.3.5 and 7 one batch of 85 cuttings were processed and set to root in a medium of 45 sand.40 perlite. 10 peat and 10 regrind polystyrene. They were then placed in the propagation area under automatic mist. I.B.A. hormone at 2000 ppm was used.

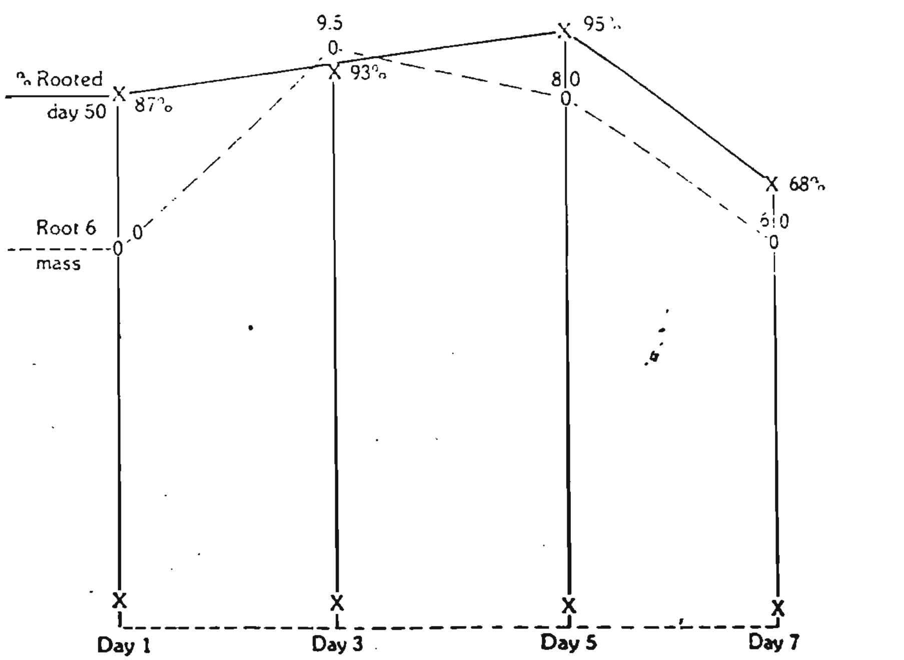
On the 28th February (day 44) the trays were removed from the misting area and were placed on a capillary bed to harden off.

On 6th March (day 50) all trays were processed and the rooted cuttings were potted up into 5cm tubes.

Results were recorded in two fields. percentages rooted and root formation. The root formation was assessed on a one to ten factor with ten being the best.

Day	% well rooted.	Total rooted.	Deaths %.	Root formation
1	70.58%	87 %	13 %	6
3	89.41%	92.94%	7 %	9.5
5	76.47%	95.29%	4.5%	8
7	60 %	77.64%	22.5%	6

Note:- The column recording deaths also includes those that had not rooted.



Graph showing:
Percentage rooted at day 50 ——————— **Root mass 1 to 10 scale** - - - - - - - -

CONCLUSIONS

The three day delay recorded the best overall results. The five day delay recorded the best total percentage but roots were not as good as for the three day batch. A rapid decline is indicated at day seven. Subsequent trials show this to be consistent with varieties that have grey and hairy leaves. These results are in line with several other trials run subsequently on all species.

It is concluded that a delay between the time of harvest and setting the cuttings to root stabilizes the sap within the plant tissues. It is also probable that a chemical reaction within the material takes place thereby causing it less stress when the leaves are stripped and the stem is recut as well as making it more receptive to hormone treatment.

APPENDIX THREE

The Effects of Weed Matting on Plant Establishment

ABSTRACT

The use of weed matting in the establishment of plantations is now widespread and there have been mixed reports of its advantages and disadvantages.

To determine the advantages and disadvantages in its use during the establishment period of Proteaceae in a plantation environment, it was decided to run a comprehensive trial. In August 1985 a trial block was set out using five plants each of fourteen different cut flower varieties in each of five different methods of establishment. The methods of establishment were:-

(a) planted directly into the ground (no irrigation, no cover).
(b) planted directly into the ground with surface irrigation.
(c) planted directly into the ground with deep irrigation 40cm below the surface.
(d) planted through weed mat — no irrigation.
(e) planted through weed mat — with irrigation.

It was intended to run the trial for four years but owing to a severe frost in the first winter when many plants were lost it was decided to terminate it after one complete year. Observations were made every sixty days during that year and the following is a summary of the records taken.

WITHOUT WEED MAT

Best survival rate was with the deep irrigation (c). Best growth rate was with surface irrigation (b).

Problems encountered were:-
Row a. (non irrigated) experienced problems with dryness in mid to late summer. This was most noticeable in Protea magnifica and to a lesser degree in Pr. neriifolia clones. Telopea showed dehydration towards the end of this dry period in rows (a) and (b) but not in (c) — deep irrigation.

Beneficial results were:-
In rows (b) and (c) all varieties showed strong well balanced growth patterns with (c) being about a month behind (b) in development.

There was almost no difference between performance in any of these three rows in the survival, growth and development in any of the four Leucadendrons trialed.

WITH WEED MAT

Best survival and growth rate was with irrigation.

Problems encountered were:-
Poor survival and initial growth rate in row (d). This appeared to be caused through the weed mat shielding the root zone from other than very heavy rain. It was noticeable that light showers did not penetrate through to ground level. At least 10mm. (1 2 inch) in a single fall is necessary to penetrate and uniformly wet the area under the matting.

All varieties showed a tendency to have pendulous rather than upright growths. This was very evident in Ld. laureolum and Lsp. cordifolium and the same syndrome has been noticed in plantations in New Zealand and other countries when they are planted through weed matting.

All clones of Pr. neriifolia laurifolia trialed showed severe chlorosis after 120 days from planting. The cause of this was eventually traced to excessively high nitrate nitrogen levels in the root zone. In two instances this was recorded at 230ppm and in seven samples was never below 160ppm at which level it almost invariable caused the death of the plants. This problem appeared to peak at around the 100 to 130 day mark following the laying of the matting. It is thought that it was caused by the break down of the herbage and roots of the grasses and clovers which were present when the matting was laid. It should be noted that it is not only associated with pasture that has recently been retired from grazing as tests in an area that had not been grazed for six years gave the same result. It does however appear to be aggravated where there has been a strong sward of clover prior to planting and covering. Because of the effects from the high nitrate nitrogen levels, many of the Proteas in the weed matting were regarded as being non-viable by late autumn. It should be noted that there was no sign of any chlorosis in the rows not covered by weed matting only two meters away. Similar symptoms were observed in Hawaii in late 1987 where a number of varieties had been planted through weed matting.

Plants of all varieties under trial which survived in the weed matting through to April then strengthened and improved in health through May.

The frosts in mid-June caused severe damage to all plants in the weed matting except Ld. cv. "Safari Sunset" and a salignum clone. All Pr. neriifolia clones and Leucospermums died and Pr. cynaroides and magnifica although damaged did survive. Telopea specioissima was not affected. This frost was recorded at -6.5°C. and lay for ten to twelve hours. Damage to the plants not in weed matting was severe but rarely caused death. The control row (a) which had not been irrigated suffered only superficial damage.

SUMMARY

Weed matting appears to be very satisfactory for Leucadendrons in all locations researched and observed. It also gives satisfactory results with all species / varieties of Proteaceae in higher summer rainfall areas but has given problems with Protea varieties in lower rainfall areas. Without irrigation problems of dry root zone can be expected in locations that do not have heavy downpours through the summer. Contrary to what had been anticipated, moisture readings in the top 15cm of soil under the weed matting without irrigation were drier than in the row without matting or irrigation. Day temperatures under the weed matting were constantly higher than without it.

Some growers have experienced Phytophthora problems in Leucospermums under high rainfall/temperature conditions when using weed matting. This is probably due to the higher ground temperature that the matting maintains near the surface. Soil temperature at 50mm below surface averaged 4°C higher under the cloth than bare ground during the hottest months.

The results show that the use of weed matting creates a high risk of frost damage at least in the first year. The reason for this has not been positively identified but it is probably due to a combination of growth being stimulated late into the winter through the influence of the higher root zone temperatures, and the weed matting stopping the flow of warmth arising from the earth during the frost. Note:- there is always some warmth rising from the soil surface unless there is a perma-frost. Similar problems were recorded in the winter of 1984 in beds of ericas planted through plastic mulch. In this instance a grid of maximum - minimum thermometers regularly recorded two degrees more frost over the plastic than over grass or bare ground walk ways between the beds.

Further trials are needed to determine whether the laying of the cloth several months ahead will eliminate the nitrate nitrogen problem during the first summer and whether early spring plantings will help in the establishment of a hardier plant before the onset of winter, thus avoiding the frost problem. It is conceded that -6.5°C is a little more than you would expect Proteas to thrive in.

There is no doubt that the use of weed matting reduces the maintenance time during the establishment period once it has been laid and in at least some crops in some areas gives a greater growth rate than without it. [Ref. to 13:7 for time and costing information.]

The long term effects of weed matting have not been tested. Observations where it has been in use for more than four years indicate that once the roots of the plants move deeper and wider than the influences of the matting, then it has little or no further effect on the plant.

INDEX