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NURSERY TECHNIQUES FOR TROPICAL AND SUBTROPICAL PINES

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CONTENTS

1. INTRODUCTION

The Danida Forest Seed Centre has initiated a series of seed leaflets on species of importance for afforestation in the tropics and subtropics. Each leaflet will contain a section on nursery techniques. In the case of tropical and sub-tropical pines, however, the same techniques have often proved suitable for a number of pine species, and variations in nursery technique are more often adapted to differences in local environmental conditions than to differences between species. For this reason, the present technical note seeks to summarize nursery techniques which are applicable to a wide range of tropical and subtropical pines; this allows the nursery section in the individual pine seed leaflets to be shortened to cover only nursery characteristics peculiar to that species. This note will be distributed together with each pine seed leaflet, to eliminate any risk of information on nursery techniques becoming separated from information on seed characteristics.

This note is based largely on the paper "Tecnicas de vivero para la producción de coniferas en los tropicos" (Nursery techniques for the production of conifer seedlings within the tropics), prepared by I. A. Napier for the second IUFRO working group (S1.07.09) symposium: forest plantations in the tropics: their role as a source of energy (44). Other important references are 22, 36, 49 and 61 for *Pinus caribaea*, 13, 22 and 30 for *P. oocarpa*, 4, 13 and 29 for *P. kesiya*, 66 for *P. patula*, 10, 11, 11a, 16, 59 and 62 for tropical and sub-tropical pines in general and 23 and 53 for basic tropical nursery practice.

The most important species of tropical and sub-tropical pines for afforestation are *Pinus caribaea* (all 3 varieties, but mainly var. *hondurensis*), *P. oocarpa, P. kesiya, P. merkusii, P. patula, P. elliottii* and *P. taeda*.

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Numbers in brackets refer to reference numbers, cf. p.18

2. NURSERY SYSTEMS

Nursery systems for pines include (l) Systems designed to raise plants for "bare-root" planting - without soil attached to their roots (2) Systems designed to raise plants for "ball-root" planting, in which each plant is planted complete with the cylinder or block of soil in which they have been grown in the nursery.

There are several variants of these systems. In both systems it is possible either to sow seed at a high density in a seedbed or germinating medium and subsequently transplant the germinated seedlings to their containers or transplant beds, or to sow the seed directly into its final position in the nursery and thus avoid the operation of transplanting.

Among systems for production of bare-root plants, the main distinction is between those which use intensive methods of conditioning the plants in readiness for planting by means of root pruning, and those which include little or no root-pruning. Among systems for production of ball-root plants, the main distinction is between individual containers, in which the soil of each container is separated from that of its neighbour by the container wall, and multiple containers (beds, trays, boxes), in which the soil is continuous and intermingling of plant roots can only be restricted by periodic root pruning.

Bare-root planting with minimal root pruning is used with success in cool temperate conditions, where planting can be done in a season when plants are dormant and evapotranspiration low. When tried in the tropics, it has almost invariably produced disastrous results, especially in the drier areas where evapotranspiration is high and breaks in the rainy season are common but unpredictable. Container plants have therefore been standard practice for pines in the tropics for some decades and, since the advent of cheap polythene in the nineteen fifties, the individual container has largely displaced the multiple container.

More recently, bare-root planting of pines conditioned by regular root pruning has been successfully carried out in several tropical areas in Queensland and Latin America. It is significantly cheaper than container planting but requires meticulous care and skilled personnel. It should only be adopted in new areas after careful small-scale testing.

Because of its proven reliability over a wide range of conditions and local skills, the individual container system receives most emphasis in this note.

3. SEED, SEEDBEDS AND SOWING

Time of sowing

The storage of pine seed is not a problem, therefore sowing dates in the nursery can be determined by the length of the nursery period, and the timing of the planting season.

Seed pretreatment

The low altitude tropical pines have no dormancy and germinate readily, so no pretreatment is needed. The speed and uniformity of germination of *P. patula* and *P. taeda* can be improved by pretreatment, e.g. in *P. taeda* from 44% (control) to 58% (24 hours soaking in water) to 81% (24 hours soak followed by 21 days naked stratification in polythene bags at 3-4°C) in 14 days (10). Soaking in 0.5% hydrogen peroxide, polyethylene glycol, or kelpak (a seaweed concentrate) was also effective in speeding up germination in *P. patula* (16, 20), but results probably do not justify the cost of the chemicals. In all cases final germination of the control after 28 days differed little from the treated seed; therefore, if germination spread over several weeks is acceptable, it is possible to dispense with pretreatment even for these species.

Floating

Placing seeds in water to separate the sinkers (mostly sound, full seeds) from the floaters (mostly empty seeds) has proved effective with *P. patula* (66). Its main use is to improve the efficiency of direct sowing into containers and, in the case of *P. patula*, it can be combined with a pretreatment to hasten germination, as described above. Floating is not equally applicable to all species, in *P. kesiya* it was found that 70% of floaters were viable and a good proportion of sinkers were empty (65).

Sowing in seedbeds or germination trays

The advantage of sowing seed at high density in a special section of the nursery is that it is easier to concentrate protective measures, during the critical germination period, over a small area than to spread them over the entire nursery. These measures may include shade and mulching, netting against birds and rodents, and fungicidal or insecticidal treatment. Equally important is the more precise control of quantity, frequency and droplet size of watering which is possible on a restricted area. The method is economic in seed (only one germinated seedling need be pricked out per container) but is more expensive than direct sowing, because of the additional operation of pricking out.

Seed is commonly sown broadcast into beds or small germination trays filled with coarse sand which may be previously sterilised if required. In Honduras sufficient pine seed is sown to produce approximately 4000 transplants per m^2, and covered with a thin layer of sand. The trays are elevated, protected against rodents, and shaded. Transplanting takes place 2 to 3 days after germination (44). Lower sowing rates (2000-3000 per m^2) may be advisable if damping off is a problem or if transplanting is done later, e.g. in Ivory Coast a sowing rate of $2800/m^2$ was recommended for transplanting 3 weeks after germination (28). Mixing seeds of the smaller-seeded pines with twice their volume of sand can improve the evenness of broadcast sowing (66). After sowing, the seeds should be covered with a shallow layer of sand. Depth of sowing varies with the size of the seed. In general sowing depth should be equal to 1 to 2 times the diameter of the seed. Deep sowing delays and reduces germination, and may increase the likelihood of damping off. Insufficient sowing depth, on the other hand, creates a serious risk of drying out and removal by birds, rodents, ants or other insects. A depth of 5-10 mm is suitable for most species of tropical pine (26, 32, 44).

The endosperm and cotyledons contain sufficient nutrient reserves to support the newly germinated seedling for several weeks, hence there is no need for fertilizers or organic matter in the germination medium. They should rather be excluded because they increase the risk of damping off.

A coarse, “sharp” washed sand or grit makes an excellent medium because on drying it does not form a surface crust which would form a physical obstacle to germination (49, 66). It is important that the surface be exactly level and the seed covering firmed, so that there is no possibility of surface wash during watering.

Shade is commonly used over the germination area. It may be removed or reduced after germination starts, or retained until after transplanting, according to local climatic conditions. Surface mulches e.g. of pine needles are sometimes used, to reduce evaporation in hot areas and to retain warmth in cold areas; they are removed when germination starts. Watering is best done by knapsack sprayer which produces a fine mist and avoids disturbance to the seed during germination. Sufficient water is applied to keep the soil constantly moist, but overwatering can increase losses from damping off fungi and must be avoided. Good results have been obtained by use of polythene sheeting over the germination beds to retain moisture (32, 49). After the initial watering at the time of sowing, it is possible to reduce the frequency of subsequent watering or to dispense with it altogether until germination starts. Shade is essential with polythene sheeting, to avoid overheating.

Damping off can be a serious threat to seedbeds in some areas. Cultural measures which reduce the risk include (l) Use of a sterile or near sterile germinating medium (2) Use of an acid germinating medium (alkaline soils favour damping off) (3) Sowing at low density and not too deep (4) Avoidance of overwatering (5) Frequent changing of the germinating medium (66). Use of fungicides is sometimes effective. Seed pelleting with Rhizoctol and a methyl cellulose sticker gave good results in coastal nurseries in Tanzania (31). Proprietary fungicides, applied as a drench both before and after sowing, include Perenox (2 g per litre per

2 m^2), Thiram (25 g/m^2) and Daconil (1.5 g per litre per m^2), Captan, Zineb, Cuman and Blitox (8, 49, 66). Perenox gives good results on alkaline soils with pH 6 or more but may become toxic to seedlings on more acid soils (48).

Transplanting or "pricking out"

The timing of transplanting of pines into containers or transplant beds may vary from 2 to 3 days to 30 to 40 days after germination. Obviously sowing density must be adjusted in accordance with the time of transplanting. Best results in many countries are obtained by transplanting the seedlings 2 to 3 days after germination when they have the size and form of a matchstick, with the seedcoat still attached (29, 44, 49). They should be lifted from the trays by the seedcoat and placed in a dish of water. Fifty seedlings are placed in each dish and transplanting is done immediately. It may be necessary to shade the beds for a short period after transplanting depending on local climatic conditions. If birds cause damage in the transplant beds by peeking the seedcoats to eat the endosperm, it is advisable to postpone transplanting until the seedcoat has fallen off. The seedlings should then be lifted by the cotyledons. They should never be handled by the stem, which is easily bruised and then becomes more susceptible to attack by damping off fungi. If transplanting is delayed for several weeks and root length is over 3-4 cm, it is necessary to sever the last one third with a sharp knife. This prevents the formation of a distorted J root and stimulates lateral root branching (38, 44). A small stick or dibbler should be used to make a hole about 5 cm deep in the container or transplant bed and to firm the soil round the root after its insertion. A practical way of ensuring uniform planting depth is to mark the stick, for example with a rubber band.

Other germinating media; "pregermination"

As alternatives to the traditional seedbed or tray, several other methods have been used successfully to "pregerminate" seeds. They can be used in an office or seed store, where conditions can be controlled even more closely than in the nursery. Moist vermiculite has been used in East Africa and Malaysia (40, 63). Seed is mixed with 2-5 times its volume of moist (but not too wet) coarse grade 3/16 inch (5 mm) vermiculite and stored in polythene bags at room temperature. When germination starts, seeds are inspected daily and any seeds with radicles emerging are sown out and covered in the usual way. Seedling emergence then occurs in 3-4 days. For *P. kesiya* it was found that damping off losses were much less among pregerminated seedlings than among seedlings raised from sowings in a normal seed bed (40).

In Sabah (Malaysia) and Surinam seeds are sown on the top of a layer of washed quartz sand in a tray or box which can be covered by a plastic lid or sheet (45, 61). Fungicide is applied and the medium is thoroughly moistened at sowing, but no further irrigation should be needed until germination starts. A sowing rate of 0.25 to 0.5 kg per m^2 is used. Germinated seedlings are transplanted into containers when radicles are 1-2 cm long.

Moist blotting paper is used as the germinating medium in Thailand and Vietnam (29, 55). A rectangular sheet of blotting paper of about 24 x 60 cm is folded from one end to make 9 furrows each 2 cm deep. 30-50 seeds are sown in each of 8 furrows, the central furrow holds a cotton wick 3 mm in diameter. The furrows are folded together and the remaining 20 cm of unfolded paper is wrapped around them to form a pack, secured at each end with rubber bands. The packs are placed on glass shelves over trays filled with water, in which the wicks are immersed. Details of seed lot, sowing date etc. are written on each pack with waterproof pencil. Captan is dissolved in the water as an inhibitor to fungus growth on the wicks which may otherwise cause blockage of water transport as the wicks become encased in mould. When germination starts packs can be inspected daily and germinated seedlings are transplanted into containers when radicles are 1.5 to 2 cm long.

Direct sowing into containers

This practice has tended to replace the use of the traditional seedbed in recent years. It avoids the expense of transplanting and the risk of casualties or damage associated with careless transplanting - mechanical damage, damping off, distorted roots, drought losses. However it is more wasteful of seed and it spreads the application of any protective measures necessary during the germination period throughout the nursery. The more fertile soil mixture in the containers may itself also constitute a greater damping off risk than the pure sand of the seedbed.

With direct sowing, 2 or more seeds are usually sown per container. After germination, containers that have no seedlings are restocked by transplanting from those that have 2 (or more) seedlings. The lifting from the pot soil, however, contains the same above mentioned risks associated with trans-planting. If necessary, extra transplants are produced separately in germination trays or seedbeds. Surplus seedlings in the containers are uprooted or cut off at soil level with a scalpel.

The precise number of seeds to sow depends on the expected germination of the seedlot. A rule of thumb proposed for *Pinus caribaea* (52) is:

1) 85%+ germination : 1 seed in each container
2) 65-84% germination: 1 seed in 50%, 2 seeds in 50% containers
3) 50-64% germination : 2 seeds in each container
4) 30-49% germination : 2 seeds in 50%, 3 seeds in 50% containers.

The seed should be placed in shallow depressions (5-10 mm deep) in the centre of the container and covered with the soil mix or a layer of coarse sand. Shade is not normally required for the germination and early growth of directly sown pines except in extremely hot locations. However, a mulch of fresh pine needles has been found beneficial in Honduras. This conserves moisture and protects the seed from the effects of the sprinkler irrigation systems. The mulch is removed 10 to 13 days after sowing during the period of maximum germination (44). Considerable care must be shown however, to ensure that diseases (e.g. Brown Needle Disease) are not brought in with the pine needles.

Direct sowing in beds for production of bare-rooted plants

Sowings are made in drills in order to allow use of tools for root pruning. 15 cm between drills is a convenient spacing. Sowing density depends on expected germination and survival of plants. A minimum final spacing in the rows of 2.5 to 4.5 cm is recommended, equivalent to 150 to 250 plants per m^2 (15, 44, 54). A pine needle mulch on the seedbed should assist germination. Shade may also be necessary after germination in extremely hot locations but must be removed as early as possible. Seedlings must be thinned to their final spacing 40 to 60 days after sowing.

4. MANAGEMENT OF CONTAINER PLANTS

Types of container

Multiple containers for production of ball-rooted plants include wooden boxes, trays and half petrol tins. Individual containers can be made from locally available materials such as banana leaves, bamboo, veneer offcuts, paper, peat, asphalt roofing paper, beer cans, milk packs, clay pots, blocks of compressed earth or moulded clay, or coconut husk fibres. Individual containers of some materials are aggregated in honeycomb units, e.g. paper pots, “Styroblock” and “Root trainer”. These rigid containers usually have grooves running along their length, and drainage holes at the base. The roots which are guided by the grooves grow vertically down and out of the drainage hole at the bottom, rather than coiling around the container. In the past they have proved too expensive in foreign exchange and have been considered to hold too small a volume of soil to be used for large-scale tropical afforestation. Because of its cheapness and wide availability, polythene is the most common container material for tropical pines.

Polythene containers may be cylindrical and open at both ends - “tubes” or “sleeves”; or they may be gusseted and sealed at one end - “pots” or “bags”. Pots should have about 20 holes (diameter about 6 mm) punched in the lower third to ensure free drainage and root egress. Tubes are more time consuming to fill, but are less liable to cause root distortion and are therefore preferable provided the soil mixture used is reasonably cohesive. Black polythene of about 38 microns (150 gauge or 1.5 mils) is most commonly used, being preferred to transparent polythene because it prevents the growth of algae and is more durable.

Size of polythene containers

Practice in regard to the size of polythene containers has varied greatly, even within the same country over a period of time. Some examples are shown in Table 1.

Bulk density of moist soil is commonly well over 1, therefore the weight of soil to be transported in container planting is considerable. A 1000 ha annual planting area using containers of 500 cm^3 and a spacing of 3 x 3 m would involve a soil weight of at least 550 metric tons to be transported from the nursery to the planting site; because of losses in handling and sieving, a considerably greater weight would need to be transported from collection site to nursery. Research has aimed at the reduction of container size from the large sizes used in early years to the smallest size which will produce plants with a satisfactory survival and growth rate in the field. Although height growth of nursery transplants is not greatly affected by moderate reductions in container size (for the same volume, container length has apparently a greater effect than container diameter (4, 29)), there is some evidence that root collar diameter and both shoot and root mass are affected more than height (32). Recently the recognition of the risk of delayed ill effects from root coiling induced by polythene containers has tended to reverse the previous trend towards smaller and smaller containers. Sizes within the range of 200-400 cm^3 are now most favoured, but commonsense variations are: (l) Bigger containers are needed for arid conditions (2) The bigger the plant size at planting, the bigger the container needed, e.g. the small container used in Fiji is designed to raise small plants 15 cm tall, the large one used in Indonesia aims at large plants 60-70 cm tall (23). If weed growth is likely to be a problem, large plants are preferred, but with intensive site preparation and weeding smaller plants are acceptable. (3) Smaller containers can be used with a fertile than with an infertile potting mixture. (4) The smaller the container the more essential it is to take precautions against root coiling (see below).

Table 1. Sizes of polythene containers

Country	Dimensions				References
	Lay flat (cm)	Diameter (cm)	Length (cm)	Volume*) (cm^3)	
Malaysia ("large")	12.0	7.5	17.5	820	(49)
" ("small")	7.9	5.0	15.0	310	(49)
Nigeria (standard in 1960s in savanna)	12.5	8.0	25.0	1240	(34)
Zambia ("standard") in 1960s] Nigeria (savanna conditions)	12.5	8.0	15.0	750	(34,59)
Zambia (minipot since about 1970)	7.5	4.8	10.0	180	(13)
Colombia	3.9	2.5	10.0	50	(35)
Colombia	9.4	6.0	15.0	420	(14)
Ivory Coast	15.7	10.0	20.0	1570	(28)
Indonesia	11.8	7.5	20.0	880	(23)
Tanzania, Swaziland,] South Africa (Natal)	10.0	6.4	10.0	320	(11,23,56)
Honduras	7.9	5.0	12.5	250	(44)
Thai	7.9	5.0	11.5	230	(29)
Vietnam	7.1	4.5	10.0	160	(55)
Fiji	3.8	2.4	15.2	70	(23)

*) Rounded to nearest 10 ccs. Maximum volume assuming containers are filled to the brim. Effective volume is normally reduced by 5-10% because soil surface remains 1/2-1 cm below the rim of the container.

Growing medium

Due to high transport costs and in some cases high cost of procurement, forest nursery growing media are usually dictated by the local availability of suitable material. Thus soil based growing media are the most common. The medium should be well drained, but contain sufficient organic material and/or clay to retain moisture and nutrients and to have the cohesion necessary to form a root ball which does not disintegrate when the container is removed. In some areas the soil mixture contains a number of different components e.g. the “Muguga mixture” used in Kenya has 5 parts forest topsoil, 2 parts local peat, 1 part clay, 1 part rotted horse manure and 1 part 6 mm crushed stone (38). Less elaborate mixtures consisting exclusively or mainly of local topsoil are in common use. The optimum texture is light sandy loam and the most common modification required is to add sand to any topsoil which has a high clay content. A maximum clay/silt content of 40% is prescribed in Honduras (44), while Malaysia and Zambia aim at not more than 20% (49, 59). A mineral soil/sand mixture is heavy. The inclusion of organic material in the medium reduces its weight and can improve growth. However, it may also encourage the development of fungal pathogens so care is required in its use. Peat, sphagnum moss, bagasse, vermiculite, coconut husk fibre and sawdust have been used to lighten soils (3, 11, 37, 44). Fresh organic matter in the soil may cause temporary yellowing and growth check in the nursery because soil organisms use nitrogen during the breakdown of the organic matter, rendering it unavailable to the young pines. This problem can be overcome by storing the soil mixture moist under a covering of grass for several months before use, to allow time for the organisms to break down the humic matter (21, 51).

When soil and sand are used, they must first be sieved. A sieve of 2-3 cm mesh is sufficient to remove stones and roots without losing the crumb structure of the soil. The mixture must be homogeneous to promote uniform growth; mixing may be done by hand but the use of a concrete mixer will improve the homogeneity of the mixture.

The nutrient status of the medium is not as important as its texture because the former is easily modified by fertilization (see following section). Acidity, however, is important. Most pines perform best in the nursery at pH 5.0-5.5, although older trees will grow excellently on soils of even higher pH after establishment in plantation. Nursery problems are compounded if alkaline soil is associated with alkaline irrigation water. Soil pH in the nursery may be reduced by either importing acid soil from another area or by artificial acidification through the mixing of aluminium sulphate or flowers of sulphur with the soil and moist storage of the mixture for 3 months before use. In Tanzania dosages of about 2 g per litre of soil of flowers of sulphur and 15 g/l of aluminium sulphate were effective in reducing soil pH from nearly 8 to less than 6, while pH of water was reduced from pH 8 to pH 5 by dissolving 25 g of aluminium sulphate per 100 litres of water (47, 64).

When introducing pines to areas in which they are not native, it is necessary to ensure that their roots have mycorrhizal associations. Inoculation of the seedlings with the mycorrhizal fungi, whilst they are still in the nursery, is the most practical approach. A small amount of topsoil from established plantations, mixed with the growing medium, is often the simplest method of guaranteeing inoculation. Where this is not possible the seed or soil may be mixed with spores of the fungi.

The containers should be placed directly on the nursery soil surface in beds 1.2 m wide, supported round the edges by boards, string or wire. Alternatively, they can be placed in elevated frames with a mesh base to facilitate air root pruning. In hot areas black polythene in the edge containers may overheat unless protected from direct insolation by edge boards or heaped up soil.

Fertilisation in containers

The application of fertilisers is necessary in almost all tropical conifer nurseries in order to produce healthy vigorous planting stock. Nitrogen, phosphorus and potassium are the most commonly applied nutrients. Considerable variation exists with respect to the amount of the nutrients that are applied in different nurseries. Table 2 gives an indication of this variation for the production of pines in different parts of the world.

Table 2. Quantities of elemental NPK applied in pine nurseries

Species	Country	Total quantity of element applied per seedling (mg)			Source	Remarks
		N	P	K		
P. caribaea	Malaysia	131	435 *) +57	43	(49)	for 5 cm
P. caribaea	Surinam	84	37	69	(61)	lay flat
P. caribaea	Nigeria	0	152 *)	0	(34)	pots
P. caribaea/oocarpa	Honduras	13	40 *)	0	(44)	
P. kesiya	Thailand	84	37	99	(29)	
P. patula	East Africa	48 *)	42 *)	32 *)	(39)	
P. patula	Malawi	35	70	110	(25)	
P. radiata	South Africa	50	70	90	(18)	

*) Added to potting mixture before pricking out. Other applications are in liquid form as top dressing after pricking out.

In most tropical soils phosphorus is the most deficient element and addition of P fertiliser is usually essential. There may be an important positive interaction between N and P and between P and K (2). Fertilisers may be added to the potting mixture before sowing/transplanting, but current opinion in many countries favours application in liquid form as a top dressing after the young seedlings are established. Application of nitrogen before or immediately after germination can lead to losses from damping-off fungi. Such applications should be delayed until the seedlings are 6 weeks old (59). It is common practice to repeat application at monthly or fortnightly intervals. As an example, in Surinam the first application of NPK 14-14-14 fertiliser was made 2 1/2 - 3 months after pricking out and a total of 6 applications were then made at fortnightly intervals to give the total input of elemental NPK shown in Table 2 (61); in order to adjust fertilisation to the needs of the growing plants, applications Nos. 3 & 4 were made at twice the rate, and Nos. 5 & 6 at three times the rate, of the first two applications. In

Thailand the fertiliser schedule for *P. kesiya*, *P. caribaea* and *P. oocarpa* provides for (1) 80 mg/container of NPKMg (12:12:17:2) starting the second month after pricking out (2) 100 mg the 3rd month (3) 150 mg the 4th month and (4) 250 mg the 5th, 6th and 7th month after pricking out. Fertilisers given to *P. merkusii* are applied in doses between 1/3 to 1/2 of the above recommended doses because of the higher sensitivity to fertiliser burn. In some countries it is considered preferable to add P to the potting mixture before filling containers, while N & K are applied later as a top dressing (44, 49); in Honduras an additional pinch of P is added to each pot during filling as an insurance against uneven mixing.

Fertilisation with micronutrients is not usually necessary in forest nurseries. Perhaps the most common problem is a chlorosis, resulting from the unavailability of iron in soils of high pH. This can be corrected by dissolving 10 g of ferrous sulphate in 1 litre of water and applying the solution as a foliar spray (22) or by acidifying the soil as described in the previous section.

Clearly each nursery must develop its own fertiliser regime based on general experience and experiments. Nutrient requirements will depend on the species and type of plant to be produced, the length of the growing period, the size of container and the characteristics of the growing medium.

Root pruning of container plants

The commonest method of root pruning container stock is to lift the bag from the ground and break the roots which have grown from the bottom of the container into the nursery floor. Use of concrete, rammed laterite or polythene sheeting as the base for the containers discourages downward rooting (59), but the lifting operation is still needed to break any roots which may have penetrated adjacent containers. An alternative used in Uganda is to place the containers on a flat sandy surface and use a wire for regular pruning of vertical roots, exactly as in the Swaziland bed method (described in chapter 6) (59). Containers may also be placed on elevated frames with wire mesh bases, so that when the roots grow out of the bag and into the air space, they are pruned automatically by air.

Periodic root pruning in the nursery will prevent the sudden loss of most of the absorbing roots at the time of lifting, which would occur if plants are allowed to root through into the nursery floor. Other beneficial effects of root pruning are the reduction in growth rate, particularly shoot growth, the lignification of the stem and the stimulation of the new lateral roots. However, it will not prevent the formation of spiral roots within a polythene container. Additional measures need to be taken at planting, as described in the following section on root coiling.

Root coiling effects

The roots of many pine plants raised in polythene containers tend to coil and spiral round the interface between the soil block and the polythene. The effect is most marked in large plants grown in small containers. It does not appear to affect growth in the nursery but can cause serious problems later, as the weight of the tree and the root thickness increase and the roots remain in a tight coil. In extreme cases mutual strangulation of roots causes death of the trees from starvation, more often losses are due to windthrow or basal stem snap. In Africa average losses from stem snap of 2-3% up to age 7 have been observed but with much higher losses in local patches (9). In a mixed *P. oocarpa/P. patula* stand of 6 years in Colombia losses from windthrow were heavy: 13% dead, 8% prostrate but alive, 53% leaning more than 15° and only 26% erect; all windthrown trees examined showed evidence of strangling roots (14).

The ill effects of coiling roots can be mitigated by the following measures (9, 12, 17, 58):

(1) Avoid use of containers which are excessively small in relation to the size of plant at time of planting; a 30 cm plant needs a considerably bigger container than a 10 or 15 cm plant.
(2) Remove container at planting.

(3) Immediately before planting, make 2 or 3 vertical incisions down the full length of the soil cylinder to a depth of 1 cm, with sharp knife, razor blade or hacksaw, to sever the coiling roots.
(4) Immediately before planting, cut off the bottom 1 cm of the soil cylinder to remove the basal root coils.

The last two operations may sever around half of the root mass but do not seriously affect survival (19). If these precautions are taken, the forester can utilise the great advantage of the individual container system - full protection of roots from desiccation between lifting and planting - while maintaining the future stability of his plantations.

5. RAISING PLANTS FOR BARE-ROOT PLANTING

In most parts of the tropics plantation establishment with bare-rooted conifer seedlings is limited. However, increasing use is being made of this type of seedling, particularly in Australia and Latin America. The cost of establish-ment of plantations with bare-rooted seedlings is often considerably lower than establishment with container-grown seedlings. Moreover bare-rooted seedlings are less susceptible to root deformation and its consequences in the subsequent development of the plantations. Experience has shown that success with bare-root planting depends on careful conditioning of the plants through root pruning, careful handling between lifting and planting, and reliable rainfall in the planting season (42).

Schedules of intensive root pruning were first developed for *P. radiata* in New Zealand (60), extended to *P. patula*, *P. elliottii* and *P. taeda* in South Africa (15) and to *P. caribaea* and *P. oocarpa* in the low altitude tropics in Queensland, Honduras and Venezuela (6, 43, 54).

For the production of bare-rooted seedlings, seed is directly sown into the beds made from existing nursery soil, therefore care must be taken in the selection of the nursery site. The soil should be moderately acid (pH 5.0 to 5.5), a sandy loam in texture and well drained. Prior to bed formation 500-1000 kg/ha of triple superphosphate fertiliser should be ploughed into the soil. Beds are typically 1.1 m wide for easy access, the length dependent on the space available, raised 10 to 15 cm above ground level, and may be boarded with wood to prevent erosion. The seedlings are raised in rows parallel with the length of the bed which facilitates root pruning. With 15 cm spacing between drills, a bed 1.1 m wide would hold 7 drills. As described on p. 6, sowing density should be aimed to produce a final stocking of 150-250 plants per m^2.

Root pruning may be done manually. A sharp flat spade is introduced at an angle to one side of the seedling row, such that the tap root is cut at the required depth. If the spade is then lifted slightly, the lateral roots are also snapped and the soil is aerated. The spade is introduced at alternate sides of the seedling row on successive pruning dates to promote the development of a balanced root system. An alternative method is to use a piano wire to undercut vertical roots, as described for Swaziland beds in the next chapter. In this case the lateral roots need to be severed by knife or machete to complete the pruning operation. Mechanical root pruning has been developed in New Zealand and Queensland by means of a tractor drawing a horizontal reciprocating blade to sever vertical roots and vertical interdrill blades to sever the laterals (6, 60).

In Honduras pruning starts when the roots have grown to a depth in excess of 15 cm (12 to 14 weeks after sowing) and is repeated at fortnightly intervals (44). In tropical Queensland, mechanical pruning starts when the shoots are 10-15 cm high, thereafter weekly undercutting has given better results than pruning at longer intervals. Undercutting is carried out at 13-15 cm depth (54). Pruning of lateral roots can be done less frequently, every 4 to 6 weeks (6, 60). In subtropical Queensland pruning can start when the plants are slightly larger (15-20 cm) and be done at longer intervals of about a month (54). Plants should be lightly watered immediately after pruning. Intensive root pruning as here described increases the root/shoot ratio, the mass of fibrous absorbing roots, the amount of stem lignification, and survival and growth after planting, as compared with unpruned plants (5, 44).

Care between lifting and planting is also essential to success. Seedlings should be lifted in the early morning after the soil has been well moistened. Lifting is done with a spade and excess soil is removed from the roots by placing them briefly in water, after which protection from desiccation is very important. Several methods of keeping the roots moist during transit have been used. In Honduras plants are packed in groups of 500, with their roots wrapped in wet burlap sacking (42). In Queensland dipping roots in a clay slurry of creamy consistency (1 kg/l) gave the best survival, followed by a sodium alginate dip, with the control (dipped in water) the poorest (7). Dipping in a clay or alginate slurry, then placing in a polythene bag to conserve humidity, which in turn is wrapped in moist sacking to prevent overheating of the polythene, may be the best combination.

Planting should be carried out as soon as possible after lifting, and always within 24 hours, starting at dawn and stopping in the late morning or whenever weather conditions become unsuitable. On the northeast coastal plain of Honduras mechanical planting of *P. caribaea* produced better survival when planting was done during the night (44).

Survival can also be improved by rigorous culling of plants, e.g. by rejecting all plants with more than 50% of the stem still succulent and unlignified (54).

Because the nursery soil remains in situ from year to year with bare-root planting, regular measures are needed to maintain its productivity. At Beerburrum in Queensland, the nursery is run on a three year cycle, one year of pine production alternating with 2 years of grass fallow, and to restore nutrient status inorganic fertilisers are added after soil sampling (23).

6. RAISING PLANTS IN SWAZILAND BEDS

The Swaziland bed technique has been successfully employed for the production of *P. caribaea* and *P. patula* in many African countries. Seedlings are transplanted (or seed is directly sown) into raised beds at a spacing of 5 x 5 cm. The soil must be sufficiently cohesive to enable it to be carved into blocks 5 x 5 cm square x 12 to 15 cm deep and the seedlings transported to the planting site in these blocks. During the growing period in the nursery, root pruning is effected by crosscutting and undercutting the bed, thus confining the root systems to soil blocks of this size. In this way a compact fibrous root system is developed and the stems are lignified. The seedlings are planted out with the soil block intact. Soil mixtures and use of fertilisers are as for individual containers.

The sides of the beds are revetted with bricks, concrete blocks or timber baulks to retain the soil, and undercutting is done by inserting a flexible piano wire under the revetting blocks at one end of the bed, so that two men pulling alternately on the wire from each side of the bed can “saw” through the soil and prune off any vertical roots. Lateral roots are pruned by crosscutting with a machete. The ground below the bed should be level and fairly hard but permitting free drainage. At the time of planting, the revetments are removed and the bed is carved up into sections suited to the size of box or tray used locally, e.g. 7 x 7 plants at 5 x 5 cm spacing would fit into a tray of 37.5 x 37.5 cm square. These are lifted on a spade and dropped into the boxes for transport to the field; after planting each consignment, the boxes are brought back to the nursery for re-use (46). The final carve-up into single plant soil blocks is done immediately before planting.

In East Africa pruning is done in accordance with the following weekly sequence: Week(l) Vertical pruning in one direction. Week (2) Vertical pruning at right angles to that of week (l). Week (3) Undercutting with piano wire. Week (4) No pruning. Week (5) Recommence cycle as in week (1) (66). The initial undercutting should be done while the beds are still empty, so that any obstructions (uneven revetment, clods of earth) can be removed without disturbance to the plants (50).

Raising of ball-rooted plants in Swaziland beds should preserve the roots from desiccation almost as well as the container system. At the same time the method produces a compact fibrous root system without danger of root coiling. The number of operations involved makes it more expensive in labour than the container system and the main disadvantage is the risk that, during a journey over bumpy roads, a great part of the soil block gets shaken off the roots; in this case the roots arrive at the planting site virtually bare-rooted but without the benefit of protection from clay slurry, polythene bags, wet sacking etc. which is incorporated in a deliberate bare-root planting system. It may be noted that the Swaziland bed system (raised and revetted beds, undercutting by piano wire and crosscutting by machete) could be easily adapted to bare-root planting simply by taking the necessary precautions against desiccation between lifting and planting.

7. CULTURAL TECHNIQUES COMMON TO CONTAINER-GROWN AND BARE-ROOT NURSERY STOCK

Protection

Measures to reduce the incidence of damping off during and immediately after the germination phase are described on page 4. Soil sterilization with methyl bromide, as practised in Zambia, is an efficient form of protection against soil-borne diseases. It also reduces the insect and weed seed population in the soil. However, it is expensive, dangerous to use, and has undesirable effects such as the eradication of mycorrhizal fungi and the fungi which compete with the causal pathogens. It is usually only employed where the control of insects, weeds or nematodes is required in addition to the prevention of damping off. In Zambia 0.5 kg of methyl bromide is used per 5000 “mini-pots” or 1000 “standard” pots (see Table 1) sealed under polythene sheeting, and detailed prescriptions are in force to ensure both efficiency and safety (13). Liquid formalin can also be used; in Nigeria 1 part of formalin is diluted in 50 parts of water and the mixture is applied at a rate of 10 litres per m^2 of bed, sealed under polythene for two days; the soil is then turned frequently for up to a week until the smell vanishes, before sowing (22).

There are several foliage diseases which cause considerable losses in conifer nurseries in different parts of the world. The following, which attack the pines, are the most important: Brown Spot Needle Disease *(Scirrhia acicola)*, Brown Needle Disease *(Cercoseptoria pini-densiflorae)*, and Dothistroma Needle Blight *(Scirrhia (Dothistroma) pini)*. See (27) for a description of these diseases and methods for their control.

Insect pests cause locally important damage in forest nurseries. Cutworms and crickets cut the hypocotyl of recently germinated seedlings. Efficient control can be effected using organic phosphate insecticides, providing damage is detected at an early stage. Similarly damage from the leaf cutting ant *Atta* sp. can be minimised by applying a Mirex bait to the insect’s nest and pathways (1). In Central America the pine tip moth *Rhyacionia frustrana* may cause losses when the seedlings are kept in the nursery too long, although this insect is more of a problem in young plantations. Useful references concerning the disease and insect problems of tropical conifers have been published by IUFRO (33).

Rodents and seed eating birds cause losses during and immediately after germination. Chemical pelleting and/or protection with a wire mesh may be necessary where losses are serious.

Weeding of beds is usually done by hand 3 to 4 times during the growing season, on beds which have previously been watered. In Honduras, experiments with the herbicide GOAL 2EC have given very promising results with *P. caribaea*. The best rate of application was 50 cc GOAL 2EC with 15 cc of Triton sticker mixed with 62 litres of water for 100 m^2 applied 3 days before expected germination. Weeding time was reduced by a factor of 10 (41).

Shade and shelter

Use of shade during the germination phase is described on page 4. The period of shading of the transplant beds varies according to the local climate, but a good rule is to avoid the use of shade wherever possible and, where it is necessary, to remove it as soon as possible. Where insolation is intense, shade may need to be retained for some time after sowing or pricking out; thus in Malaysia a three week period of half shade is recommended (49). A variety of local materials e.g. banana or palm leaves for full shade, bamboo slats for partial shade, or imported material such as rolls of hessian or "Sarlon" plastic cloth can be used. Some nurseries, especially at higher elevations or where sowing is done in the cool season, use no shade at all in the transplant beds. However, in sub-tropical areas or at very high elevations the plants may need to be protected against frost at night. Hessian supported 2-3 ft. above the plants is effective (50). Protection against hail storms is necessary in a few areas; a fine mesh netting keeps out hail stones without restricting light (15, 66); switching on the nursery sprinkler system is also effective in breaking up the force of hail storms.

Irrigation

Transplant beds should be kept moist but not waterlogged. A moist soil should feel springy and resilient, while a soft soggy soil is too wet (13). The actual amount of water applied varies greatly according to local evapo-transpiration rates, but the rates reported are mainly in the range of 2-8 mm a day (16, 49, 59, 66). The highest rates apply to the more arid areas and watering can be reduced in cloudy weather and omitted in rainy weather. Water demand increases with the size of the plants and in S.E. USA plants receive 4 times as much water when they are nearing plantable size as when they are recently germinated (24). This trend towards heavier watering rates as the plants get older may be reversed during the last 2 months or so if water restriction is an intentional part of hardening off (see next section). Frequency of watering is progressively decreased with time; newly germinated seedlings may be watered lightly twice a day, while older plants may be watered heavily once or twice a week.

The quality of water needs to be checked. Highly alkaline water (pH>8) may need to be acidified (see p. 9) and water with a high salt content (> 500 ppm total dissolved solids) should be avoided.

In small nurseries water can be applied manually by hose or watering can. In large nurseries a mechanical system with sprinklers or spray lines is common. In Honduras, for example, a sprinkler irrigation system operating at a pressure of 50 p.s.i. (3.5 kg/cm^2) and powered by a 7 horse power centrifugal diesel pump has been found adequate for nurseries raising 1 to 2 million seedlings. Spray lines are 10 m apart, with full circle sprinklers at the same spacing along the spray lines, elevated 60 cm above ground level. At the beginning of the production period the seedlings are watered each day in the late afternoon or early morning. Watering frequency is progressively reduced to once every 4 or 5 days as the seedlings develop. The irrigation systems are designed to supply the growing area with 7.5 mm of water per day but usually only a third of this is required (44).

In Thailand, container plants are successfully irrigated from below (29). Each concrete bed is 10 cm deep, holds 1000 polythene tubes and has outlet holes for water. Water is fed into the bed until the bottom one third of the tubes is immersed. After pricking out germinated seeds from blotting paper packs (see p. 5), the tubes are left standing in the water until the cotyledons have unfolded. Thereafter immersion to the same depth is done once or twice a week. Fertilisers are added to the irrigation water as required.

Hardening off

The most effective method of conditioning or "hardening off" plants in preparation for the shock of planting out is by intensive root pruning, as described on pp. 11, 13 and 14. Reducing the amount of water and fertilisers (particularly nitrogen) in the last two months in the nursery also helps to restrict the development of tender succulent shoots and to promote lignification. Shoot pruning the pines several weeks or months before planting out also stimulates the lignification of the stem and the development of secondary foliage and produces seedlings of uniform size for handling and planting out. This technique is used in Brazil and Queensland with *P. caribaea* (44, 54). The effect on the subsequent form of the trees may be of concern, but is said to be slight (4.7% malformed 3 years after planting in one Queensland trial).

Culling

The selection and rejection (culling) of seedlings at the end of the nursery growing period according to their suitability for planting out is of the utmost importance but is not frequently discussed in the literature. In Australia bare-rooted *P. caribaea* seedlings are classified into 8 grades according to their shoot development. Of these the first two are considered unsuitable for planting (stems still entirely succulent) (6, 42, 54). In Honduras seedlings of *P. caribaea* and *P. oocarpa* considered suitable for planting out have the following characteristics: height, 15 to 25 cm; root collar diameter, 3 to 6 cm; root/shoot ratio (dry weight), greater than 0.25 for bare-rooted seedlings and greater than 0.8 for containerised seedlings. They should also have 2/3 of the stem lignified, a compact, fibrous root system and be free from physical defects (44).

Period in the nursery

Seedlings of *P. caribaea*, *P. kesiya* and *P. oocarpa* 20 to 30 cm in height can be grown in 4.5 to 6 months in the tropics. This period may be longer if there is a rigorous programme of root pruning. The nursery period is longer at low temperatures. Large plants of *P. patula* may need as much as 14-20 months at high elevations in Tanzania and Zimbabwe (10, 50), but this may be reduced by locating the nursery at a lower elevation than the intended planting site, or by using smaller plants as is done in Colombia, where *P. patula* can be raised in 6-7 months at elevations up to 2000 m. It is highly desirable to keep the period to less than a year, in order to avoid having to look after twice the area of nursery.

8. REFERENCES

Aguirre Castillo, C. 1978

Control de la hormiga arriera *Atta spp.* y en plantaciones forestales. In: Proc. Symposium Plagas y enfermedades de pinos en el tropico. IUFRO Working Groups S2.06.12 and S2.07.07 September 1978, Piedras Blancas, Medellin, Colombia.

Anthony, J. 1971

Growth and development of potted seedlings of *Pinus caribaea* Mor. under different combinations of nitrogen phosphorus and potassium. Malaysian Forester 32 (3): 182-202.

Anthony, J. and Freesaillah Bin Che Yeom. 1969

Observations on the growth and development of *Pinus caribaea* Mor. seedlings grown in various potting mixtures. Malaysian Forester 32 (3): 303-328.

Armitage, F.B. and Burley, J. 1980

Pinus kesiya. Tropical Forestry Paper, No. 9. Commonw. For. Inst. 0xford. 199 p.

Bacon, G.J. and Bachelard, E.P. 1978

The influence of nursery conditioning treatments on some physiological responses of recently transplanted seedlings of *Pinus caribaea Mor. var. hondurensis*. Aust. For. Res. 8, 171-183.

Bacon, G.J. and Hawkins, P.J. 1977

Studies on the establishement of open root caribbean pine planting stock in Southern Queensland. Australian Forestry 40(3): 173-191.

Bacon, G.J., Hawkins, P.J. and Jermyn, D. 1977

Root dip evaluation and short term storage trials with 1-0 slash pine seedlings. Aust. For. 40 (3), 167-172.

Bakshi, B.K., Reddy, M.A.R., Puri, Y.N. and Sunjam Singh, 1972

Survey of the diseases of important native and exotic forest trees in India. Dehra Dun, India; Forest Pathology Branch, Forest Research Institute and Colleges. 117 p.

Ball, J.B. 1976

Plastic containers and coiling roots. Unasylva Vol. 28, No. 111, p. 27.

Barrett, R.L. 1973

Forest nursery practice in Rhodesia. Rhod. Bull. For. Res. No. 4, Forest Research Centre, Highlands.

Barrett, R.L. 1978
Forest nursery practice for the wattle regions in the Republic of South Africa. Wattle Res. Inst., Pietermaritzburg.
Bharathie, K.P. 1973(a)
Improvement of nursery techniques for tropical pines in Sri Lanka (Ceylon). Sri Lankan Forester II (1 and 2): 34-56.
Brahim Ben Salem. 1971
Root strangulation: a neglected factor in container-grown nursery stock. Univ. California (thesis).
Calvert, G.M. 1970
Provisional large scale nursery techniques for pine. Res. Note No. 5. For. Dept. Zambia. 26 p.
Cannon, P. 1981
Respuesta de los arboles en plantaciones al uso de envases en el vivero. Informe de investigación No. 74. Carton de Colombia S-A. 13 p.
Denison, N.P. 1979
Recent developments in nursery practice, establishment procedures and tree improvement for afforestation. 5th Afr. For. J. 110, 12-15.
Donald, D.G.M. 1968a
Fundamental Studies To Improve Nursery Production Of *P. Radiata* And Other Pines. Annale Univ. Van Stellenbosch, 43 (A) L. 180 P.
Donald, D.G.M. 1968b
Planting Of Trees In Polythene Bags. (Letter To) 5th Afr. For. J. 67, 28-29.
Donald, D.G.M. 1972
The Use Of Inorganic Fertilisers For The Production Of Pines In The Forest Nursery. Sth Afr. For. J. 81, 2-6.
Donald, D.G.M. 1979
Nursery and establishment techniques as factors in productivity of man-made forests in southern Africa. 5th. Afr. For. J. 109, 19-25.
Donald, D.G.M. 1980
Dormancy control in *Pinus patula* seed. Proc. Forest seed, nursery and establishment research working group, 3rd meeting, Saasveld For. Res. Stn. George.
Durham, P. 1965
Some problems in growing *P. patula* in areas of alkaline, volcanic soils. Tech. Note (Silvic.) No. 80, Silviculture Section, Lushoto.
Ekwebelam, S.A. 1974
Nursery techniques and establishment of pines in the South of Nigeria. Obeche, 10: 77-97.
Evans, J. 1982
Plantation forestry in the tropics. Clarendon Press, 0xford, 471 pp.
FAO 1970
Report on the Training Centre on Forest Tree Improvement, N. Carolina State University, Raleigh.
Foot, D.L. 1967
Nursery and establishment technique on the Vipya Plateau, Malawi, with special reference to the formation of man-made pulpwood forest. Paper 5b/6, Proc. Symposium on Man-made Forests, FA0 Rome.
Gosh, R.C., Bakhshish Singh and Sharma, K.K. 1976

Optimum depth of sowing for propagation of tropical pines. Indian Forester 102 (9) 555-567.
Gibs0n, I.A.S. 1979
Diseases of forest trees widely planted as exotics in the tropics and southern hemisphere. Part II. The genus pinus. Commonw. Mycological Inst., Kew, England, and Commonw. For. Inst., Oxford, England. 135 p.
Goudet, J.P. 1975
Plantations experimentales d'especes papeteiéres en Cote d'Ivoire. Bois et Forets des Tropiques. 159: 3-27.
Granhof, J.J. 1974
Nursery technique as practiced at the pine project. Report of the Thai/Danish pine project 1967-1974.
Greaves, A.1982
Pinus oocarpa. Review article, Forestry Abstracts Vol. 43, No. 9, Commonw. Agric. Bureaux.
Hocking, D. and Jaffer, A.A. 1969
Damping-off in pine nurseries: Fungicidal control by seed pelleting. Commonw. For. Rev. 48: 355-363.
Hodgs0n, T.J. 1977
Experiments on sowing and container size with *Pinus patula*. South African Forestry Journal 103: 55-61.
IUFRO 1978
Proc. Reunión de los grupos de trabajo de la IUFRO S2.06.12 y S2.07.07, plagas y enfermedades de pinos en el tropico. Septiembre 1978, Piedras Blancas, Medellin, Colombia.
Jackson, J.K. 1977
Results of nursery research. In: Savanna afforestation in Africa, FA0 Forestry Paper No. 106-111.
Ladrach, W.E. 1977
Panales de tubos: Un método para producir árboles en viveros. Informe de Investigación, No. 18. Carton de Colombia, S.A. 8 p.
Lamb, A.F.A. 1973
Fast Growing Trees of the Lowland Tropics. No. 6. *Pinus caribaea*. Inst.Pap. Commonw. For. Inst. 0xford, 254 p.
Marrer0, J. 1965
Potting media for Honduras pine. Res. note, Inst.Trop.For., Puerto Rico. I.T.F.-5. 7p.
May, W.B. 1953
Nursery notes. E.A.A.F.R.0. Tech. Note 1.
May, W.B. 1954
Fertilisers and forestry. E.A.A.F.R.O. Tech. Note 3.
Mitchell, B.A. 1961
Pregermination of tree seeds in polythene bags. Malaysian Forester 24 (2):142-145.
Munguia, O.E. 1981
Uso de herbicides in la producción de plántulas de *Pinus caribaea* a raíz desnuda. In: "Actas de las Terceras Jornadas de Reforestación". COHDEF0R, Tegucigalpa. pp. 108-115.
Napier,I.A. 1981

Calidad de la plántula: Un factor decisivo en el establecimiento de pinos a raíz desnuda en los tropicos. In: "Producción de madera en los neotropicos via plantaciones". Proc. IUFRO/MAB/Forest Service (USDA). IUFRO Working Group S1.07.09. September 1980. Inst. Trop. For. Rio Piedras. J.L. Whitmore, ed. pp. 172-190.

Napier, I.A. 1982

La poda de raíz del Pinus oocapa y *Pinus caribaea* en los viveros de Honduras. Siguatepeque, Honduras; Escuela Nacional de Ciencias Forestales. Artículo científico No. 5. p. 15.

Napier, I.A. 1983

Tecnicas de vivero para la producción de conifero en los tropicos. (Nursery techniques for the production of conifer seedlings within the tropics). Paper presented to the 2nd IUFRO Working Group (S1.07.09) symposium: Forest plantations in the tropics: their role as a source of energy. Univ. of Vicosa, Minas Gerais, Brazil. Feb. 1983.

Nichols0n, D.I. 1965

A nursery technique in Sabah. (Letter to) Mal. For. 28, 149-15.

Parry, M.S. 1952

The softwood plantations of the East Transvaal and Swaziland. E. Afr. Agric. J. 17(4), 188-200.

Parry, M.S. 1957

Experiments on Pinus patula. Tech. Note (Silvic.) No. 7, Silviculture Division, Lushoto.

Parry, M.S. 1958

Perenox and acid seed beds. Tech. Note (Silvic.) No. 10, Silviculture Division, Lushoto.

Paul, D.K. 1972

A handbook of nursery practice for *Pinus caribaea* var. *hondurensis* and other conifers in West Malaysia. FAO. Working Paper No. FO: SE/Mal 12. 139 p.

Procter, J.E.A. 1963

Nursery practice in the Southern Highlands. Tech. Note (Silvic.) No. 32, Silviculture Section, Lushoto.

Procter, J.E.A. 1967

A review of nursery practice and research in Tanzania. Paper 5 b/7, Proc. Symposium on Man Made Forests, FAO Rome.

Reyes, J.A. 1983

Cantidad de semillas para la producción de plántulas de pino en viveros forestales de Honduras. Nota técnica 5, ESNACIF0R, Siguatepeque, pp. 5.

Seeber, G. 1976

Nursery techniques. In: Manual of reforestation and erosion control for the Philippines, 231-389.

Shea, G.M. and Armstrong, P.A. 1978

Factors affecting survival in open root plantings of caribbean pine - Coastal Queensland. Dept. of For. Queensland, Australia, Technical Paper No. 8. 18 p.

SILVICONSULT 1981

The *Pinus* provenance trials in the Bai Bang paper mill project, Socialist Republic of Vietnam, 5 year report. Lund, Sweden.

Solberg, K.H. 1978

Tube size and plant age. Nursery and field experiments, *Pinus caribaea* and *Pinus oocarpa*, Tanzania. Tech. Rep. No. 10, EAC/NORAD Lowland afforestation project, Dept. of Silviculture, Agric. Univ. of Norway, 35 pp.

Stone, E.C. 1971
Prevention of container-induced root malformation in *Pinus pinaster* and *Pinus halepensis* seedlings following trans- planting.

Thomson, B.R. 1968
A review of nursery techniques for tropical pines and eucalyptus. For.Res.Pam. No.15. For.Res.Div. Zambia. 91 p.

Van Dorsser, J.C. and Rook, D.A. 1972
Conditioning of radiata pine seedlings by undercutting and wrenching: Description of methods, equipment and seedling response. New Zealand Jour. For. 17 (1): 61-73.

Voorhoeve, A.g. and Van Weelderen, A.W.H. 1971
Nursery practice of *Pinus caribaea var. hondurensis* in Surinam. Turrialba 21(1): 89-97.

Wakeley, P.C. 1954
Planting the southern pines. Forest Service, U.S. Dept. of Agric., Washington D.C.

Watkins, G. 1959
Sowing seed in polythene bags. E.Afr. Agric. J. 24, 197-202.

Willan, R.L. 1963
Nursery experiments on pines. Tech. Note (Silvic.) No. 52, Silvicultural Section, Lushoto, Tanzania.

Wormald, T.J. 1970
Experiments undertaken in cooperation with the FAO reforestation officer 1968 and 1969 (in the Philippines). Cited in Armitage and Burley 1980.

Wormald, T.J. 1975
Pinus patula. Commonw. For. Inst. 0xford. Tropical Forestry Paper No. 7. 200 p.