the seed in the last stages of maturation. This may be avoided by the early collection of seed heads.

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PROPAGATION OF SOUTH AFRICAN PROTEACEAE BY SEED

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Thirty years ago the germination of Proteaceae seeds and their survival through to a saleable plant was a great mystery to me and, judging by the results I sometimes see in New Zealand and other countries, it still is to many people.

In this paper I will outline the methods I have developed during those thirty years and now use to propagate this family of plants from seed in my particular climate. In doing so I must generalise as there is insufficient time to go into the finer details for each species and cultivar. In practice one should never generalise about proteas.

Proteas are unique in some of their demands for survival. A basic understanding of where, how, and why they grow in nature will help understand why they need these specific conditions.

Almost all the proteas we know in New Zealand gardens come from the Cape Province of South Africa and are mostly found in an area about 600 km long by 80 km wide, stretching from Capetown eastwards to Port Elizabeth along the coast and incorporating the mountain ranges that run parallel to the coast line. Rainfall is similar to New Zealand—750 to 2000 mm, (30 to 80 inches) with dry autumns. Although some kinds, mostly leucadendrons, and the more common proteas are found on the coastal plains, most grow in the mountains—from around 500 to 1000 m. Here they are exposed to constant air movement which is mostly gentle. They are often shrouded in cool afternoon mists, even right through the summer months and are growing in incredibly rocky ground which is usually steep and well drained. None of the plants are found growing on a north facing slope unless they are of the blue/grey leaf forms, such

as *Protea amplexicaulis, P. laurifolia, P. eximia,* etc. and, although it can snow at these levels, it is rare for frost temperatures to drop below −2 or 3°C. The soil amongst the rocks usually has very low nutrient levels, especially phosphate; the pH is low, in some places as low as 3.0.

From this brief outline we can see that proteas are very selective where they grow and, in fact, almost nothing else will grow where they are found. They require good air movement, good drainage, low phosphate and pH levels, and light intensity below that occurring on a sunny north face. They will tolerate high rainfall provided it does not occur in the autumn and they do benefit greatly from cool afternoon mists dampening and cooling their leaves. As seedlings they will tolerate ground frosts of a short duration (two hours) at temperatures down to −3.5°C.

There is one great difference between the conditions where proteas are found in South Africa and the New Zealand climate and that is the temperature/humidity ratio. In South Africa when it rains it also gets cold, as the rain clouds come in from the southern oceans. In New Zealand when it rains, especially in the summer it often comes from the northern tropics and is accompanied by high humidity and temperatures. The 80/80 combination is quite common and this is our undoing as it induces fungal invasion in proteas both above and below the ground. It is a problem we must always be aware of, not only in the summer but also in the winter months when we can have warm day temperatures at humidity levels of 85% and over. Proteas do not tolerate hot, moist air.

How do we provide conditions that match those in which proteas will succeed?

Dealing with the environmental ones first, air movement and light control, my preference is to do all propagation out-of-doors but under a rain-proof roof. This is achieved by having a structure with benching 60 cm above ground level over which is a PVC roof, 1 to 1½ metres above the benching. This roof is sitting on runners so that it can be run back off the entire area to let the rain fall on the seed trays or full light on the seedlings. Alternatively it can be left in place to protect them from frosts, excessive rainfall and light levels. There are usually no sides on it but hessian is sometimes stretched around it as frost protection.

This structure provides the best possible air movement, regulates the light on a bright sunny day to around 6,000 f.c., which is the ideal light intensity, and allows to either expose the seedlings to rain and light, or protect them as necessary.

All the other needs of the protea plants are incorporated in the medium used for seed germination and for subsequent growing on. I only use soil-based media for any phase of protea propagation with never more than 10% peat in any mix.

Trials concluded last February, which were carried out over the

previous three years, show conclusively that proteacea plants are seriously affected in their ability to develop a satisfactory root system (in at least some New Zealand soil types) if the roots have been in contact with peat (at more than 10% of the volume of any medium) at any stage of development from initiation to final siting. Those that have been in contact with pinebark are even worse.

For the seed germination phase I use 50 parts turf loam, 20 parts coarse river sand, and 30 parts either perlite or coarse pumice. Alternatively, 50 parts turf loam and 50 parts Waikato grade 14 pumice sand (from Mercer) can be used.

If the seed is being sown toward mid-winter when slow germination and development is expected I replace 10 parts of the pumice with 10 parts of peat. This helps to stabilise the pH, which tends to rise with the water I have to use.

For sterilising I prefer heat at 185°F for 20 minutes. Failing this, methyl bromide is all right provided it is applied four to five weeks prior to use.

If using loam, pumice, or perlite of unknown phosphate and pH levels these should be checked before large scale seed sowing.

Seed trays should not be deeper than 5 cm (2 in.). The reason for this is that seedling proteas have very dominant tap roots in their initial stage of development and if sown in deep trays, they develop such a long and massive tap root before they are ready to pot up that severe damage can be done to them during handling. By keeping the depth to 5 cm it will force them to produce a more fibrous root system that is easier to handle. My preference is to use the Worsdale tray for all seed germination for reasons I will explain later.

Protea seed falls into two categories—that of the winged type and that of the hard-shelled forms. All the proteas that one is likely to come across in the nursery trade, except *P. magnifica*, as well as about half of the leucodendrons, have winged seeds. These are the types that are held captive in the seed heads until released by fire, which happens every 15 to 20 years in nature. Seeds of these are all easy to germinate, although viability does vary greatly from year to year in some cultivars. The hard-shelled seeds are found in the remainder of the leucodendrons, all the leucospermums, and most of the other genera: *Mimetes, Paranomus, Serruria,* etc. These seeds are shed each year, usually mid-summer to early autumn. They are often slow and erratic in germination, taking from 3 to 15 months to germinate.

There has been some work done in South Africa and by myself on breaking dormancy in these seeds. The treatments given in South Africa range from soaking in hydrogen peroxide and/or low doses of acid, soaking in sour milk for 3 weeks, pouring boiling water over them, grinding nicks in the shell, and even cracking the seeds with a hammer.

Gert Britts at the Protea Research Station in South Africa, has

completed a 24 month trial using one variant of *Leucospermum cordifolium*, sowing seed every 30 days during that period. His results clearly show that germination was greatly improved in the months when a sharp drop in temperatures was experienced within 30 days of seed sowing (as would occur in early winter), with poor results recorded on a rising temperature pattern. His findings are in line with the observations I have made on a number of cultivars covering several species. An extension to these observations is that these seeds seem to become more difficult to germinate as they age, probably because of dehydration after removal from the heads. I am of an opinion that very high germination rates could always be achieved with this type of seed if they were never allowed to become dehydrated between harvest and sowing. This problem can be alleviated to some degree by soaking them in water for 30 minutes at 60°C just prior to sowing but this will not totally compensate for dehydration as they appear to go into a state of dormancy. Stratification has been trialled on a number of occasions with inconsistent results, probably due to variable seed quality.

Because of the foregoing, my advice is to sow all proteaceae seed in the autumn on a falling temperature pattern. Some of the winged types give good germination with spring sowing but there can be a problem getting such juvenile plants through the high temperature and humidity periods of early summer.

For seed sowing, trays are filled to the rim with a medium that is of such a moisture content that it will just hold together in your hand if it is squeezed gently. This moisture content is important as it will not be watered again until germination has commenced. Firm down the medium in the tray but do not pound down hard, just firm. Put the seed into a container, and to every 200 seeds add 200 ml volume of dry coarse sand. To this add ¼ tsp. captan and mix it all well. Sow the seed not exceeding a density of one seed per sq.cm.—otherwise when they germinate the seedlings will push each other up into the air and some will dehydrate and die. Firm the seed down, but do not pound it, and top up the tray to overflow with medium, levelling it off by drawing a lath over the surface. Do not firm down this surface. Stack the finished trays one on top of the other, putting a barrier of weed mat or tray liner between them. Stack out of direct sunlight and strong drafts. Do not sheet down with plastic or any other material.

The stacked trays are left unattended for 17 days at temperatures 18°C and over, or 21 days below that temperature.

On the due date, unstack and place the trays in the germination area. Water very lightly and then immediately cover to a depth of 2 to 3 mm with sand into which, for every liter volume of sand, 2 mg of captan has been added.

If the moisture content is correct at sowing, as described earlier, seed of most of the winged cultivars will germinate from the

18th to 25th day at the higher temperature, and 25th to 35th day at the lower range. The hard-shelled types can be left stacked with safety until the 30th to 35th days then spread out and handled in the same way. Light levels are of great importance in the first 90 days following germination. It should be controlled to give an average level of approximately 6,000 f.c. It is not necessary to measure this light but it must be controlled so that the stems on the seedlings maintain a green/brown to green/red colour, depending on cultivar. If the colour of these stems becomes green/white and almost translucent, the light level is too low, but if the stem colour becomes dark brown to reddish light intensity is too high. The high incidence of fungal invasion in some operator's hands is a direct result of too low a light level, while the bright-coloured stems are a result of too much light at some stage. In cloudy weather seedlings should be exposed to full light. Under well controlled conditions development of the seedlings is rapid and most cultivars will be ready to pot up within four weeks from seed germination. I prefer to do this at the first true leaf stage. If they are left any longer most will develop long tap roots that will be damaged on further handling.

Maintenance from seed germination to potting consists of providing adequate air movement and proper light control. These are the most important ingredients to success. If these are well controlled most other problems will not appear.

Spraying with captan at 75% strength every 10 days should be done and on the 20th day after germination Alliete® at half strength should be applied. Watering should be prudently done, taking care not to overwater. The plants are better being a little too dry than too wet. Exposure to natural rain is highly beneficial and if possible should be used as the water source rather than tap water.

Contrary to general practice, I always water late in the day leaving the plants wet overnight, which is the same as they have in nature. If frosts are not a problem the seedlings may be exposed to dews each night which will practically eliminate the necessity to water during this phase. Nightly exposure to dews will also greatly reduce the incidence of fungal invasion. Frosts, unless below −3°C, are not a great danger on well-grown seedlings. I have had a range of cultivars frozen to −5°C for 3 hours without any losses. However, frosts of greater than −2.5°C at tray surface level may affect seeds that have started germination but not emerged. It is generally better to avoid temperatures below −2°C.

Seedlings that have not been well handled and are in soft condition through low light levels, or from being kept in high humidity conditions, such as closed-in glass or tunnel houses, will suffer damage at levels just below 0°C.

Seven days before the seedlings are to be potted up, apply captan at the standard rate as a drench. This will clean up any fungal problems that may be present.

The following day the plants should be "wrenched". This is carried out by poking your finger up through the mesh on the bottom of the trays and disturbing the liner. If solid based trays have been used wrenching may be done by using a table fork to disturb them. Either method will effectively disturb the long tap root of the seedling and cause the plant to produce a strong fibrous root mass over the next five to seven days. The trays of seedlings should not be watered at least until the day following the wrenching or even the second day, but to protect the plants from dehydration they should be kept in full shade and out of strong drafts for the period between wrenching and until they are again watered.

Withholding of water is important for two reasons. Firstly, watering immediately following wrenching can induce fungal problems in the root system which enters through the damaged tissue caused by the disturbance and, secondly, the plants' roots must be made to hunt a little for moisture and it is, therefore, necessary to keep them on the dry side. This wrenching will reduce losses at potting up to nil provided it and the potting phase are well done.

Potting up should be done before the plants get too big and especially before they get weak at ground level, which they will do if left too long in an undisturbed state in a gentle environment. It should be done as they are getting their first pair of true leaves.

The medium I use is ⅔ turf loam and ⅓ pumice sand or coarse river sand. This should be sterilised either by heat or gas as was the germination medium. Moisture content should be the same as for seed sowing. Terazole® may be incorporated at the standard 100 gms per cubic metre to give added protection from *Phytophthora*, especially when entering the warmer early summer months.

Container size for the cultivars common in the nursery trade is not critical and the 5 cm square liner is satisfactory. With some of the more difficult subjects the initial container size is critical as it is important that these cultivars rapidly get their roots to the perimeter and bottom of the pots. This is particularly so with those that are found in dry rocky ground in nature. These cultivars do not do well unless their roots are somewhat constricted and able to run along a hard surface. Under cultivation the sides of a tube acts as a substitute for rocks. If you look closely at the roots of these cultivars you will see that they have the ability to fasten themselves to a hard surface like ivy does on a wall and this enables them to get moisture from the condensation on the underside of the rocks. With these cultivars it will be found that the small 2.5 mm round propagation tube will give best results in the initial potting phase with a 50/50 mix of loam and pumice sand. (This is also true for the Western Australia banksias.)

When potting up, plants should be extracted from the trays gently, taking care to cause as little damage as possible to the roots. They should be set at a height in the liner a little lower than they

were in the tray and the liner should be filled to an over-full level. The medium must be left relatively loose in the liner, just firm enough to hold the plant upright. Proteas will only generate roots if there is oxygen in the soil. For this reason the medium should be left uncompacted and preferably not watered for at least three days following potting up. They should however be protected from conditions that will cause dehydration the same as following the wrenching phase. Three days following potting the plants may be watered sparingly and exposed to higher light levels and adequate air movement. They can be placed in an open environment provided they are protected from prolonged periods of high light intensity (7,000 f.c. and over), constant strong winds, and frosts below −2°C. It may be necessary also to protect them from excessive rainfall.

For this, or any other phase of production, I do not favour tunnel houses or glass houses because of the problems proteas experience with the high humidity created in these structures. Fungal problems can be induced into the plants under such conditions and, although it can be controlled by weekly drenchings of fungicides, it is only controlled but not cured and may be carried through to the later stages of the plants' development. This can be seen in the high casualty rates often experienced in the growing on phase in production nurseries and later in garden centres where maintenance spraying is not regular or carried out at all.

Once the seedlings have developed to the stage of potting up, hardened off, and producing a strong healthy root system, they can be grown on. However the operator should always bear in mind that proteas are like people. To stay healthy they need good air, the right amount of light for their particular species, not too much water, and a restricted diet.