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Comparative Observations on the Nursery Technique in Different Parts of the World

Peitsa Mikola

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COMPARATIVE OBSERVATIONS ON THE NURSERY TECHNIQUE IN DIFFERENT PARTS OF THE WORLD

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HELSINKI 1969

CONTENTS

Suomalaisen Kirjallisuuden Kirjapaino Oy Helsinki 1969

INTRODUCTION

Artificial afforestation and reforestation have been greatly expanded in the last 20 years and will probably continue to increase in the future. Developing programmes for tropical and subtropical areas, in particular, include large afforestation schemes and the creation of forest industries, which have already considerably improved the national economy of many countries (see BROWN 1967). According to the estimate of FAO Secretariat (1967), at least 2.5 mill. hectares of new forests are being planted every year (plus all the planting included in the normal regeneration of managed forests), and probably this annual area will be doubled in 15 or 20 years.

Such a planting programme requires a tremendous number of tree seedlings, which have to be raised in forest nurseries. If an average of 2 000 seedlings are planted per hectare (depending on spacing, the usual figures vary from 1 000 to 5 000 plants per hectare), 2.5 mill. hectares of new afforestations alone correspond to an annual need of 5 thousand million seedlings, and probably several times more are used for reforestation. A reliable nursery technique is vital for the success of plantations, the economy of which depends to a great extent on the costs of nursery operations. Forest nurseries, therefore, are gaining ever-increasing importance in world forestry.

In 1967, as an FAO André Mayer fellow, I had an opportunity to visit more than 80 forest nurseries in 20 countries, most of them in the tropics and subtropics. Although the primary purpose of the journey was to study the use of mycorrhizal inoculation in afforestation (MIKOLA 1969 a, b), an excellent opportunity was also provided to see the nursery techniques of different countries and to compare them with each other and with the conventional methods of cool and temperate countries. Nursery technique is rapidly developing everywhere in the world. Because experience gained in one country may be applied with advantage elsewhere, the following miscellaneous observations on the present techniques are reported here.

I presume that the reader is familiar with the conventional nursery technique of cool and temperate countries, as it is practised in Central Europe and the United States, for instance, and has been described in numerous textbooks (ARNBORG & STEFANSSON 1951; WAKELEY 1954; OHMASA 1956; STOECKELER & JONES 1957; RUPF, SCHÖNHAR & ZEYHER 1961; EDLIN 1964; etc.). Standard operations included in this technique are: soil preparation, sowing, transplanting, lifting and packing, weeding, fertilization, watering, and protection. Seedlings are raised in beds in natural soil, either agricultural or forest soil, and, depending on tree species and climate, the time needed for the production of plantable seedlings is usually 2 to 4 years; during this time the seedlings are ordinarily transplanted once. After lifting the bare-rooted seedlings are bundled and packed in boxes, bags or bales for shipping. The recent trend everywhere has been towards rationalization and mechanization of the nursery work (de PHILIPPIS & GIORDANO 1967). This has led to an increase in the size of nurseries. Small local and temporary nurseries have been abandoned and large central nurseries with a high degree of mechanization and automation have been established.

There are special nursery techniques in the temperate zone too, such as for poplar cuttings or ornamentals. This review, however, is mainly concerned with the raising of conifers, and comparison is made with the conventional European technique. Very different techniques, such as for raising of teak seedlings, which I also saw during the tour, are omitted.

AFRICA SOUTH OF THE SAHARA

SOUTH AFRICA. I visited five nurseries in Swaziland, viz. four belonging to the Usutu Pulp Co. and one to Peak Timbers Ltd. This was in March, 1967.

South Africa has a long tradition of nursery practice (HILEY 1959; DONALD 1965), and the South African methods have been adopted, as such or with some modification, in other parts of Africa south of the Sahara. The African methods differ considerably from the conventional European techniques. Reasons for the differences are mainly climatic. In warm, dry climates, planting of bare-rooted plants is not successful and, therefore, seedlings are usually grown in different types of containers (clay pots, wooden boxes etc.), such as are described in manuals of tropical forestry (PARRY 1956; LETOURNEUX 1957; and others). In the warm climate the growth of seedlings is very rapid; they are seldom kept longer than one year in the nursery and even so pine seedlings may be 25—30 cm tall at the time of lifting. Cypress grows somewhat faster than pines and eucalypts much faster. Timing of nursery operations is determined by the optimum planting season, in other words, seeding and other operations are timed so that the seedlings are of the desired size at the planting season, i.e. early rainy season. Because of difficulties of transportation, nurseries are small and are located in the midst or the immediate vicinity of the areas to be planted. Usutu Pulp, for instance, today has six nurseries, each of them producing about 1 mill. plantable seedlings per year, whereas in the 1950's, when 5—7 000 hectares were planted annually, the number of nurseries was over ten.

The main species of the Swaziland plantations is *Pinus patula*, constituting about 80 % of the production of the nurseries. *Pinus elliottii* and *P. taeda* are also grown (about 15 % together), and *Eucalyptus* (mostly *E. grandis*) seedlings are raised mainly for firebreak plantations (about 5 %). Other species are grown only for experimental and ornamental purposes. Plantable areas lie in the »high veld», 900—1 600 m above sea level; the elevation of the nurseries visited varied between about 1 200 and 1 300 m.

Swaziland has become famous for its special nursery technique, known as the »Swaziland technique», which was developed in about 1950 and was rapidly adopted in many other African countries and even elsewhere (PARRY 1956, pp. 50—54). The main reason for developing a new technique was the large amount of lumber needed for making transplant trays by the former technique and which was both expensive and difficult to obtain and transport to the nursery sites in the wild, uninhabited mountains where large-scale afforestation was started.

The Swaziland technique, which was developed by R. P. Stephens at Peak Timbers Ltd., was used for pines in all the nurseries of the company at the time of my visit. Only eucalypts were raised individually in polythene tubes. The essential feature of the technique is the raised transplant bed or »Swaziland bed», to which seedlings are transplanted from seedbeds soon after germination and where root pruning is performed below the bed with a steel wire (usually a piano wire). The beds were 25 m long, 30″ wide and 4″ high. Red bricks were used for edging the beds at Peak Timbers nurseries.

Usutu Pulp changed its nursery technique a few years ago, starting to raise seedlings in polythene tubes. The tubing technique was tried for the first time in 1965, when about 10 % of the seedlings were raised in tubes, whereas by 1967 all the seedlings for Usutu Forest were raised in tubes. The main reason for abandoning the Swaziland technique was the large amount of work needed for transplanting the seedlings into the beds. With the new method seeds are sown directly in tubes, three seeds per tube (Fig. 1), the emerging seedlings are thinned to one seedling per tube, and thus transplantation is unnecessary.

In Usutu nurseries the height of the tubes was 10 cm and the diameter 6 cm (»4 inches flat»). They were made of thin black polythene, which disintegrates rapidly after planting. At planting the tube was not torn or removed. The tubes were filled manually; a female worker filled 1 000 tubes per day.

Fig. 1. Direct sowing of *Pinus patula* seed into polythene tubes. Usutu, Swaziland.

In the African nursery techniques all the soil needed for tubes or Swaziland beds is imported to the nursery from outside and removed again with the seedlings. The soil for tubing or beds is specially prepared: the ingredients of the mixture are sieved and thoroughly mixed, fertilizers are added in some nurseries, and the presence of mycorrhizal fungi is ensured. The ingredients and the mixture are usually stored under a shelter, to protect them from drying. Every nursery usually has its own mixture, depending on experience and the availability of suitable ingredients.

The Peak Timbers nurseries used a soil mixture of the following composition: 6 parts of hardwood forest top soil, 4 parts of top soil from a pine plantation, and 2 parts of horse manure. The same mixture was used for both seedbeds and transplant (Swaziland) beds. Commercial fertilizers were not used regularly; incidentally only K and P fertilizers had been added to the beds.

In Usutu nurseries the soil composition varied: one nursery used a mixture of 90 % of natural grassland top soil and 10 % of pine soil, whereas the other three took all the soil from pine plantations; one of them added 10 % of horse manure to the tubing mixture. In one nursery, where all the soil came from pine plantations, NPK-fertilizer (2: 3: 2) was used for top dressing (2 oz. per 750 tubes), whereas no commercial fertilizers were used in the others.

When softwood afforestation was started in Swaziland (in 1948 at Peak Timbers and in 1950 at Usutu), pine forest soil was brought for mycorrhizal inoculation of the first nurseries from distant pine plantations. In the early years, when there were no local pine plantations, as small an amount of mycorrhizal inoculum was added to the soil mixture as was still effective; at that time 10 % of pine soil in the soil mixture for Swaziland beds was customary. Today, when the nurseries are surrounded by pine plantations, there is no need for saving and many nurseries even use pine forest soil as such for tubing.

The planting season in Swaziland is from November to January, i.e. the early part of the rainy season. At Peak Timbers nurseries the seed was sown in February and March and the seedlings were transplanted into Swaziland beds six weeks after sowing. At planting time, 10—11 months after sowing,

the height of the pine seedlings was 20—30 cm. At Usutu Forest a general tendency was to reduce the nursery period of the seedlings. Therefore, the seed was sown 1—2 months later than at Peak Timbers and the seedlings were correspondingly smaller at the time of planting. Sowing even as late as August has been tried, when the seedling height at planting is only 5—10 cm, which is considered sufficient for planting the second rotation, immediately after clear-cutting and slash-burning. Eucalypts were usually sown in August and planted at the age of 4—6 months.

The permanent working crew of every nursery at Usutu Forest consisted of 8 men. Nurseries acted at the same time as fire stations, with necessary equipment, and the nursery crew was always ready to be sent out to fight fires. In addition to the permanent crew, some 20 temporary workers, mainly women, were needed at busy seasons, such as the time of tube filling and sowing.

ZAMBIA. I visited two nurseries in the Copper Belt, Chichele and Chati, both of them producing about 1 mill. seedlings per year. This was in March, 1967.

The main species of Zambian softwood plantations is *Pinus khasya* (*P. insularis*). *P. merkusii* is another successful pine species but its seed is difficult to obtain. Other pines have given less satisfactory results. *Eucalyptus* spp. (mainly *E. grandis*) constitute about 30 % of the production of the nurseries. The main obstacle to afforestation in Zambia is the very long and severe dry season. Therefore, plants that are healthy and vigorous at the commencement of the dry season are essential for the success of the plantations and the nursery technique aims at the production of strong, thriving seedlings.

The Zambian nursery technique has undergone a rapid change. Softwood afforestation on a field scale was started in about 1964. It was preceded by a period of intensive research and experimentation in nursery and plantation technique. Formerly, seedlings were raised in wooden boxes according to the traditional South African tray method, and Swaziland beds were also tried in the 1950's. Since the late 1950's, however, polythene tubes have regularly been used. Because of very detailed instructions (Allan & Endean 1966) exactly the same technique was used in the two nurseries visited, and probably in other Zambian nurseries, too.

Seed is sown broadcast in seedbeds, and the emerging seedlings are transplanted into tubes about two weeks after germination. »Root pruning» is performed from time to time by lifting the tubes from the ground and clipping off the protruding roots. The tubes are of thin black polythene, 15 cm in height and 8 cm in diameter; in other words, the Zambian tubes are bigger than those used in Swaziland. This also means that a larger amount of soil has to be transported to the nursery every year.

Soil for seedbeds and transplant tubes is specially prepared. Natural forest topsoil from local hardwood forests (miombo) is used. It is sieved, sterilized in an oblong pile (clamp) with methyl bromide, and fertilized with NPK (3: 4: 3) at a rate of 2 oz. per cubic foot (corresponding to about 1 g per tube). The use of farmyard manure is strictly prohibited. The same soil is used for both seedbeds and transplant tubes.

Soil inoculation with mycorrhizal fungi is not practised in the Zambian nurseries today. When Chichele and Chati nurseries were first established, they were inoculated with soil brought from an old nursery at Dola Hill, but annual reinoculation was discontinued a few years ago. In spite of soil sterilization, the seedlings develop rich mycorrhizal root systems. Apparently the nurseries are now well infected with mycorrhizal fungi, and the soil beneath the tubes is the probable source of the infection of the roots. Originally Zambia had great difficulty in obtaining mycorrhizal inoculum (Mikola 1969b).

Soil sterilization with methyl bromide is considered necessary because of damping-off. Treatment of soil with aldrin is also necessary, at least for *Eucalyptus*, because of termites (Cooling 1962). All attempts to raise eucalypts in Zambia failed consistently until 1958 for two reasons: termites and boron deficiency in the soil. Termites are today controlled with aldrin both in the nursery and after planting in the field, whereas boron is applied in the field only.

The dry season in Zambia lasts from April to October, and the main planting months are December and January. Pines are sown in the nursery in April and transplanted into tubes in May or June. Accordingly, the nurseries are practically empty from January until April. (When I visited the Zambian nurseries in the middle of March, soil sterilization and preparation of seedbeds was in progress.) Eucalypts are sown as late as August. A recent trend in Zambia is to reduce the nursery time for pines as well, and sowing can be postponed until June or July. Nevertheless, seedlings are 20—30 cm tall at the time of planting. Because seedling growth in the nursery coincides with the dry season, ample watering is essential. Ordinarily the nurseries are watered twice daily, corresponding to 5—7.5 mm of water per day. Nurseries have permanent watering pipe installations with sprinklers and motor pumps.

Seedlings are dispatched from the nurseries to the field in 15 × 15 × 5″ wooden boxes holding 18 plants.

For more detailed descriptions of the Zambian nursery technique, see the plantation manual of Allan & Endean (1966).

EAST AFRICA. I visited altogether 27 nurseries in East Africa, viz. 6 in Uganda, 7 in Kenya, and 14 in Tanzania. This was done in February and early March of 1967. The locations of the nurseries ranged from the coastal plain of Tanzania to 2 500 m elevation in the Kenyan Highlands and from Western Uganda to the Southern Highlands of Tanzania.

The recent research and current practices in East African nurseries have been excellently reviewed by Procter (1967). Below are reported some of my personal field observations.

In general, the size of East African nurseries is small. The largest of the nurseries visited, Sao Hill in Southern Tanzania, produces some 2 mill. seedlings per year but the annual production of most of the nurseries ranges between 0.5 and 1 million. Consequently, most nursery work is done manually.

The principal species at high elevations (above 1 500 m) are *Pinus patula* and *Cupressus lusitanica*. Owing to *Dothistroma pini*, *Pinus radiata* has practically disappeared from East African nurseries. It was the main species only in Turbo nursery in Western Kenya, where the climate is not favourable for *Dothistroma*. *Pinus elliottii* is raised to some extent in several nurseries, e.g. in the Southern Highlands of Tanzania. *Pinus caribaea* is preferred at low altitudes (below 1 500 m), being the only conifer in the coastal plains. Other conifers (*Pinus khasya*, *P. oocarpa* and other spp. of *Pinus*, *Araucaria* spp., *Callitris* spp., etc.) are raised just for experimental plots.

Broad-leaved trees are raised to some extent, *Eucalyptus grandis* being the main species. Eucalypts are raised principally for fire-break plantations. Research nurseries (e.g. Lushoto in Tanzania, and Entebbe and Kampala in Uganda) raise quite a number of local and exotic broad-leaved trees for experimental plantations. The only pure broad-leaved nursery visited was Tengeru in Tanzania (near Arusha) where *Grevillea robusta*, *Olea welwitchii*, and some other species were raised on a field scale for taungya plantations.

The Swaziland technique was the standard method in the East African nurseries (Figs. 2—4). 6″ boards usually served as the edges of the beds. The former technique of growing seedlings in wooden trays was still in use in some nurseries, e.g. in Kaptagat nursery in Kenya, which was located close to a sawmill and therefore plenty of cheap lumber was available. In general, however, wooden trays were only used for dispatching the seedlings. Several nurseries had even abandoned wooden boxes for dispatching, because of their bulkiness, and started to use plastic bags for packing. When seedlings were packed in plastic bags, more soil was left in the nursery or lost during transport and, consequently, the seedlings were almost bare-rooted at planting. Such seedlings could be successfully planted in the Southern Highlands of Tanzania, for instance, where the planting season is always cool and foggy and the risk of drying out is therefore minimal.

The new technique of growing seedlings individually in polythene tubes is becoming more popular in East Africa, too (Fig. 5). Other kinds of plant containers are also used, mostly waste materials such as old tin cans, used milk cartoons, etc. Broad-leaved trees, as well as experimental lots of conifers for species trials, were always raised in individual containers, usually polythene tubes. Likewise, the tube technique was favoured for *Pinus caribaea* under very warm conditions, such as in the coastal plains. Thus, the tube technique was the standard method in broad-leaved

Fig. 2. Swaziland beds. Kanyawara, Uganda.

nurseries (e.g. Tengeru in Tanzania), research nurseries, and also pine nurseries in the coastal lowland. But even pine nurseries in the highlands will probably follow Zambia's example; Olmotonyi and Narok nurseries in Tanzania (near Arusha) had already changed their technique and raised both pines and cypresses, as well as eucalypts, in tubes. The seed, however, was still sown in seedbeds, and small seedlings were transplanted into the tubes. Kibaha, near Dar-es-Salaam, was the only nursery visited where pine (*Pinus caribaea*) seed was sown directly into tubes, as is customary today at Usutu Forest in Swaziland.

The composition of the soil mixture used for Swaziland beds or tubes deserves particular consideration. After prolonged experiments in Muguga, Kenya, MAY (1953) gave detailed instructions for preparation of nursery soil, and this »May» or »Muguga mixture» was formerly generally used in East African nurseries. Later on, however, nurserymen

Fig. 3. Young transplants in Swaziland beds. Penon nursery, Kenya.

Fig. 4. Transplanting into Swaziland beds. Sao Hill, Tanzania.

have modified the mixture according to local experience, and today almost every nursery has its own favourite mixture. Below are examples of some mixtures:

	Original »May mixture»	Kinale, Kenya	Turbo, Kenya	Lushoto, Tanzania	Narok, Tanzania	Kawetire, Tanzania
Forest top soil (from local broad-leaved forests)	5	4	9	5	7	4
Grassland soil	–	–	–	–	–	6
Manure	1	–	–	2	2	1
Sand or gravel	1	1	–	–	2	–
Clay	1	–	–	1	–	–
Peat	2	–	–	–	–	–
Pine soil (from pine plantations)	1	3	1	–	1	1

Different ingredients of the mixture are stored separately under shelter in the nursery. They are sieved and mixed just before the preparation of the beds or filling of the tubes. Pine soil was formerly considered necessary to ensure mycorrhizal infection of the seedlings. In early times pine soil was often hard to obtain and was brought from long distances and, therefore, the amount used in the mixture was as small as was considered effective. Today, nurseries are often surrounded by pine plantations and all the forest soil to nurseries could be taken from them as well. On the other hand, old nurseries are usually well infected with mycorrhizal fungi and, therefore, deliberate inoculation is not necessary. Many nurserymen no longer bring new pine soil to the nursery every year but instead mix the remaining soil of the Swaziland beds with the new soil, thus securing the presence of mycorrhizal infection.

Commercial fertilizers are also added to the mixture in many nurseries but not in all of them. The standard dose is 1 oz. of NPK (ammonium sulphate, superphosphate and muriate of potash in proportions of 3: 3: 1) per four gallons of soil or 1 lb. of ammonium sulphate and 1 lb. of superphosphate per m^3.

The same soil mixture is ordinarily used for all tree species, with the exception that

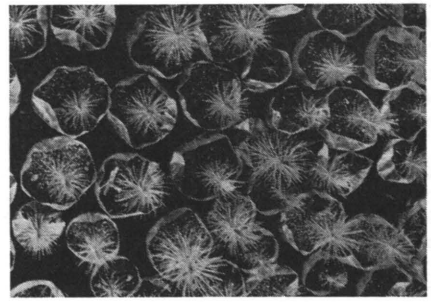

Fig. 5. *Pinus elliottii* seedlings growing in polythene tubes. Lushoto, Tanzania.

pine soil is not added to the mixture for cypress and broad-leaved trees.

The above mixtures are for transplant beds and tubes. For seedbed soil, there is also a great variation, ranging from pure river sand to the same mixtures as are used for transplants. In some nurseries seed was sown on the standard soil mixture and covered with pure sand.

Timing of nursery operations depends on climatic conditions. Near the Equator, as in northern Tanzania and southern Kenya, there are two rainy seasons annually and, consequently, two suitable planting seasons, November and April. November is usually preferred, because the short dry season from January to March is less severe than the long one from June to October, and it is very important that the seedlings become well established before the long dry season sets in. In some areas, such as the Kenyan Highlands, and particularly in some years, rains in November and December are irregular and may even fail completely, and under such conditions April is a more reliable season for planting. In southern Tanzania there is only one long rainy season, the early part of which, i.e. November and December, is used for planting.

25—30 cm is considered the optimal height for plantable seedlings, and sowing is timed so that the seedlings have this height at the commencement of the rainy season. The time needed depends, in turn, on the climate and tree species. Thus, at high altitudes, as above 2 000 metres in the Kenyan Highlands, *Pinus patula* needs 16—18 months in the nursery, in the Southern Highlands of Tanzania (1 800—2 000 m) 12—14 months, and in western Uganda (about 1 500 m) 10—12 months. *Pinus elliottii*, *P. caribaea* and *Cupressus lusitanica* grow a little faster and are therefore sown one or two months later than *P. patula*. 4—6 weeks after sowing the seedlings are ordinarily transplanted into Swaziland beds.

Seedbeds are usually protected against direct sunshine and so are transplant beds during the first weeks after transplanting. Reed screens and bracken leaves were the methods most commonly used for shading.

All the nurseries in East Africa, as well as elsewhere in Africa, were conspicuously clean; hardly any weeds were seen. Weeding, however, was going on all the time. All weeding was done by hand; no chemical weed-killers were used, neither was any soil sterilization practised in East Africa. The heaviest work in the nurseries was watering. Nurseries usually had a reservoir, where water was pumped with a hand or motor pump, but from the reservoir to the beds water was carried in sprinkling cans. The daily rate of watering was about 5 litres per m^2. Thus, even during the quiet season a considerable number of workers were employed in the nurseries, in weeding, root-pruning, and watering. During my visit, transplanting was in progress in several nurseries and in some others, where the work was timed for April planting, preparation of beds was in progress.

NIGERIA. I visited four nurseries in Nigeria in October of 1967.

Softwood afforestation is quite recent in Nigeria. Of the four nurseries visited, only one (Bukuru in Jos Plateau) operated on a field scale, whereas in the other three seedlings were being raised for experimental plots (Fig. 7). In all the nurseries the main crop consisted of eucalypts and other hardwoods, whereas only a few thousand pine

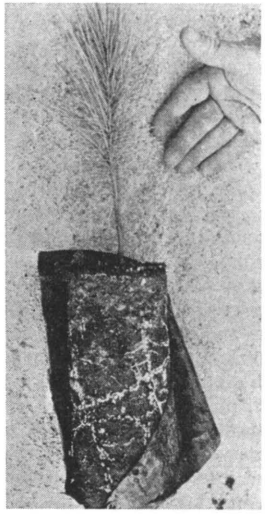

Fig. 6. A plantable *Pinus caribaea* seedling in a polythene bag. The bag has been opened to show the mycorrhizal development of the roots. Samaru, Nigeria.

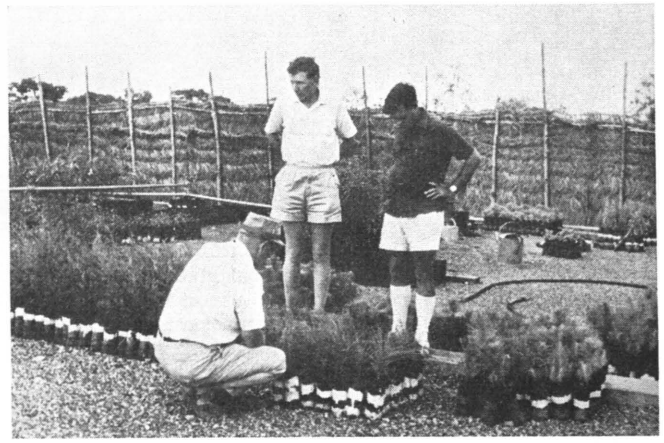

Fig. 7. Plantable seedlings of different tree species in polythene bags. The bags have been marked with paint rings to indicate the species. Samaru, Nigeria.

seedlings were raised annually. Nigeria has considerable experience in growing tropical hardwoods in the nursery (see IYAMABO 1967). The technique of growing hardwoods has therefore been adopted to conifers too, and the South African technique has had less influence in West Africa.

Of the different species of pines, *Pinus oocarpa*, *P. khasya* and *P. caribaea* have proved most promising in Northern Nigeria, with its long and severe dry season, whereas *P. caribaea* is the only conifer suitable for the hot rainy south.

The present nursery technique somewhat resembles that of Zambia, although several details are still under experimentation. Seed is germinated in bags mixed with moist sand. From time to time the content of a bag is poured into water, and germinating seeds are picked out and transplanted into polythene bags. Unlike the Zambian tubes, the bags had a bottom (Fig. 6). They were 25 cm in height and 8 cm in diameter. Seedlings are planted out in the field in June — August at the age of 6—8 months.

The composition of the soil mixture is still under experimentation. Bukuru nursery used a mixture of 4 parts of sand, 2 parts of compost and 1 part of natural top soil from indigenous hardwood forests. Mycorrhizal inoculation was performed individually by bringing about one teaspoonful of pine soil to the base of each seedling; this was done one or two months after transplanting.

MEDITERRANEAN AREA

TUNISIA. I visited nine nurseries in Tunisia in October, 1967.

The Mediterranean climate is characterized by very dry, warm summers and cool rainy winters. The greatest hazard for afforestation is the long, severe summer drought, which in Tunisia is further accentuated by the fact that only the most barren and unproductive sites, i.e. eroded mountain slopes and coastal sand dunes, are allocated for afforestation.

Pinus pinea is the main species in the nurseries raising planting stock for sand dune afforestation in the northeast (Cap Bon). Formerly, *P. halepensis* had been raised and large areas in Cap Bon had been planted with this species, but it was no longer raised in any of the three nurseries visited in Cap Bon. *Eucalyptus* spp. (mainly *E. camaldulensis*) and *Acacia cyanophylla* are other important species in Cap Bon nurseries. *Acacia cyanophylla* in particular, as a nitrogen-fixing plant, is an excellent pioneer species for sand dunes, and good soil for the nurseries is obtained from *Acacia* plantations.

Fig. 8. Seedlings of *Pinus halepensis* in polythene bags. The beds are bordered with clay pots. Mellegue nursery, Tunisia.

In the most humid part of Tunisia, along the north coast and in the northern mountains, it is possible to grow *Pinus pinaster* and *P. radiata*, which are the main species in the nurseries of that area (Tamera, Sahouania, and Ain Draham). Other conifers were *Pinus pinea* and *Cupressus sempervirens*, and *Eucalyptus* and *Acacia* spp. are raised here too. Further south, the nurseries (Mellegue and Ain Djemala) raise seedlings for afforestation of limestone mountains and, consequently, *Pinus halepensis* is the main species.

Annual production ranges from 0.5 to 2 mill. seedlings per nursery.

Detailed instructions have been given to the nurseries and, accordingly, the techniques were very similar in all the nurseries visited. The polythene bag technique is used everywhere. Formerly seedlings had been raised individually in clay pots, but clay pots are both bulky and expensive and therefore they have been replaced by polythene bags. It is estimated that the same space in the nursery bed is needed for 100 clay pots as for 400 polythene bags. Nurseries still had large numbers of clay pots, which were not used at all or were kept for raising eucalypts and acacias, whereas pines were always raised in polythene bags. In several nurseries clay pots were lined to make the edge rows of the nursery beds (Fig. 8).

In general, the Tunisian nursery technique resembles very much that described previously for Usutu Forest in Swaziland. These are the essential differences: Bags of transparent polythene with bottom were used in Tunisia, whereas Usutu nurseries used bottomless tubes of black polythene. The Tunisian bags were somewhat bigger, i.e. the height was 25 cm and the diameter 8 cm (»5 inches flat»). In Tunisia the nursery beds were dug into the soil so that the tops of the bags or pots were at the ground level, whereas in Swaziland, as well as in Zambia, the tubes stood on the ground.

Fig. 9. A general view of Tamera nursery, Tunisia. All the seedlings (*Pinus pinaster*) are growing in polythene bags.

Seed was sown directly into the bags, three seeds per bag, and the surplus seedlings were later removed. In many nurseries, however, the surplus seedlings were not discarded, but were transplanted into new bags. This operation was usually not very successful, however, because it was difficult to remove the seedlings from the original bags without damaging the roots and therefore many seedlings died after transplanting. In Tamera nursery (Fig. 9) the surplus seedlings were »bulleted». This was done by making a clay cake or »bullet», 10 cm long and 5—6 cm thick, which was cut from one side to the middle and the roots of a seedling were placed in the slit, which was then closed again. The »bullets» were then put into nursery beds and the space between them filled with sand. The bulleting method was said to originate from Madagascar. Both transplanting and »bulleting» the surplus seedlings seemed futile, because it was slow and cumbersome work and there was no need to save the seed.

For drainage, the lower part of the bags had some holes. Because some roots grew through these holes into the ground, »root pruning» was performed from time to time by lifting the bags from the ground, cutting the outgrowing roots and replacing the bags.

The soil mixture in the bags varies according to the tree species and the local soil conditions. In the Cap Bon nurseries, for instance, where *Pinus pinea*, *Eucalyptus* and *Acacia* seedlings were raised for sand dune afforestation, top soil from local bush (*Quercus coccifera*, *Juniperus oxycedrus*, etc.) or from *Eucalyptus* and *Acacia* plantations was used as such. Nurseries of the north coast used a mixture containing two parts of top soil from local *Quercus suber* forests and one part of river sand. Mellegue and Ain Djemala nurseries also used a mixture of local soil and sand, but added about 25 % of cattle manure. A very large amount of soil has to be brought to the nurseries every year (about 500 m^3 per 1 mill. seedlings). The soil is probably very alkaline, at least in the *Pinus halepensis* nurseries of the limestone area, but no pH determinations had been made.

No commercial fertilizers are used in any Tunisian nursery. Neither is any mycorrhizal inoculation practised.

The ordinary planting season in Tunisia is the early winter, i.e. November and December. Pines are sown in nurseries in winter, from January to the end of March, *Pinus radiata* even as late as April, i.e. they are planted at the age of 8—11 months, whereas the fast-growing eucalypts and acacias are sown later, usually in June.

In spite of the hot dry summer, no shading was used in Tunisian nurseries. The research

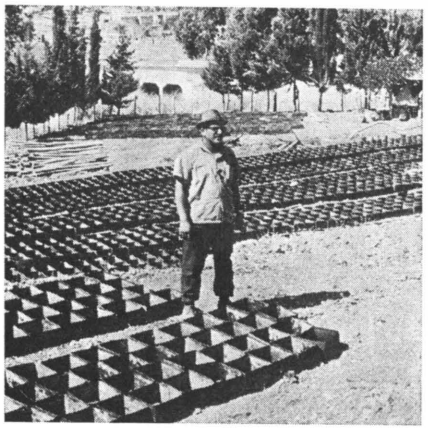

Fig. 10. Empty tins ready for filling with the soil and sowing. Little Mt. Hermon nursery, Israel.

nursery of the Forest Research Institute at Ariana was the only one where reed screens were used to protect the seedlings from the sun.

The high salinity of the irrigation water, particularly in late summer, is a serious problem in many nurseries.

Because of the inefficiency of the labour and low degree of mechanization, the number of workers in the nurseries was surprisingly high. A nursery with an annual production of 1.5 mill. seedlings was said to employ 25 permanent workers and, in addition to that, some 30 temporary workers were needed at peak seasons. All the nursery workers were men; no women were seen.

ISRAEL. I visited seven nurseries in Israel in late September of 1967.

The climatic and soil conditions of Israel very much resemble those of Tunisia, described above. The soil is everywhere highly calcareous, terra rossa and rendzina being the dominant soil types. The pH of these soils ranges between 7.5 and 8.0. Only sites which are unsuitable for agriculture are allocated for afforestation, i.e. barren and rocky mountains and coastal sand dunes.

Pinus halepensis and its close relative *P. brutia* are the principal species used for afforestation of the calcareous mountains. *Cupressus sempervirens* and, to a lesser extent, *C. arizonica* are grown for planting on deeper soils, and the nurseries also usually raise small numbers of *Pinus pinea* and *P. canariensis* seedlings. *Eucalyptus camaldulensis* and *Acacia cyanophylla* are the main hardwoods, comprising together some 20 % of the production of the nurseries.

In spite of similar climate and soils, the nursery technique in Israel was very different from that of Tunisia (KARSCHON 1961). The technique was exactly the same in all the nurseries visited in Israel and apparently determined by higher authorities. A tray method was the standard technique for aleppo and brutia pines and cypresses. The trays were iron-plate tins, $24 \times 24 \times 14$ cm in size, with a replaceable perforated bottom (Fig. 10). To protect the tins against corrosion, they were treated with coal tar. *Pinus pinea* and *P. canariensis*, as well as eucalypts and acacias, were usually grown individually in polythene bags, clay pots or other containers (Fig. 11).

Trays of the same kind were used for both sowing and transplantation. To improve drainage, crushed rock or coarse gravel was first placed on the bottom of the tin, which was then filled with soil. Different soil mixtures were used for sowing and transplanting. A mixture of sand and grey rendzina was most commonly used in seeding trays, whereas terra rossa or other local soil without admixed sand was used for transplants. Special soil mixtures were also used for eucalypts and acacias. About 100 m³ of new soil per million seedlings was brought to the nursery annually.

Seed is sown either broadcast or in rows and covered with sand or rendzina soil. This is done in October. About three months later young seedlings are transplanted, 16 seedlings per tin. Sowings are protected from birds with wire netting but no shading is used in Israeli nurseries. The ordinary planting season is in December and January, i.e. pines and cypresses are planted at the age of 14 or 15 months. The slow-growing *Pinus brutia* is sometimes kept in the nursery for two years. Eucalypts are sown in May or June and planted out at the age of 6 or 8 months.

No commercial fertilizers are used in Israeli nurseries. All the weeding is done by hand and no chemical fungicides or insecticides are applied, neither is any soil sterilization practised.

The seedlings are usually removed from the tins in the nursery; they are packed into wooden boxes for transportation and planted with naked roots. For difficult sites only the tins are brought to the planting site and the seedlings are planted with a soil ball around the roots.

ITALY. I visited five Italian nurseries in September 1967. Two of them were located in central Italy near Rome, whereas the three others were in northern Italy, i.e. outside the range of the typical Mediterranean climate.

Pinus radiata is the principal conifer in the central Italian nurseries. Eucalypts are also raised on a large scale and, of course, poplars, for which, however, the technique is completely different.

Pine seed is sown in seedbeds and the young seedlings are transplanted into black polythene bags. For eucalypts the technique is the same, with the exception that eucalypts are transplanted 30 or 40 days after sowing, whereas pines are transplanted at the age of three months. Both species are planted out six months after transplanting, and nursery operations are timed for the planting season from November until January.

Transplantation into polythene bags is highly mechanized. (The transplanting machine is described in FAO Forestry Equipment Notes A.56.68, 1968.) A crew of one man and three women transplants 700 seedlings per hour.

The soil for seedbeds and potting is an artificial mixture containing 90 % of natural top soil and 10 % of cow manure. No commercial fertilizers are used. The ingredients are thoroughly mixed and seasoned in heaps for two years. Before use the soil mixture is usually sterilized with steam. Because of damping-off, sterilization is considered necessary for pines, whereas it is not so important for eucalypts. To go through the transplanting machine the soil has to be relatively dry and, therefore, the seedlings are thoroughly watered immediately after transplantation.

The conventional open-bed technique of temperate areas was used in northern Italy, i.e. both seedlings and transplants were raised in natural soil in beds on the open field.

An interesting feature in northern Italy was the long time that the young trees remained in the nursery. While radiata pine seedlings in central Italy were planted at the age of 9 months, white pines (*Pinus strobus* and *P. griffithii*) were kept two or three years in seedbeds and again two years in transplant beds, i.e. the trees were planted out at the age of 4 or 5 years. For faster growing conifers (*Pinus nigra*, *Pseudotsuga menziesii*, etc.) the nursery period was somewhat shorter. Such plants were already rather big, 1 to 1.5 metres tall, and therefore wide spacing (30×80 cm) was used in the transplant beds. Seedlings and transplants are usually raised in separate nurseries, in other words, seedlings are raised in a central nursery near the forestry headquarters, whereas transplant nurseries are located near the planting sites, in order to reduce the work and cost of the transportation of large transplants. Both seedling and transplant nurseries were on old agricultural soil, usually abandoned fields. Heavy fertilization was applied, e.g. before transplantation

Fig. 11. Seedlings of *Cupressus sempervirens* growing in iron tins, 16 seedlings per tin. In the background *Pinus pinea* seedlings are growing individually in polythene bags. Megiddo nursery, Israel.

the soil received 30 tons of manure, 700 kg of superphosphate, 300 kg of ammonium sulphate, and 300 kg of potassium sulphate per hectare.

SPAIN. I visited three nurseries in Spain, each of them representing rather different conditions and, correspondingly, different techniques were practised.

El Serranillo nursery northwest of Madrid was the only one in a typical Mediterranean climate. It raised *Pinus halepensis* and some other conifers (*P. nigra*, *Cupressus arizonica*) for afforestation of dry limestone mountains, where potted plants are essential for the success of plantations. Formerly, the seed was sown in beds in March and the seedlings were transplanted into clay pots or polythene bags one year later, and after another year the transplants were ready to be planted out. A recent trend, however, is to refrain from transplantation and to sow directly into polythene bags, as is done in Tunisia. Depending on the size of the seedlings, they are planted out at the age of one or two years. Local field soil (calcareous clay) was used as such for potting, and superphosphate was the only fertilizer applied in El Serranillo nursery; the rate was 2 kg per m^3 of potting soil.

Charca Verde nursery was located in a siliceous area northwest of Madrid, at an elevation of about 1 000 metres. The principal species were *Pinus silvestris*, *P. nigra*, and *Cupressus arizonica*. The local climate is sufficiently humid for the conventional open-air nursery technique, i.e. seedlings were raised in seedbeds for two years without transplantation and then planted out with naked roots. Formerly seedlings had been transplanted but, to reduce the costs, transplantation is now replaced by root purning at the beginning of the second growing season. The nursery had a permanent irrigation system from a nearby river. Fertilizers were applied at a rate of 200 kg of NPK per hectare before sowing.

The third nursery visited in Spain was El Garmo in Viscaya Province near the north coast. The climate is relatively humid and suitable for *Pinus radiata*, which was the main species grown. *Pinus radiata* was sown broadcast in seedbeds in May and planted out into the field in November or December, i.e. at the age of 6 or 7 months, when the height is 15 to 20 cm. Other conifers (*Pseudotsuga menziesii*, *Picea sitchensis*, etc.), with slower growth, were transplanted and kept in the nursery for two or three years. No irrigation was usually needed for *Pinus radiata*. The annual fertilization comprised 300 kg of superphosphate and 100 kg of ammonium sulphate per hectare.

AUSTRALIA AND NEW ZEALAND

I visited nine nurseries in the area, viz. four in Australia, three in New Zealand, and two in the Territory of Papua and New Guinea. The Australian nurseries were visited in April and the others in May of 1967. Pines were the principal crop in six nurseries, araucarias in two, and eucalypts in one nursery. The nursery technique depended both on tree species and on climatic conditions.

Pinus radiata is the main species in South Australia with its winter rain climate, as well as in New Zealand, where precipitation is fairly evenly distributed round the year. On the east coast of Australia, with summer rains, *Pinus elliottii* is the favourite pine species, and *P. caribaea* in the tropical areas of Queensland and New Guinea. Douglas fir, larch, and some other pine species are raised in New Zealand to a lesser extent.

Both *Pinus radiata* and *P. elliottii* are fast-growing and easy to raise in the nursery. Large nurseries, like Kaingaroa and Athol in New Zealand, produce several million seedlings per year. Nursery technique is about the same for both species, and similar to that in the southern United States, for instance. Seed is sown in drills in beds on the open field and seedlings are grown to a plantable size without transplanting. A plantable size corresponds to a height of 20—30, for *P. elliottii* even 40 cm, which the seedlings usually attain in 8—10 months. In New Zealand, however, *Pinus radiata* seedlings are sometimes kept in the nursery for 1 $^1/_2$ years. Thinning is often desirable, and root pruning is practised regularly. Douglas fir and other relatively slow-growing species are transplanted and kept in the nursery for two or three years.

Nursery operations are timed according to the planting season or early rainy season. Thus, in South Australia the planting season is in June and July and, accordingly, *Pinus radiata* is sown in the nursery in September, i.e. before the commencement of the dry season. In New Zealand all the winter from June through August is favourable for planting and, correspondingly, nursery sowings can be timed for a longer period, from September until February.

Fertilization policy is rather conservative. Thus, Mt. Gambier nursery in South Australia was raising radiata pine seedlings for sixth successive year and no fertilizers had ever been used. Beerburrum nursery in Queensland, raising slash pine, only used cow manure, at a rate of 25 tons per hectare annually, and fallowing and green manuring (legumes) were also regularly practised. The New Zealand nurseries used both organic (»blood and bone») and mineral fertilizers, although the rate was often perhaps insufficient, e.g. in Kaingaroa nursery symptoms of nutrient deficiency were clearly visible. Because nutrients are rapidly leached from some volcanic soils, more liberal application of top dressing during the growing season would probably be beneficial.

The polythene tube technique was applied for *Pinus caribaea* in Queensland and New Guinea, as well as for other pines (*P. patula*, *P. khasya*) in New Guinea. Seed was sown broadcast in seedbeds and the seedlings were transplanted into polythene tubes or bottomless bags, but unlike the African technique, as late as three months after sowing. Local top soil (from nursery, forest, or grassland) was used for tubing.

An interesting modification of the tube technique was seen in Olsen's Bridge nursery in Victoria, where pine veneer is used for the tubes. A veneer sheet 15 × 18 cm in size is rolled to make a cylinder, 15 cm high and 5 cm thick, which is then filled with soil and two or three eucalypt seeds are sown directly into the tube. (*Eucalyptus regnans* was the only species in the nursery.) Such tubed plants are easy to handle in the nursery and during transportation, and since the veneer rots rapidly in the soil, they can be planted without removing the tube. A special tubular spade had been constructed for planting the tubed plants.

Araucarias were also raised in tubes. Galvanized iron was used for tubing. The nursery procedure for raising araucarias is briefly as follows:

Fig. 12. Araucaria seedlings in metal tubes in a »high shade nursery». Bulolo, New Guinea.

Seeds are sown broadcast into seedbeds, where they are covered with sawdust, and the seedlings are allowed to grow for several months. From the seedbeds the seedlings are transplanted into the iron tubes. Technically this is done by putting a spadeful of soil on the middle of an iron sheet of 20 × 18 cm, placing a seedling on it, top outside the sheet, and rolling the sheet into a cylinder, 20 cm high, enclosing the soil and seedling roots. An experienced nursery worker does this in a few seconds. At the time of planting, the transplants are brought with the tubes to the planting site, where the tubes are opened again and the iron sheets are returned to the nursery for reuse. Timing of the operations varies. Thus, in Queensland hoop pine (*Araucaria cunninghamii*) is tubed at the age of 20 months and planted out three months after tubing. In New Guinea, again, both hoop and klinkii (*A. hunsteinii*) are tubed at the age of 7—9 months, whereas hoop is planted about 10 and klinkii 16 months after tubing. Araucarias are shaded all the time in the nursery; formerly the so-called low shade technique was used, slit screens being 60 cm above the beds, whereas modern nurseries have permanent screens at a height of 2 metres, allowing people to move freely below (Fig. 12).

LATIN AMERICA

I visited some ten nurseries in South and Central America, viz. in Chile, Argentina, Brazil, Trinidad and Puerto Rico, in June of 1967. The nursery technique for *Pinus radiata* in Chile and for *P. elliottii* in Argentina was conventional. The most interesting observations were made in the State of Sao Paulo in Brazil and in Trinidad.

Pinus elliottii is the principal species in the nurseries of Sao Paulo. The nursery technique can be called soil block technique. Seedlings were raised in compressed soil blocks, the height of which was 15 cm and the diameter of the hexagonal cross section 8 cm. A special machine was used, making seven blocks at a time (Fig. 13). The material for the soil blocks consisted of three parts of loamy subsoil and two parts of bagasse or cow manure. In the middle of the block the machine made a hole, 10 cm deep and 3 cm wide, which was filled with natural soil, and seed was sown or young seedling transplanted into this hole. *Pinus elliottii* was usually sown directly, 2 seeds per block, whereas eucalypts and some other species were first germinated in special germinating boxes and the young seedlings were transplanted into the blocks. In the Horto Florestal nursery of Sao Paolo, soil for the central hole in the blocks was taken from a nearby pine plantation, in order to guarantee early mycorrhizal infection of the seedlings.

After sowing the soil blocks were set on nursery beds and mulched with pine needle litter or shavings, which were removed after germination.

Soil blocks are sufficiently compact to last for 6—8 months, i.e. the time that the seedlings stay in the nursery. The roots gradually penetrate the soil block. For transportation the seedlings with the soil blocks or root balls were packed in wooden boxes, 35 seedlings per box, and were planted in the blocks.

Sowing or transplanting into the blocks was done in May or June and the seedlings were planted out in December and January.

Trinidad has a tropical climate without a very severe dry season. *Pinus caribaea* is the only pine species raised in the nurseries. There were only two pine nurseries in Trinidad, with a total production of some half a million seedlings per year.

Both nurseries used the traditional tray technique (Fig. 14), as has been described in the older nursery manuals for the tropics (e.g. Parry 1956). In the early days of pine planting, about 1956, the Swaziland technique was used, but after a few years' experimentation the older tray method was adopted. I failed to discover, why the nurseries in Trinidad had shifted from the Swaziland technique to the tray method, whereas the opposite change had taken place in the African nurseries.

Seed was sown in sand in large germination boxes with a surface are of about 3 m² and a depth of 40 cm. First a thick layer of gravel

Fig. 13. Machine for making soil blocks. Horto Florestal, Sao Paulo, Brazil.

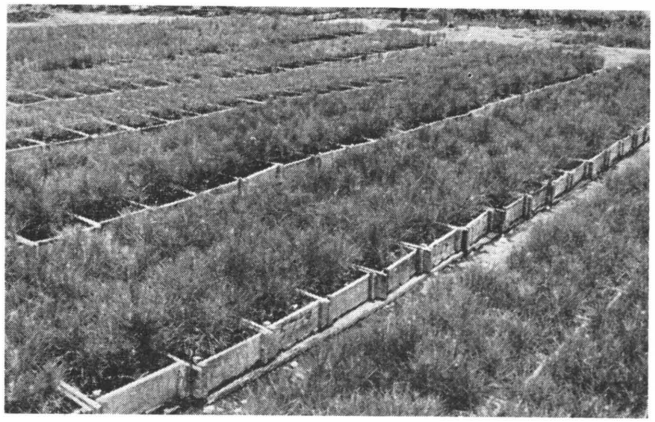

Fig. 14. *Pinus caribaea* seedlings in wooden trays, 53 seedlings per tray. Cumuto, Trinidad.

was placed on the bottom of the boxes, to guarantee good drainage, and on the top of it a layer of sand, 15 cm thick, which was sterilized with formaldehyde against damping-off. The germination boxes were kept heavily shaded under a shelter.

About three weeks after sowing the young seedlings were transplanted into wooden trays or boxes, $50 \times 35 \times 10$ cm in size, 53 seedlings per tray (the number 53 corresponds to 6×9, leaving one corner open). The soil mixture for transplant trays consisted of 40 % of forest top soil, 25 % of manure, 25 % of bagasse, and 10 % of sand. For mycorrhizal infection, a small amount of pine soil was added to the trays. Ammonium sulphate was applied as top dressing if symptoms of nitrogen deficiency appeared.

Because of the long rainy season, field planting is possible from May to the end of September. Seedlings are planted at the age of 8 months, corresponding to a height of about 20 cm, and sowings in the nursery were timed correspondingly. Vertical root pruning was performed monthly.

The trays are taken to the planting site, where the seedlings are loosened by cutting vertically with a knife. Because of the warm and humid climate, the wooden trays only last two or three years.

Although the climatic conditions of Puerto Rico are very similar to those of Trinidad, the nursery technique is quite different (Marrero 1962). Pine seedlings are raised there in polythene bags, approximately as has been described above for Nigeria. The method of mycorrhizal inoculation is also the same, i.e. the bags are inoculated individually with pine soil a few weeks after transplanting. So far pines have been raised in Puerto Rico on an experimental scale only.

COMPARISON WITH RECENT TRENDS IN FINLAND

For many decades, tree seedlings for planting were raised in Finland by the conventional European method, i.e. in natural field soil in open-air nurseries. Seed was sown into drills in seedbeds and the seedlings were usually transplanted into transplant beds at the age of two years, where they remained for one (pine) or two (spruce) years before planting out. Moderate fertilization and watering were applied, and weeding usually constituted a considerable part of the nursery work and expenses. In recent years, however, a complete revolution has taken place in Finnish nursery practice, the use of plastic greenhouses of light construction and of an artificial soil substrate (fertilized peat) being essential features of the new technique.

The new Finnish technique shows some interesting similarities to the practices of tropical and subtropical nurseries. Although the tropical nursery technique has probably not directly affected the recent development in Finland, nor vice versa, there is good reason for the comparison.

Because no detailed account of the new Finnish technique is available in the English language, its main features are briefly described below. The technique has been described in the German and Swedish languages by Leskinen (1965, 1966).

Plastic greenhouse were first introduced into Finnish forestry in the 1950's by the Tree Breeding Foundation,which in the beginning used them for grafting and other breeding work (Leskinen 1963). Later, however, they were also adopted in commercial nurseries for the production of l-year-old seedlings, which were transplanted the following spring into transplant beds on open field. Today in Finnish forest nurseries practically all seed is sown and seedlings are grown in greenhouses the first summer. In recent years many nurserymen have even started to grow transplants in greenhouses. A standard greenhouse has a height of 2.5 or 3 metres, a width of 7.5 or 10 metres, and the length can even exceed 100 metres. For details of construction, see Leskinen 1963.

The main reason for the use of the greenhouses in forest nurseries is to overcome the difficulties caused by the cold climate and short growing season. Greenhouses are erected early in the spring (in April) when there may still be snow on the ground, and thus sowing can be started about one month earlier in the greenhouse than in the open. All through the summer the air in the greenhouse is warmer than outside and, consequently, the seedlings grow much faster, being as tall or taller after one summer than after two years in the open. The greenhouses are removed in September, in order to harden the seedlings before winter. The seedlings hibernate under a protective snow cover, and the following spring they are transplanted either into greenhouses or into the open field. Spruce transplants are usually kept two years in the nursery beds, whereas in the greenhouse they attain the same or larger size in one year.

Thus, the aim of the greenhouses in forest nurseries is to hasten the development of the seedlings and to shorten the nursery rotation. By this method larger seedlings are produced in two years than in four years in the former open-field nurseries. The nursery rotation can probably be shortened even more: on an experimental scale seedlings have been transplanted into greenhouses in the middle of the first summer and then they can be planted out the following spring, i.e. one year after sowing. Thus, the length of the nursery rotation approaches that of the tropics. The colder the climate, the greater the advantage of the greenhouses appears in comparison to an open-field nursery, as is clearly seen, for instance, in a big State nursery 150 km north of the arctic circle.

The greenhouses also offer other advantages. Watering can be controlled more precisely than in the open, by adding fertilizers to the irrigation water the nutrient level is easy to adjust, pesticides can be applied more economically than in the open, and artificial increase of the CO_2 content of the air is possible. All these measures have been applied advantageously in Finnish nurseries. There

are also good chances for automatic control of different operations, such as ventilation, irrigation, fertilizer application, and CO_2 generation. Because of liberal irrigation the humidity of the greenhouse air is high, which, together with high temperature, creates a really »tropical» climate in the greenhouses.

Fertilized peat is used as growth substrate in the greenhouses. The beds are usually made ready before the houses are erected. A 15 cm thick layer of shredded peat is spread evenly on the ground, and calculated amounts of fertilizers are added and thoroughly mixed.

Peat is an ideal substrate for growing tree seedlings in the nursery (PUUSTJÄRVI 1967). It has been used for a long time for growing ornamentals and vegetables in greenhouses and was adopted in forest nurseries simultaneously with the plastic greenhouses. A raw *Sphagnum* peat is preferred for forest trees. It is a rather inert material, which decomposes slowly but has both a high water-holding capacity and good aeration. The basic fertilization varies somewhat, depending on the quality of the peat; the following average dosages per cubic metre are recommended (PUUSTJÄRVI):

Ground dolomite limestone	6–8	kg
Potassium sulphate	1	»
Double superphosphate	0.6–0.8	»

Trace elements (B, Cu, Mn) are also added. Nitrogen is given repeatedly during the growing season, either in powder form or in solution with irrigation. Combined fertilizers (NPK) are also often used for top dressing.

Seed is sown broadcast on the top of the peat substrate and needs no cover.

Peat beds in the greenhouses have some resemblance to the Swaziland beds of tropical nurseries. The seedlings develop dense and compact root systems in well fertilized and watered peat, and when the seedlings are lifted, the peat adheres to the roots. Thus a great deal of the substrate is removed with the seedlings. The same peat is used for two or three seedling crops. With advanced humification of the peat aeration gets poorer; therefore fresh peat is preferred for seedbeds in greenhouses and the old humified material is used for soil amendment of transplanting fields in the open.

Because the peat, when taken from the bog, is free of weed seeds, practically no weeding is needed in the greenhouses. But after prolonged use of the same peat, weeds appear in the greenhouses, and therefore frequent renewal is advisable.

A peat substrate in greenhouses gives much higher yields of seedlings than the conventional technique. Up to 150 000 plantable seedlings per 1 kg of Scotch pine seed can be obtained with the new technique, whereas the corresponding figure for open-field nurseries hardly exceeded 50 000. This is a great advantage, because shortage of seed is the factor limiting reforestation.

The Finnish nursery technique has other aims too in common with tropical silviculture, viz. to omit transplanting of seedlings and to produce potted seedlings that are easy to handle and transport. Peat pots (»jiffy-pots»), filled with fertilized peat, have given excellent results. Two to three seeds are sown per pot and later on surplus seedlings are cut off. With this method in plastic greenhouses plantable seedlings can be raised in one growing season without transplanting. Packing of the seedlings with peat pots and their transportation to planting sites involves considerable difficulty and high cost. To reduce these drawbacks, Japanese paper pots, likewise filled with peat, have been introduced to replace the inconvenient peat pots. This technique has a great resemblance to the present practice of Usutu Pulp of Swaziland, for instance. Polythene tubes or bags, which have a wide application in the tropics and subtropics, are very little used in Finnish nurseries. Probably the filling of the tubes or bags would be too big a problem in a country with an annual planting programme of some 300 million seedlings.

Modern nurseries in Europe and the United States, using the conventional technique, are highly mechanized and the need of human labour has been reduced to a minimum. For the time being, the new Finnish technique means a decreased degree of mechanization. The advantages of the technique (higher yields, shorter rotation, elimination of weeding, etc.) are so great, however, that they fully compensate for the increased human labour needed, and the price of the seedlings is even lower than with the old method. The new technique is still in process of development and offers so great possibilities for mechanization and automation (watering, temperature control, CO_2 fertilization, etc.) that the quality of the seedlings can probably be considerably improved at the same time as production costs are lowered. The same holds true, perhaps to a still greater extent, of the nurseries of the tropical and subtropical countries.

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