SOUTH AFRICAN NURSERY PRACTICE - THE STATE OF THE ART

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Abstract.--The state of S. African nursery practice is briefly sketched from its beginnings in the late 19th century to the present day. Systems used and numbers raised by species are summarized for 1984/85; cultural practices and their effect on plant quality, survival and early growth on planting are examined. It is concluded that while satisfactory plants are being grown with current practices, substantial improvements in efficiency are possible, indeed essential, if the industry is to meet the challenge of rising costs.

INTRODUCTION

South Africa has never been heavily afforested and what indigenous forests there were, were destructively exploited during the settlement of the country (Luckhoff, 1973). The country has been forced to afforest to supply the timber essential for its development.

Plantation forestry in South Africa started in 1876 when a stand of *Eucalyptus globulus* was established as a fuel plantation near Worcester in the Cape (Annual Report, 1887). Today, there are over 1,1 million hectare of man-made forest planted with a large variety of pines and eucalypts. Six species, however, account for nearly 80 percent of the afforested area: *P. patula* 22,7%, *P. elliottii* 13,3%, *P. taeda* 7,4%, *P. radiata* 5,1%, *P. pinaster* 3,6%, *E. grandis* 26,0%. Table 1 lists the area by region, ownership and type of timber (van Wyk, 1985).

Ownership patterns have changed significantly; up to the mid-forties virtually all plantations were State property. It was only after the second World War that private enterprise became interested in afforestation. The advent of fast growing short rotation crops, such as *Eucalyptus grandis* and *Acacia mearnsii*, further stimulated private investment, until today 70% of the plantation area is privately owned (Directorate of Forestry, 1984). The country's present timber requirements are largely met by local production and some hardwood chips are exported. To meet future requirements, however, additional plantings of 39000 ha will be needed per annum to the end of this century. (Directorate of Forestry, 1982).

Moisture is the major site factor limiting afforestation and only a narrow belt along the south and east coasts and on the mountains on the eastern side of the country receive sufficient rainfall to support commercial plantations (Fig. 1). The country splits naturally into three regions depending upon the rainfall patterns:

(i) the winter rainfall area in the S.W. Cape which receives its rain from an extension of the southern cyclonic system.
(ii) the constant rainfall area in the South Cape, along the seaward side of the coastal mountain range from Mossel Bay to Humansdorp.
(iii) the summer rainfall area comprising the remainder of the Cape, Natal, Transvaal and the Orange Free State, its rain mostly originating from

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Table 1.--Plantation Area by Forestry Zone

Zone	Total Area (ha)	Ownership		Type of Timber	
		Private	Public	Softwood	Hardwood
1. N. Transvaal	60 016	43 430	16 586	25 505	34 511
2. E. Transvaal	255 231	165 096	90 135	166 968	88 263
3. Central Tvl & OFS	22 600	15 600	7 331	15 297	7 303
4. S.E. Transvaal	235 774	210 776	24 998	102 332	133 442
5. Maputoland	16 521	0	16 521	15 453	1 068
6. Zululand	91 540	56 132	35 408	35 454	56 086
7. Natal Midlands	162 221	151 202	11 019	62 936	99 285
8. N.Natal	38 928	35 051	3 877	9 290	29 628
9. S.Natal	89 503	72 512	16 987	39 409	50 095
11. E.Cape	25 727	2 981	22 746	23 835	1 892
12. S.Cape	76 613	18 905	57 708	70 542	6 071
13. W.Cape	30 063	7 359	22 704	28 519	1 544
TOTAL:-	1104 737	778 717	326 020	595 539	509 198
% of Total:	100	70,5	29,5	53,9	46,1

Table 2.- Plants Raised by Systems for Commercial Afforestation, 1984/85.

System	Box	Polypot/sleeve	Bare-Root	Speedling tray	Total	%
Pines	11490	6928	14124	11745	44 287	58,3
Eucalypts	1914	3122	-	21025	26 061	34,3
Wattle	1409	385	-	3793	5 587	7,4
Total	14813	10435	14124	36563	75 935	100,0
%	19,5	13,7	18,6	48,2	100,0	

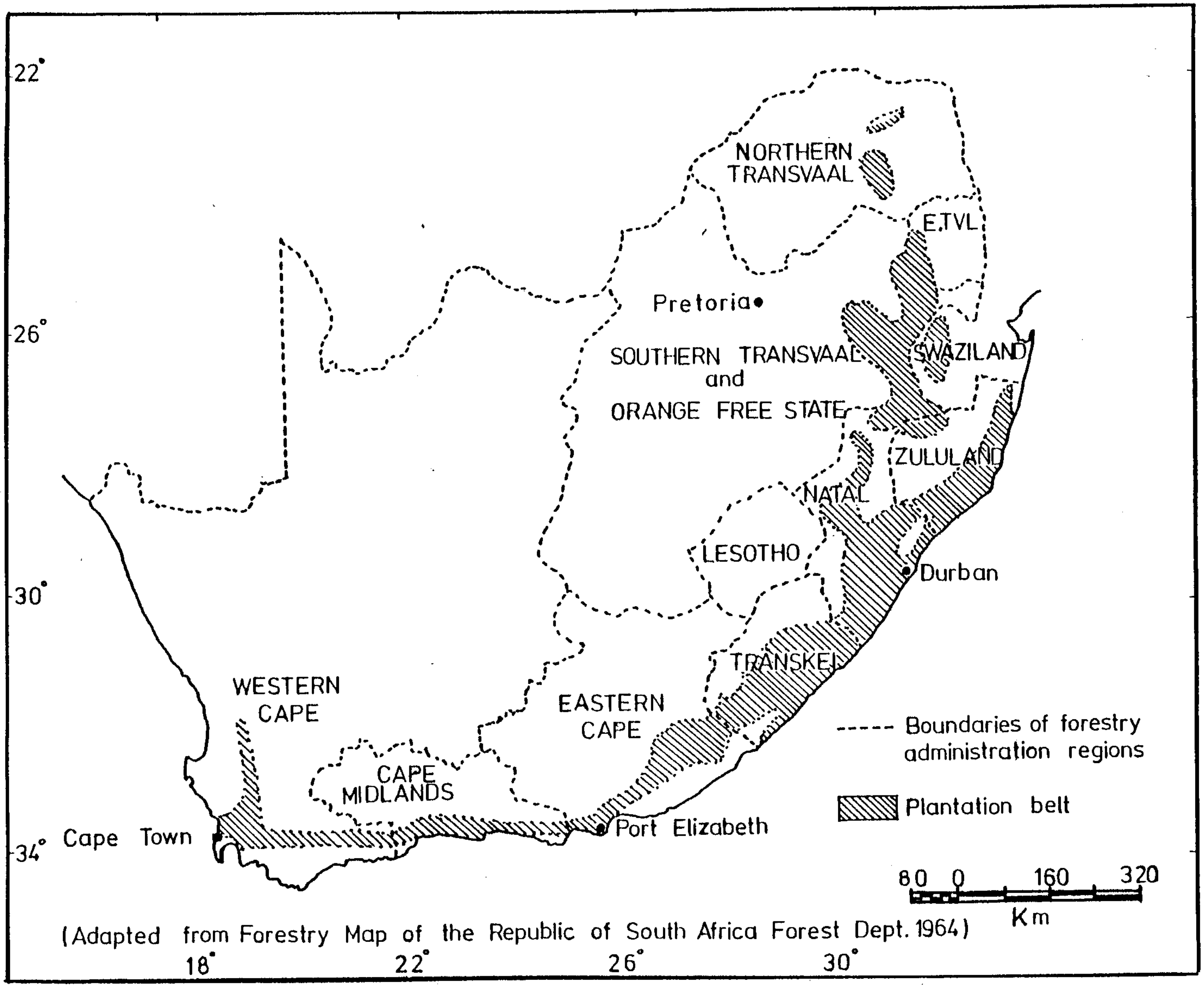

FIG 1 SOUTH AFRICAN PLANTATION BELT (DONALD, 1968)

the Indian Ocean and brought over the continent by the S.E., E and N.E. winds (Donald, 1968).

Temperature is seldom limiting within the plantation belt, although frost can cause a change in the species selected for a particular region.

History of S. African Forest Nurseries

The early history of the S. African forest nursery industry was dominated by the State (Donald, 1965). It increased capacity from some 8 million per annum at the time of Union (1910) to over 33 million at the founding of the Republic (1961), in keeping with the increasing area of plantation. Surveyed in 1960/61 (Donald, 1965) there was a total of 36 nurseries registered to sell plants for afforestation and some 150 non-registered nurseries raising plants for their own use. Two thirds of these were State nurseries.

Surveyed again in 1984/85 the number of nurseries had decreased to 23 registered and 60 non-registered, but the number of plants produced had increased dramatically to some 76 million plants. In 1960/61 half of the 33 million plants raised were pine (50,1%), while half were eucalypt (49,9%). Wattle (*Acacia mearnsii*) afforestation at that time was done by *in situ* sowing and natural regeneration. In 1984/85 the availability of selected wattle seed has increased this species percentage of production to 7,4%, pines increased to 58,3%, while eucalypts have fallen to 34,3%. Only 27,7% of the 83 nurseries are now State owned.

The greatest change in the industry has occurred in the nursery systems used. In 1960/61 the box system dominated the industry. The use of polythene sleeves had just started and the bed and tray system, developed at Usutu Forests in Swaziland, was used by only a few nurseries. By 1984 it was virtually extinct. The perfection of conditioning of bare-root stock during the seventies, however, has allowed the use of the bare-root system, while the Speedling tray, developed in California for horticulture in the sixties and introduced into the Republic in 1975 (Kruger, 1984) has become the industry's major nursery system. Table 2 gives the breakdown of plants by systems for the year 1984/85.

The two new systems, bare-root and speedling trays, have been widely adopted by private industry. The box system owes its survival entirely to the State, as it is still the prescribed system for Forest Department Nurseries (Deputy Director-General, 1981).

The Systems Used

1. The box system

This system has not changed since it was initially introduced at the end of the last century. The boxes today are made of wooden slats instead of half paraffin tins. The slats should be pressure treated with wood preservatives, if more than one crop is to be grown in them, but as they are seldom returned to the nursery, it is normally not done. Box size varies, but the commonest size is 250 x 300 x 100 mm. Thirty plants are planted initially per box and the crop sold at 40 boxes per thousand plants. The cost of the box, particularly if it is only used once, has put it outside acceptable levels for private enterprise. In addition to its high cost, the system requires some 400 tons top soil per million plants, and in many areas suitable nursery soil is becoming difficult to obtain.

As the plants are transported to the field in the box, transportation to the field and handling of the boxes during planting is difficult and expensive. Not withstanding its numerous disadvantages, the system is the most robust of those available, which is why it receives State blessing. Plants can be transported over considerable distances without damage and although up to a third of the dry weight of the root is lost during trowel planting; the plant usually survives with no noticeable check in growth. Planting can also be done during unfavourable weather conditions.

2. The polypot/sleeve system

Initially introduced in the early sixties, polypots became very popular in the late sixties and early seventies. It is a single plant container system usually formed from 125 gauge polythene with a depth of 100 mm and 85 mm diameter when filled with soil. The system is as robust as the tray system, uses slightly more soil and is more labour intensive even when filling the sleeves can be partly mechanised. The polythene which was significantly cheaper than the box when the system was first introduced is no longer so much cheaper, following the substantial oil price increases in the late seventies.

It too can grow good plants but the polythene must be removed before the seedling is planted. Failure to do this in the early years gave rise to severe stability problems from encircling or strangulation root, the trees usually blowing over or breaking off in the third or fourth year. If the seedlings have been retained more than a few months in the nursery, the polythene tube must be cut to ensure that incipient strangulation roots are also cut. Just peeling off the polythene will leave the encircling root system intact, so that it can still cause instability problems.

3. The Bare-rooted System

Various trials with bare-rooted pine seedlings have been carried out since afforestation commenced (Henkel, 1894). Results have been very variable and, outside the winter rainfall area, usually unacceptable (Hutchin, 1893; Fenn, 1962). Planting is normally done when the seedlings are actively growing so that they are very susceptible to weather conditions at the time of planting. The introduction of root undercutting and intensive wrenching, as developed in New Zealand (van Dorsser & Rook, 1972) which induced shoot dormancy during the growing season, allowed the successful adoption of the bare-root system (Donald, 1976a; Denison, 1981). The plant produced under this regime has a dormant and lignified shoot with a short densely fibrous and active root system, capable of rapid root regeneration. These plants have the ability to withstand considerable stress without ill-effects and can be successfully cold-stored between lifting and planting, if required (Donald, 1976a).

Trials with eucalypts were started and appeared promising but the advent of the speedling tray removed all incentive for work on bare-rooted eucalypts.

4. Speedling tray

Speedling trays were introduced to South Africa in the mid-seventies. Trials using *Acacia mearnsii* were first started by the WRI in 1976 (Barret, 1981).

The system today is the most widely used in the S. African forest nursery industry. A variety of tray sizes are available but the most commonly used is the 128. This multi-plant container takes 128 plants in inverted pyramid-shaped, open bottomed cavities, constructed of polystyrene. The depth and diameter of the cavity is quite different from the styroblock container developed for the N. American forest industry. Cavity depth is only 63 mm, while the top is 37,3 mm square. The truncated top of the pyramid, that is the bottom of the cavity, is 9 mm square. Cavity volume is 36 ml.

The system is used for wattle, eucalypts and pines, mostly Pinus patula. Recently poplars, which had previously been raised as open-rooted cuttings have also moved over to speedling trays (Jones, 1985). Growing media used are mostly composted pine bark, which may or may not be enriched. Reed peat was used initially but deposits are very limited. Spagnum peat is not naturally available in S. Africa. Some imported peat is occasionally used, usually mixed with bark, to improve the aeration of the latter. The 128 tray is 340 mm by 480 mm. It is raised from the ground on wire or aluminium rails to allow roots to be air-pruned. Copper coating the trays using PVA paint and a copper salt to prevent the roots from penetrating the styrene walls, is standard practice. It also keeps bryophytes from developing on the trays.

Initially the plants were carried to the field in the trays. Today they are removed from the trays and handled as plugs in a similar manner to bare-root seedlings. As the trays do not leave the nursery, their life has been greatly increased, at least six crops being raised from a tray.

Current Practice of Nursery Management

1. Seed treatment

Seed for afforestation can be purchased from the Forestry Department Seed Store, Pretoria, from Mondi Forests, Sabie and from the Institute for Commercial Forest Research (wattle only) - Pietermaritzburg. Virtually all seed of the commercial pines is derived from seed orchards. Seed data is not supplied automatically but will be given on request (Donald, 1983a).

The Forest Department currently sells their seed by weight but hope in the near future to fix the price according to the number of viable seed in the seed lot (Herps, 1985). This will ensure that accurate seed test data are available and all nurserymen must request that it be supplied. Few nurserymen do not stratify pine seed. The operation includes water soaking for 24 hours and the separation of empty seed by flotation. After separation the sinking seeds are drained, sealed in a large polythene bag and placed in refrigeration at 2 - 3°C. Where commercial cold stores set at other temperatures are available, they are also used. The stratification period varies with species: in Pinus elliottii it is normally 30 days, in P. radiata 40 days, P. pinaster and P. taeda 60 to 90 days, but the period is more often dictated by the experience of the individual nurseryman and the time available to him.

Kelpak, a locally produced seaweed product which contains gibberellins and cytokinins as well as a complete range of trace elements, has been shown to increase the germination capacity of the pines (Donald, 1983b). It is used in a 1 in 500 mix in place of water before stratification and has been adopted by the more advanced growers.

When the seed has been stratified most nurserymen treat it with a bird repellent. This consists of Thiram (50% TMTD) using 15% of the dry weight of seed and a synthetic latex sticker to hold the thiram on the seed coat. Thiram can be detrimental to germination if it gets into the medium, as the roots will not grow into medium containing it (Donald, 1968). Only two examples of failure of this repellent have been recorded, both from Zululand. Crows pulled the white-coated seedlings from the ground but did not eat them, while the local sparrow population attained a liking for Thiram and were not discouraged by it (Young, 1979).

Great strides in the treatment of eucalypt seed have been made in recent years through sieving to remove chaff and killing seedcoat mycoflora with a Captan dressing (Donald, 1984). These techniques are still not fully adopted by the industry, however. The larger speedling tray nurseries are using them, combined with fluid drilling sowing equipment.

Pine seed is sown manually in the smaller nurseries or by Stanhay seeders (bare-rooted) or pneumatic mechanised sowing equipment (speedling tray) in the larger nurseries. Sowing densities vary; many smaller nurseries sow densely and prick out the seedlings at the desired espacement in the container or bed in which they will be grown. Mechanised bare-root systems mostly sow at 150 mm between rows and aim at 40 to 50 mm between seedlings within rows. As seed is relatively cheap, more seed is usually sown and the resultant seedlings thinned to the required espacement.

Empty cavities are bad news for the speedling tray nurseryman. Costs remain unchanged but the cost per thousand plants is increased as the divisor is reduced. Nurserymen are currently sowing two and even three seeds per cavity and thinning the surplus seedlings to avoid empty cavities.

2. Irrigation

Apart from a small area in the Southern Cape, South Africa experiences seasonal rainfall. Even during the wet periods, however, failure of the rainfall to reach the expected levels is common. Consequently irrigation is a *sine qua non* for the South African nurseryman. The small quantity of rooting medium and the consequent poor moisture holding capacity of the containers used, particularly the speedling tray, make frequent irrigation essential.

Only small temporary nurseries still use manual watering. Nurseries growing a quarter million or more seedlings find it pays to mechanise irrigation. A variety of systems is used; rainbird, rosehead and perfapipe being the most common. Speedling tray nurseries almost universally use microjet. The biggest nurseries have fully automated, computer controlled systems which also supply the crop's nutrient requirements through the irrigation system.

Germinating seeds and young seedlings require frequent waterings whether in beds or containers. The pattern changes in beds and to a lesser extent in boxes and polypots as the seedlings grow and can utilize the available rooting depth. Irrigation of speedling trays does not change as seedlings grow; if anything, the additional transpiration further accelerates the water removal. Neglecting irrigation over a weekend can and has caused severe crop losses in this system.

Monitoring in the box system is done by weighing the box at field capacity and allowing the mass loss to increase to approximately two-thirds towards temporary wilting point before re-watering. With the sand soils used in this system it is equivalent to the soil to dry to between 15 and 16% moisture content before re-watering. Maintaining the soil at field capacity would double the watering bill without significantly improving plant growth (Donald, 1971). The same moisture contents are effective for bare-root systems, with the equivalent of approximately 25 mm rain per week being required.

Water use was monitored in box nurseries using water-loss recorders at the extreme ends of the country - at Grabouw in the S.W. Cape (lat 34°09'S, long 19°,1'E) a warm temperate region enjoying a winter rainfall; and at Manzengwenya in coastal Zululand (lat 28°, 07'S, long 32°, 23'E) a subtropical region with a mainly summer rainfall but also experiencing winter rains. Water requirement by the box plants was virtually the same in both nurseries. Water consumption was actually higher at Grabouw as the nurseryman was applying more water than necessary. Manzengwenya was within acceptable levels for efficient irrigation (Donald, 1971).

3. Maintenance of Fertility

South African nursery systems which use soil as the growing medium (box, poly-pot and bare-root systems) mostly apply inorganic fertilizers according to the number of plants raised. No effort is made to maintain the fertility of the soil per se (Morze, 1977; Cawse & Martyn, 1981; Young, 1981). In the box and poly-pot systems the soil is removed from the nursery with the crop and even with the bare-root system monitoring of soil nutrient levels is seldom done. The application of one gram 2 : 3 : 4 (21) a granular complete fertilizer per plant meets the nutritional requirements of all the commercially grown species. It is applied as three top dressings of 0,2, 0,4 and 0,4 grams per plant, at six to eight week intervals starting six weeks after pricking out or eight weeks after sowing. This prescription has reduced the nursery period from twelve to seven months and still allowed adequate time for conditioning and hardening the seedlings (Donald, 1972). Some nurseries, mostly in Natal, mix straight fertilizers into the soil before sowing or pricking-out (WRI, 1972). This system also works but requires more fertilizer for the same effect and allows leaching of the fertilizer before the plants are large enough to utilize it. Root scorch is a very real hazard when seedlings are pricked-out into pre-mixed soil.

Granular prescriptions are equally suitable for speedling tray seedlings but the high K content in the bark growing media make the 2 : 3 : 2 (22) mix more suitable. Because of the very small rooting volume of the 128 trays, applications should be made at 7 to 10 day intervals; 15 g per tray being evenly broadcast over the tray.

Granular fertilizers should be broadcast on to dry foliage and the fertilizer should be brushed off the foliage before irrigation is applied. Failure to do this has caused leaf rot in eucalypts particularly *E. fastigata* and *E. nitens*. The causal fungus was *Hainesia lythri* (Lundquist, 1985).

Large speedling tray nurseries apply the crop's nutrient requirements through the irrigation system and either make up their own solutions or purchase available commercial horticultural mixes such as "chemicult" or "tree liner" (Barret, 1983).

Organic additives such as peat or hop waste are not freely available in South Africa and are not used as a means of maintaining soil condition. Cover cropping is also unknown except occasionally to break in a new nursery. Slow release fertilizers have been tested at various times (Donald 1977; Faculty of Forestry, 1985) but are unable to supply adequate nutrition for the rapidly growing seedlings. They are not used in practice nor does there appear any justification for the appreciable additional cost involved.

4. Root Manipulation

The two most serious nursery root problems are J-rooting and strangulation roots. The first is caused by pricking-out seedlings whose roots are beyond the primary root stage (Donald, 1968); the second by failure to remove the polythene bag or sleeve at planting or removing it without cutting the incipient strangulation roots, which form immediately under the plastic (Donald, 1979).

Pricking-out of pines should be done in the cotyledon stage before any lateral roots appear. This makes it difficult, if not impossible, to bend the roots and thus removes the J-root phenomenon. J-roots can also occur in eucalypts but, unlike pines, secondary roots can form on the outside of the J, so instability is not such a problem.

Root development in the speedling tray is normally excellent. Roots may penetrate the styrene where trays have been used several times; it can be prevented by dipping the trays in a PVA + copper dip. Roots reaching the bottom of the trays grow into the air and dry out. This combination of aerial and chemical pruning gives rise to compact fibrous root systems which are easily removed from the cavities and which handle and plant without difficulty.

Root pruning is carried out on box and poly-pot plants and on bare-root seedlings, but for different reasons. In the containers, pruning is done to keep the root system within the soil volume which will be removed from the nursery. It is done throughout the crop's nursery life. Neglected root-pruning at this stage gives rise to uneven growth in the box as the plants tap a much greater soil volume than their neighbours.

Pruning in the bare-root system is normally only done when the plants have reached the required height for planting. The object is to create a dormant seedling. Root growth capacity, measured over 7 days in a controlled environment (Burdett, 1979), has been examined for all systems and, with the exception of the box system, has proved adequate. Verticle root pruning between the rows in two directions in the box has markedly improved RGC and made lifting and planting easier (Donald, 1982). RGC can be stimulated by a number of easily applied techniques e.g. a 1% sucrose root dip on lifting, but the relationship between RGC and survival and early growth on field planting has proved tenuous under South African conditions (Donald, 1982).

5. Weed control

Weeding has not given as many problems in the South African forest nurseries as is experienced in other major nursery orientated countries, e.g. USA, UK, New Zealand. The major reason for this has been the preponderance of container systems and the use of soil imported from forest and heath lands; soils with relatively low weed seed populations. The development of the speedling tray system which uses composted pine bark as a growing medium restricts weed problems to wind-distributed species such as the composites. With the introduction of bare-root system, weed problems became more pressing, however, as populations build up over time.

Virtually all weed control in S. African forest nurseries was done manually prior to the 70's. Even today most smaller nurserymen rely on manual control (Nursery questionnaire, 1984). Large bare-root nurseries introduced soil sterilisation with Basamid or Methyl bromide to overcome the problem (Cawse & Martyn, 1981). Although this is effective, it is too expensive to be used as a weed control system per se (Donald, 1985).

Although chemical weed control in bare-root nurseries has been in use for many years (van Dorser, 1973; Bacon, 1979) South African experience, apart from the limited use of White Spirits in the 60's (Donald, 1968) has not been encouraging. Work which started in the 80's, however, has produced useable results.

Today, Goal 24EC (oxyflourfen) used at 3 l ha^{-1} as a pre-emergent spray will give 2 to 2,5 months weed-free beds, without adversely effecting the pines (Donald and Kirby Smith, 1982). Subsequent control is achieved by re-applying Goal or using low rates of Velpar (200 g ha^{-1} hexazinone) at 8 to 12 week intervals. Costings undertaken in 1982 showed that the above recommendations were significantly cheaper than manual weeding or Basamid treatment before sowing. Table 3 taken from Donald & Kirby Smith, 1982, summarises these costs.

5. Lifting and Transport

Plants raised in boxes and poly-pots experience minimal exposure to the roots between nursery and planting as the containers are transported intact. Disturbance at planting, however, is appreciable. Box plants are removed by trowel, which can cut from 25 to 38% of the total dry weight of the root system (routine student practicals, unpublished data). Poly-pot/sleeves require two cuts approximately 10 mm deep on either side to remove incipient strangling roots. This can remove up to 50% of the root dry weight depending on how long the plant has remained in the nursery (Germishuizen, 1979). These quite appreciable root losses, surprisingly, have no apparent effect on the ability of the plants to survive and grow.

Speedling tray plants are removed from the trays in the nursery and transported, in similar containers to bare-root seedlings, as plug seedlings. The plug is compact, handles well and plants easily, but its volume is only 36 cm^3 so it has little moisture reserve. No roots are lost on lifting. Plants raised in speedling trays usually survive and grow better than poly-pot or box plants (Donald, 1985; Barret, 1981 and 1983).

Bare-root seedlings are lifted with care and minimum handling to prevent stripping the finer roots (Young, 1981; Denison, 1981). Some nurseries count the seedlings in the bed prior to lifting having first culled runts and badly formed seedlings, (Denison, 1981), but most do this operation during lifting when excessively long lateral roots are also pruned (Cawse & Martyn, 1981). Plants are mostly transported in wax coated cardboard containers when they are likely to be carried long distances.

Table 3.--Comparison of Weed Costs Per 100 m^2 Under Various Control Systems.

System	Chemical (R)	Application (R)	Hand weeding (labour units)	Unit cost (R)	Total (R/100 m^2)
1. Hand weeding**	-	-	6	7,50	45,000
2. Badamid (30 g/m^2) + handweeding**	14,55	2,45	1,6	7,50	29,000
3. White Spirits 64,5 L/100 m^2	37,56	1,13	0,2*	7,50	40,35
4. Goal 3 L/ha pre-emergent only	0,75	0,27	0,25*	7,50	4,22
+ three Velpar @ 0,2 kg/ha	0,51	0,81			
5. Goal 3 L/ha pre & post-emergent	1,50	0,54	0,25*	7,50	4,35
+ Velpar 0,2 kg/ha	0,17	0,27			

* Hand weeding required to remove weeds resistant to the herbicide.
** Data supplied by Sappi Forests (Pty) Ltd, Eastern Transvaal Division.

Table 4.--Common Pathogenic Fungi Causing Serious Problems in South African Forest Nurseries.

Botrytis cinera (Fr.) Pers
Cylindrocarpon destructans (Zins) Scholten
C. scoparium Morgan
Diploidea pinea Dismi Kikx
Fusarium equiseti (corda) Sacc
Fusarium oxysporum Schlecht
Phytophthora cinnamomi Rands
Phytophthora cryptogea Pethybridge & Lafferty
Phythium debaryanum Hesse
Phythium irregulare Buisman
Phythium ultimum Trow
Rhizoctonia solani Kuhn

Nurseries supplying locally more often put out the seedlings wrapped in wet hessian.

Lifting bare-root seedlings is done in the early morning when temperatures are low and plant turgor is high (Denison, 1981). Foliage should be dry at lifting, particularly if cold storage is contemplated. RGC of pines stored with wet foliage is significantly poorer than those with dry foliage (Donald, 1982).

6. Protection against fungal attack

Pathogenic fungi found in forest nurseries in the north of the country have been surveyed by Darvas (1976) and in the south by Botha (1981). Table 4 summarises the more important pathogenic fungi associated with forest nurseries in the Republic.

A variety of remedies have been used on damping-off and root-rot problems over the years e.g. powdered charcoal, Bordeaux mix, Cheshunt mix; and numerous proprietary fungicides. Sometimes they work, but as often they do not. The emphasis today is placed on prevention rather than cure. This involves the use of a disease-free site and growing medium, water free from pathogens and strict sanitation to prevent reinfection (von Broembsen, 1981). Soil can be sterilized with methyl bromide, Bazamid or Vapam. All three work but Basamid is the cheapest and easiest to apply (Donald & von Broembsen, 1977). Water from rivers, lakes and dams in S. Africa is known to contain spores of Phytophthora, Phythium and other fungi (von Broembsen, 1981). Only bore hole water can be accepted as uncontaminated. Water from contaminated sources can be cleaned effectively by passing it through a 5 um filter or by treating it chemically with copper or chlorine (von Broembsen, 1981). Effective sanitation is inexpensive to apply but requires good planning and strict adherence to the rules. Its object is to prevent re-infection so the movement of any infected soil or plant material into the nursery or within the nursery must be stopped. Copper treated foot baths or mats and dips for tractors and lorries are necessary to prevent fungal entry while treated and contaminated soil containers must be strictly segregated until re-sterilized or destroyed. Infected plants should be isolated and burnt. Good drainage within the nursery and the prevention of run-off water entering the site from up slope is essential if fungal free plants are to be produced.

When fungal infection occurs in the modern speedling tray nursery fungicides are applied through the irrigation water. The two most commonly used fungicides are Benlate and Captan, either alternately or mixed. The same fungicides can be used with other systems as together they give a wide spectrum of fungal control. Prevention, however, is still better than cure.

Nursery Efficiency

Two basic concepts govern the philosophy behind nursery practice in Southern Africa:

1. The nurseryman cannot lastingly improve the growth of his plants on a given site beyond that which the site is capable of producing. He can, however, reduce this maximum growth.

2. That plant quality significantly affects survival and early growth, but provided the plant survives, does not stagnate and is not suppressed by adjoining plants it will yield the maximum growth that that species site combination can produce (Donald, 1976b).

The nurserymen must therefore produce plants which will survive wherever they are planted; he must produce them in the numbers required, when they are required and he must do it as economically as possible.

Comparisons of nursery efficiency between nurseries of different size and using different systems are difficult to make. Survival and initial growth of the plants produced can be measured if the trouble is taken to organise such an exercise. Costs per 1,000 seedlings would appear ideal, but cost data are seldom freely available and are strongly influenced by nursery size. The plant percent, that is the number of useable seedlings produced expressed as percentage of the number of viable seed sown, has also been used, but the number of viable seed in the seed lot is not always available and some growers particularly speedling tray growers, frequently sow two or three seeds per cavity to prevent empty cavities. Full stocking being a more important criterion for them, than the plant percent.

Some work to compare nursery efficiency has been attempted in South Africa. Costs per 1,000 plants raised were compared for 19 Forest Department nurseries by Perry in 1980. The information collected allowed the costs to be subdivided into operations, but excluded all overheads. Table 5 shows the range of costs recorded.

Perry also calculated the effect of nursery size on the economy of scale on the costs per 1,000 seedlings. This is clearly illustrated for the different systems in Figure 2. For container systems and the manually operated bare-root system the cost savings beyond a million seedlings are limited. The mechanised bare-root system continues to score as numbers increase within the range of nursery size covered.

It is necessary to convert the data to percentages, however, if it is to be of value to the individual nurseryman (Table 5). By expressing his own figures as a percentage of his total cost the nurseryman can determine how he compares with other nurseries. Where a particular percent greatly exceeds the expected value, some attempt to explain and hopefully improve the situation would be called for.

Cost differences within systems for nurseries raising approximately the same number of plants are appreciable and should give managers considerable food for thought. Witfontein should be able to make considerable savings under weed control and soil transportation for example.

A study to physically compare plants raised from the same seed lot by different nurseries using different systems was organized by the author in 1981 and 1982 (Donald, 1984). _Pinus elliottii_ was chosen for the exercise as it is the only pine planted in all regions of the South African plantation belt. Although 12 nurseries agreed to participate, only six eventually completed the task. Stock No. 28447 was procured from Seed Store, Pretoria and subjected to routine seed testing to determine the number of viable seed per kilogram.

Table 5: Cost of Raising Nursery Seedlings as a Percentage of the Total Cost per 1000

As percentage of Total Cost per 1000

Nursery	Container /bed	Soil	Seed Sowing Prick-out	Weeding	Insecticides Fungicides	Pruning	Watering	Maintenance of fertility	Capital costs	Total Cost /1000 R - c	Capacity x 10^3	System
1. Dargle	51,97	10,81	14,09	2,45	0,64	1,03	8,96	0,68	9,36	R28-11	800	
2. Grabouw	35,33	10,08	22,81	7,80	2,75	1,24	4,90	8,02	7,06	R40-43	560	
3. Hogsback	44,60	6,44	22,59	5,73	-	0,51	15,76	1,29	2,88	R42-76	400	
4. Isidinge	38.72	20,01	21,86	0,63	-	2,37	13,41	-	3,45	R53-93	150	
5. Nelshoogte	46,00	11,68	23,63	3,38	0,09	5,46	0,88	0,67	8,20	R32-80	1000	
6. Kluitjieskraal	37,22	10,40	8,60	15,59	0,11	1,12	9,37	8,68	8,90	R36-62	1225	Box
7. Weza	42,92	13,29	25,37	3,86	0,43	0,37	5,50	0,37	7,88	R32-36	850	
8. Witklip	39,64	17,53	31,48	1,15	-	1,74	4,82	0,37	3,28	R46-09	300	
9. Witfontein	40,70	23,42	16,28	11,35	0,14	-	0,26	1,08	6,77	R49-07	750	
10.Witwater	41,05	15,09	9,12	-	-	1,17	19,65	3,94	9,99	R40-15	120	
11.Woodbush	35,18	17,98	10,33	13,95	-	2,49	13,95	0,62	5,51	R51-90	150	
12.Dukuduku	19,90	13,15	39,59	1,72	0,14	13,94	-	0,75	10,81	R27-84	2200	Polypot
13.Entabeni	12,04	16,57	24,88	38,18	-	0,86	4,10	-	3,38	R55-90	337	
14.Tweefontein	16,53	14,49	23,92	1,62	-	7,10	8,64	16,53	11,16	R35-20	1300	
15.DR de Wet	26,14	30,74	27,58	-	-	-	-	0,79	14,75	R30-38	1000	Speedling tray
16.Grabouw	4,86	-	34,34	16,46	3,10	10,19	6,75	5,40	18,89	R14-82	400	open-rooted manual pruning
17.Lottering	2,78	-	27,40	47,14	-	8,13	10,16	0,37	4,02	R15-37	1500	manual "
18.Tweefontein	3,59	-	11,61	12,85	0,98	15,98	9,13	9,39	36,46	R15-33	400	manual "
19.Dukuduku	2,67	-	22,25	19,84	0,46	4,68	7,35	-	43,20	R18-09	3000	mechanical"

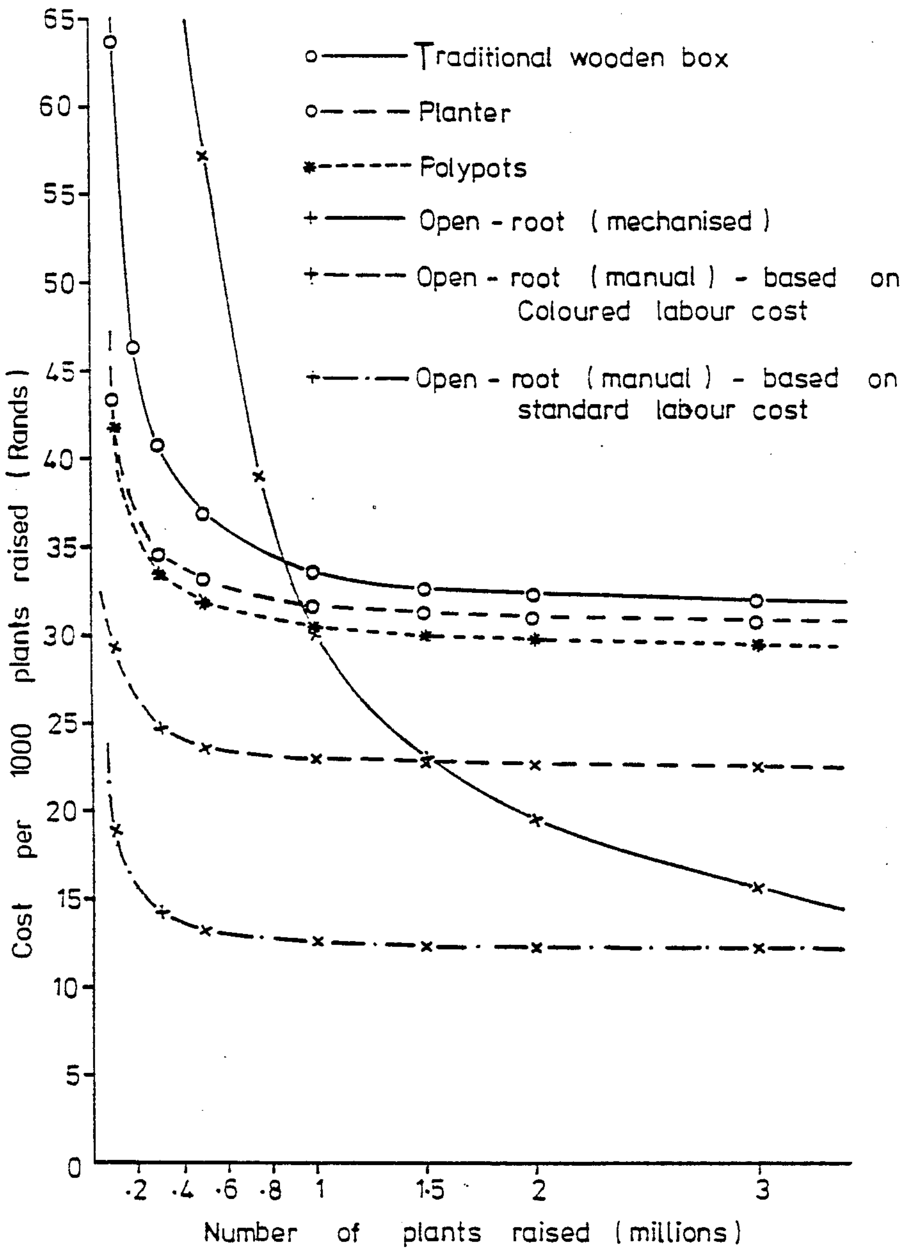

FIG 2 THE EFFECT OF SCALE OF OPERATIONS ON THE COMPARATIVE COSTS PER 1000 PLANTS UNDER VARIOUS NURSERY CONDITIONS

Table 6.--Nurseries Participating in the Efficiency Study.

Nursery number	Region	System	Seed treatment Stratification (days)	Seed treatment Sowing	Nursery period (months)	Transport system to Tweedie	Plant %
1	S. Cape	Box	29	Direct	6	Plane	70,1
4	E. Cape	Box	21	Dense	6	Plane	28,1
7	E. Tvl	Bed	28	Direct (machine)	5	Train	67,9
8	SW Cape	Bed	30	Direct (manual)	6	Plane	26,7
9	S. Cape	Bed	0	Direct	6	Plane	66,9
10	E. Tvl	Speedling	49	Direct (prick out blanks)	4	Train	79,8

Table 7: Plant parameters of *Pinus elloittii*, stock No. 28 447

Nursery	Collar diam. (c)		Shoot length (S_1)		Root dry weight (R)		Shoot dry weight (S_2)		Total dry weight		Mycorrhizal infection		Mean root count plant[1]			Ratios	
No.	X (cm)	C.of V (%)	$\bar{X}$ (cm)	C.of V (%)	X (g)	C. of V (%)	$\bar{X}$ (g)	C. of V (%)	X (g)	C. of V (%)	%	C. of V (%)	Pts	<1cm	>1cm	$\frac{S_1}{C}$	$\frac{R}{S_2}$
1	0,36	23	23,3	27	0,27	57	2,54	49	2,81	49	12,8	51	1,5	1,0	0,0	64,7	0,11
4	0,23	36	13,1	26	0,17	66	0,71	65	0,82	65	25,8	85	3,6	0,2	0,0	57,0	0,15
7	0,28	15	17,2	29	0,20	37	0,85	31	1,06	29	18,6	34	5,4	9,2	0,0	62,3	0,24
8	0,58	23	21,5	17	0,75	48	4,58	50	5,33	49	31,4	28	2,6	15,2	1,8	37,2	0,16
9	0,33	18	13,0	20	0,28	42	1,35	35	1,63	35	23,2	33	1,9	5,9	0,1	39,5	0,21
10	0,23	11	13,2	13	0,16	20	0,42	14	0,58	12	24,6	75	2,0	1,5	0,0	57,5	0,37

Table 8.--Mean Survival, Height and DBH of *Pinus elliottii* Aged 33 Months.

Nursery	Type	Survival at 3	5	33 months	Height at 33 months (m)	DBH (cm) at 33 months (cm)
1	Box	100,0	100,0	98,0	2,43	3,8
4	Box	97,0	88,0	78,0	2,07	2,8
7	Bare-root	98,0	96,0	90,0	2,55	3,5
8	Bare-root	92,0	92,0	90,0	2,43	3,5
9	Bare-root	97,0	97,0	94,0	2,47	3,1
10	Seedling	98,0	97,0	94,0	2,46	3,6

Seed was dispatched to the participating nurseries in 0,5 to 1 kg lots in August, 1981, with instructions to prepare plants for March 1982 planting. Between March 22 and 26, 1982, 150 randomly selected plants were dispatched from each nursery; 100 to the trial planting site at Tweedie in Natal and a further 50 plants to the Faculty of Forestry at Stellenbosch for laboratory analyses. Plants were sent by road, rail or air depending upon the distance to be covered.

Plant percent was acceptable (>66%) for all but two nurseries whose management should examine their techniques. Nursery 4 for example lost 45% of its viable seed in the sowing operation and a further 27% after pricking out. Nursery 8 on the other hand experienced all 73,3% of its losses during germination.

Survival was enumerated at 3, 5 and 13 months but as the plants were heavily browsed during their first year height was not enumerated (Donald, 1984). A final enumeration was conducted at 33 months when survival, height, and diameter at 1,3 m (DBH) were recorded for this paper.

Table 8 summarises this data. The 33 months survival is not given as it did not differ from that at 33 months.

Nursery 4 had a significantly poorer survival than the other nurseries at 33 months, no other differences were significant. Although it has the smallest trees, the mean height and DBH of nursery 4 did not differ significantly from those of the other nurseries.

Table 7 shows how varied the nursery stock was, yet, apart from the survival of nursery 4 plants, differences were minimal.

Nursery 4 plants were everything that the nurseryman tries to avoid: thin, small plants with poor foliage development, minimal roots with no root growth capacity, a very low R/s ratio and a high S/c ratio. There is no doubt, however, that they will yield an acceptable final crop with only a small reduction in the first thinning yields to indicate any differences in the plants.

This exercise was designed to compare nursery efficiency and to shed light on the effects of plant quality; in fact it further demonstrates how difficult it is to quantify plant quality meaningfully, on a reasonably easy site for afforestation which has been well prepared. It did pin point management shortcomings in some of the participating nurseries but they should have seen these for themselves.

The Future

When the forest nursery scene was surveyed in the 60's temporary nurseries and local permanent nurseries were the major source of plants. Today temporary nurseries are unknown, and local permanent nurseries are in decline. The central permanent nursery is here and will continue to dominate the scene for foreseeable future; boxes and poly-pots are unlikely to last into the 90's. Bare-root and speedling tray systems which were virtually unknown in the 60's will dominate the nursery scene to the end of the century. Nursery numbers will continue to decrease but nursery size will increase.

Techniques such as precision sowing and fluid drilling which sow pre-germinated, fully primed or even pre-germinated seed will remove the need for double sowing. Bark composts will replace soil in all but bare-root systems. Fertilizer prescriptions which are already based on the seedling count will continue in this trend. Strict hygiene will remove a great deal of the pathogen problems we currently experience, while the whole concept of mycorrhizal inoculation, which is just appearing today with spores, will be commonplace, with vegetative inoculum tailored for specific conditions.

Nurseries will be fully computerised. Most of the larger speedling tray nurseries are already computerised for irrigation and nutrition but they must still be drawn into the whole aspect of nursery management, including growth modelling and nutrition supply based on the expected growth rate. Destructive sampling to obtain reliable growth models for pines and gums has only just started (Donald and Young, 1983). As they appear to be unique for each region, if not each nursery, much more data will be required to complete the picture. With reliable growth models and micro processors at their finger tips nurserymen will be able to create any plant scenario they require.

With eucalypts clonal production from cuttings which has already appeared (van Wyk, 1984) will increase greatly by the end of the century. Pines may take longer but, even here, clonal production from selected clones for insect and/or fungal resistance is likely to increase substantially.

Nursery practice has been the Cinderella of the forest industry virtually since its inception, hopefully those days are gone for ever.

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