Establishment and management of tree plantations in southern Brazil

Finnish - Brazilian cooperation in forest research

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Metsäntutkimuslaitoksen tiedonantoja 594
The Finnish Forest Research Institute, Research Papers 594
Joensuu 1996

Parviainen, Jari, Tervo, Leo, Carneiro, Jose & Soares, Ronaldo. 1996. Establishment and management of tree plantations in southern Brazil. Finnish - Brasilian cooperation in forest research. Metsäntutkimuslaitoksen tiedonantoja 594 53 s. The Finnish Forest Research Institute, Research Papers 594, 53 p. ISBN 951-40-1503-7, ISSN 0358-4283.

Implementing a large-scale planting programme in Brazil requires reliable and efficient production of planting stock. The current reforestation area corresponds to an annual production of 200 million seedlings, which is slightly more than Finland´s current production of forest tree seedlings. To date, forest tree nursery production in Brazil has been based primarily on the production of containerised planting stock. Especially eucalyptus seedlings have been raised in containers.

The choice of seedling production and plantation establishment method depends on the company´s objectives. When considering the minimisation of risks, the containerised option is safe choice; success of planting is assured, the planting period can be extended, and nursery work can be rationalised. Bare-rooted stock are easy to produce and plant, and do not require high investments, but the climatical conditions for planting (i.e. survival) of bare-rooted stock have to be certain. Finnish methods of raising containerised planting stock are appropriate for application in most regions of Brazil following minor modifications which depend on the used tree species. Where sosio-economic conditions and infrastructure allow even the most advanced tree seedling raising and planting methods can prove to be both successful and cost-competitive.

Key words: pine, eucalyptus, plantations, tree seedling production, planting

Publisher: The Finnish Forest Research Institute. Accepted for publication by Professor Matti Kärkkäinen, Research Director, in March 23, 1996.

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PunaMusta Joensuu 1996

Preface

Ten years ago, in 1985, the Universidade Federal do Paraná (UFPR) and the Finnish Forest Research Institute (Metla) undersigned a cooperation agreement in forestry research. The importance of forestry cooperation was emphasized in the technical and economic bilateral cooperation discussions held between Brazil and Finland in 1984, and the forestry cooperation was included in the minutes of the negotiations. The goal was to promote research in subjects of mutual interest, to establish collaboration contacts and encourage dissemination of information about forestry and forest industry. The original programme was composed of four themes: production methods of containerised tree seedlings, dendrochronology of *Araucaria angustifolia*, productivity and strain of workers in clear -cuttings of *Eucalyptus* plantations and the energy potential of thinning residue of *P.taeda* plantations (Material published in the report: Parviainen, J. and Carneiro, J. (ed.) 1988 , Metsäntutkimuslaitoksen tiedonantoja 302).

This first phase of the cooperation was financed by the Finnish Ministry of Foreign Affairs, Department of Commercial Policy. In order to strengthen collaboration and to outline, in detail, the most interesting fields and themes of cooperation, two forestry seminars were organized in 1987-1988. The first forestry seminar, with associated field excursion for the Brazilian participants was held in Finland, Helsinki in August 1987 (Material published in the report: Metsäntutkimuslaitoksen julkaisuja 273/1987). A corresponding seminar and excursion for Finnish participants was then organized in Brazil/Curitiba in October 1988 (Material published in the report: Bilateral Symposium Brazil-Finland on Forestry Actualities, 16 A 22 de Outubro, Curitiba 1988).

The next phase of collaboration was started in 1989, when the Finnish Ministry of Trade and Industry awarded funds for implementing two joint projects under the auspices of agreement. The other one of these new projects deals with the feasibility of logging mechanization in Brazilian pine and eucalyptus plantations and the another one with the raising and production technology of containerised tree seedlings. The logging mechanization project was finalized in 1991 and the results published (Hakkila, Malinovski & Sirén, Metsäntutkimuslaitoksen julkaisuja 404) and presented in a seminar in Curitiba in May 1992.

The project with containerised tree seedlings included an experiment in the forest research nursery of the Federal University of Paraná and several experiments in the nurseries of forest industry companies in South-Brazil as well as plantation experiments in the field. The original project was extended to last until to the end of 1995 in order to gain long-term experiences from the field experiments. The Finnish Company VAPO Oy was involved in the project throughout developing and delivering a root pruning equipment to Brazil for testing the applicability of the VAPO-method in subtropical conditions. In Brazil The Rigesa Company in Santa Catarina/Canoinhas made it possible to test, modify and adapt the Finnish methods in the practical forest nursery operations.

In addition to the containerised tree seedling project Prof. J. Carneiro, as researcher and the former Brazilian cooperation coordinator, initiated to gather material in order to write a forest tree seedling manual for South American conditions. Main results achieved in this cooperation has been included in Carneiro's manual. The manual (*Producao e controle de qualidade de mudas florestais*) was completed at the end of 1995 and will be an important contribution to disseminate all the newest international results and practical experiences on the forest tree seedlings for South-American conditions.

This report deals with the establishment and management of forest plantations in South-Brazil and with the results of the containerised tree seedling project. For background and summarizing the cooperation also the state of the art of the plantation forestry in Southern Brazil has been reviewed.

The authors are grateful to the authorities who provided the framework and necessary support for the collaboration in both countries. Special thanks are extended to the Ambassador Pekka J. Korvenheimo, who was promoting widely the cooperation from the very beginning, to Mrs. Irmeli Mäki from the Finnish Ministry of Trade and Industry, to the VAPO company in Finland and as well as to Rigesa Company and its Forestry Director Etsuro Murakami in Brazil. We thank also all the organizations and persons who contributed to different phases of the project as well as several companies in Brazil and Finland who kindly offered their facilities and nurseries for testing the methods.

The report was revised by Professor Pentti Hakkila. Manuscript was skillfully typed by Mrs. Päivi Mäkkeli, figures drawn by Mrs. Seija Sulonen and the English language checked by Erkki Pekkinen.

Joensuu, Suonenjoki, Campos and Curitiba

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1. Introduction

Brazilian forestry is characterised by two contrasting factors: the diminishing of rainforests in the Amazon region and the extensive plantation forestry practised in southeast and southern Brazil. The total area covered by forests in Brazil (340 million hectares, 38 % of the landarea) is roughly sixteen times that in Finland (23 million hectares, 77 % of the land-area). Despite widespread planting of new forests, the forest cover in the Amazon region of northern Brazil is estimated to diminish annually by millions of hectares.

The establishing of plantation forests generally reduces the pressure to cut down virgin forests, but establishing plantation forests in the southern part of Brazil is not a substitute to the felling of rainforests in the Amazon region. According to the concept of sustainability, the plantations play a significant role in the worldwide carbon sequestration (UNCED Earth Summit in Rio 1992, the Helsinki-process and the Montreal-process). New requirements for sustainable forestry also presuppose that forest plantations are managed on an environmentally sound basis and that the adopted criteria and indicators are taken into consideration (see ITTO guidelines 1993).

Brazil's programme for establishing plantation forests is among the biggest in the world. Brazil has assumed the role of a trail blazer in promoting plantation forestry in the tropics and subtropics. The current area of plantation forests in southern Brazil is about 7 million hectares. This is nearly one-third of Finland's total forest area. In the 1980s, the target set for establishing plantation forests in Brazil was 16 million hectares by the year 2000 in order to meet the demand for forestry industry products at home and abroad (Kengen 1987, Murakami 1987, Rezende and Neves 1988). However, Brazil's economic situation and the cessation of taxation legislation supporting the establishing of plantations together mean that this target will not be reached. The current rate of reforestation has fallen to a mere 100 000 ha per annum; at its peak in the early 1980s the corresponding figure was 400 000 ha.

Forest regeneration, and forest tree seedling production, are being reassessed because of Brazil's economic situation. Since the Government revoked its previous taxation incentive targeted at companies investing in the establishing of plantation forests, companies are now forced to finance their forest planting activities internally. Consequently, more rational and cost-effective seedling production and planting options are being sought. Even though success may be achieved in cutting down the costs, it has become apparent that willingness to invest in plantation forests has undergone a lasting fall in Brazil.

Implementing a large-scale planting programme in Brazil requires reliable and efficient production of planting stock. The current reforestation area corresponds to an annual production of 200 million seedlings, which is slightly more than Finland's current production of forest tree seedlings. To date, forest tree nursery production in Brazil has been based primarily on the production of containerised planting stock. Especially eucalyptus seedlings have been raised in containers. In favourable climatical conditions pine tree seedlings are produced mainly as bare-rooted.

Intensive reforestation has been practised in Finland for over 40 years. The area of artificially regenerated forests totals 5,1 million hectares. This is equivalent to c. 25 % of the whole area of productive forests in Finland. New techniques for the production of Scots pine (*Pinus sylvestris* L.) seedlings especially have been developed during this period. The methods have received international attention, and many of the production solutions have been adopted in different parts of the world.

Plastic greenhouses have been introduced owing to the short growing season and need to speed up seedling production. The first fully automated production line for containerised forest tree seedlings (based on the paperpot method) was developed in the 1960's. Since then, various types production lines have been developed for raising small and large containerised seedlings. At the present (1994) annual production of tree seedlings in Finland is around 155 million, of which 80 % are containerised. The reforestation area totals 100 000 - 120 000 hectares annually. The experiences gained so far with plantations established using containerised seedlings have been favourable, and hence the proportion of containerised seedlings is continuously increasing (see Parviainen 1984, 1986, 1988, 1992).

Brazilian eucalyptus and pine plantations annually yield 90 million m^3 of timber. Fourty million m^3 of this amount is consumed by the forest industries and the remaining 50 million m^3 end up in energy generation. The harvested volume is expected to surpass the combined wood consumption of Finland and Sweden within ten years.

The harvesting and wood procurement conditions in the Brazilian plantation forests resemble the prevailing Finnish conditions in many respects. Wood harvesting in Brazil relies primarily on the use of chainsaws and agricultural tractors. Given that there is generally an adequate supply of labour, low wages and fairly high labour productivity, the overall costs remain low. Nevertheless, Brazilian forest industries are showing keen interest in developing new methods and in mechanising wood harvesting since the harvest volumes are due to increase, the supply of labour is feared to fall, and wages are expected to rise (see Hakkila et al. 1992 a and b).

The Finnish Forest Research Institute (Metla) and the Federal University of Paraná (UFPR) in Brazil have engaged in cooperation in forest research since 1985. The purpose of the cooperation is to promote forest research of mutual interest, bring about contacts among staff employed by various forestry organisations and government departments, and encourage information exchange in general. The research work conducted has opened up a channel for the launching of economic and technological cooperation and for commercial contacts between Finland and Brazil.

The objectives of this joint study are:

1) to present the state of the art situation of plantation forestry in southern Brazil

2) to compare and test different tree seedling raising methods, particularly for containerised pine and eucalyptus seedlings/ cuttings at the nursery production

3) to follow and compare the early development of these seedlings on typical planting areas

4) to evaluate the applicability of the Finnish production methods of containerised seedlings to South Brazilian conditions

Due to the similar production goals in the Finnish natural forest stands and Brazilian plantations (stand structure, tree size and homogeneity) it can be assumed that the same basic solutions in the establishment and management are applicable despite differences in the tree species and climate. However before the experiences gained under different conditions can be transferred as such or modified from one country to another, large scale practical experiences and tests are required.

2. Forest vegetation zones in Brazil

The original vegetation cover of Brazil (Fig. 1) may be described as follows:

- the *Amazonian forest* (rain tropical forest) covering all of the Amazon river basin, ca. 40% of the country
- the *Atlantic forest* covering the coastal mountains and the inland tablelands
- the *Araucaria* (*Araucaria angustifolia*) *forests* located in the southern parts of the country
- the *Cerrado*, low density forest vegetation with scattered and crooked trees, typical vegetation of compacted soils and soils with high aluminium content
- the *Caatinga*, light vegetation of species adapted to long dry periods
- the *Pantanal*, or swampy land, in the central-western parts of the country, rich in fauna (birds, rodents, cats, fish and alligators)
- the *native grasslands* located in the extreme south (*pampas*).

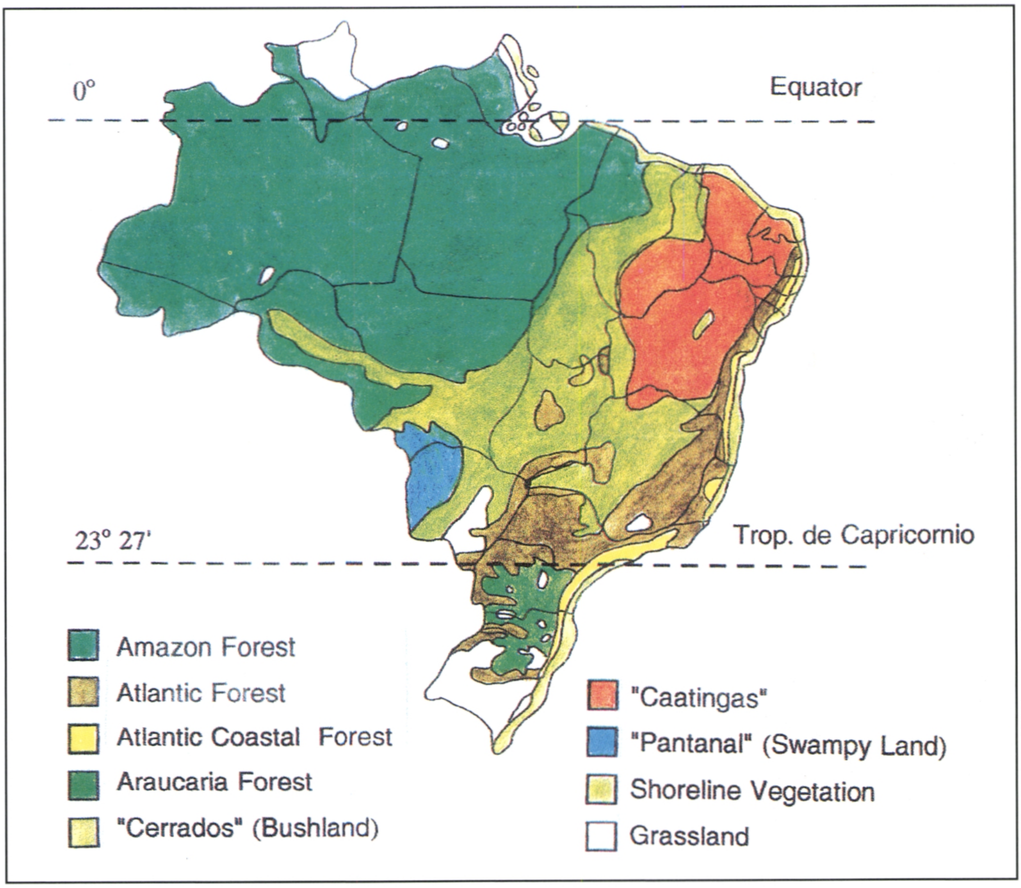

Figure 1. The original vegetation cover in Brazil.

Today, Brazil's indigenous forest resources are considered to have undergone changes as follows (Netto and Hosokawa 1979, Fernandes 1991, Sucheck 1991):

- the *coastal Atlantic forests* have practically been cleared for agriculture (coffee, sugar cane, rice, etc.) and pasture. The remaining virgin forests are at their most abundant in the vicinity of the coastal region in southern Brazil and in the not-accessible mountains near the coast (see Fig. 2). The climate in these regions is tropical and the forest cover is provided in the form of multi-storeyed mixed broadleaved forests.
- the *Araucaria forests* were practically exhausted in the early part of this century, most of the timber being exported. In association with araucaria, or *Paraná pine* as it is also called, there were a few high-quality broadleaved (hardwood) species, which were all intensively exploited to make room for agriculture. On the plains, only remnants of native forests are to be seen, as forest islets or distinct conservation areas. At present, native forests are being set aside through the issuing of felling restrictions and prohibitions.
- the *Cerrado* had essentially no value as timber and these areas were converted into pasture, with recent inroads being made by agriculture following the establishing of soil amelioration practices and irrigation to some extent.

Figure 2. The coastal Atlantic natural forest consist of multi-storeyed mixed broadleaved tree species. (Photo: Jari Parviainen)

- the *Amazonian forests* continue to exist, with perhaps as much as 80-90% of the their original coverage remaining. These forests are highly heterogeneous, with some 200 mature trees representing as many as 200 different species present on a single hectare of forest, making economic wood harvesting difficult. The obstacles presented by these forests - the generally poor soil, the severe climatic conditions with high temperatures and high humidity, the occurrence of various tropical diseases such as malaria - all have helped delay the opening up of this frontier to other land uses.

3. Vanishing of the forests in southern Brazil

Wood was the first product found in Brazil by the country's Portuguese colonisers: i.e. Brazil-wood (*Caesalpinia echinata*). Because of its red colour and good quality, Brazil-wood was harvested and delivered to Portugal during the 16th, 17th and 18th centuries. It was such an important product that it was eventually adopted as the name of the newly discovered country.

The first German and Italian immigrants came to Brazil's southern coastal regions in the early 1800s. At that time, the demand for wood was low. Land was being cleared for agriculture, but as chainsaws and clearing machinery were lacking, the growing of food crops on the relatively small clearings did not significantly disrupt the environment. In those times, Brazil was a country importing wood raw material. The first railway through the Araucaria growing area was constructed in 1885.

The situation was completely changed during the period between the two world wars. Timber harvesting was stepped up as more and more land was cleared for agriculture and coffee plantations (Fig. 3). Increasingly more forests were cut down to meet the demand from export markets. Exports of Araucaria in 1946 amounted to 0.7 million cubic metres: by 1951 this had risen to 1.2 million cubic metres; and in 1970 the figure of 2.5 million was broken. This level was maintained throughout the 1970s. In the 1980s, as accessible forests began to be depleted, there was a rapid decline. The principal importers of Araucaria wood were the United Kingdom and Argentina (Seitz 1983).

The rate at which forests were being depleted in southern Brazil is depicted by the following table on Araucaria forests and the graphic presentation on the trends in forest area in the states of Sao Paulo and Paraná (Fig. 4, Nock 1981, Stöhr & Hoogh 1979).

Depletion of Araucaria forests in the state of Paraná (Seitz 1983):

Year	Area (sq. kms)	%
initial forest area	73780	100.0
1930	39580	53.5
1950	25224	34.2
1973	4376	5.9
1978	3166	4.3

Figure 3. Clearing of forest land for growing coffee, sugar cone, other food crops or cattle grazing is the main reason for vanishing of forests in southern Brazil. (Photo: Jari Parviainen)

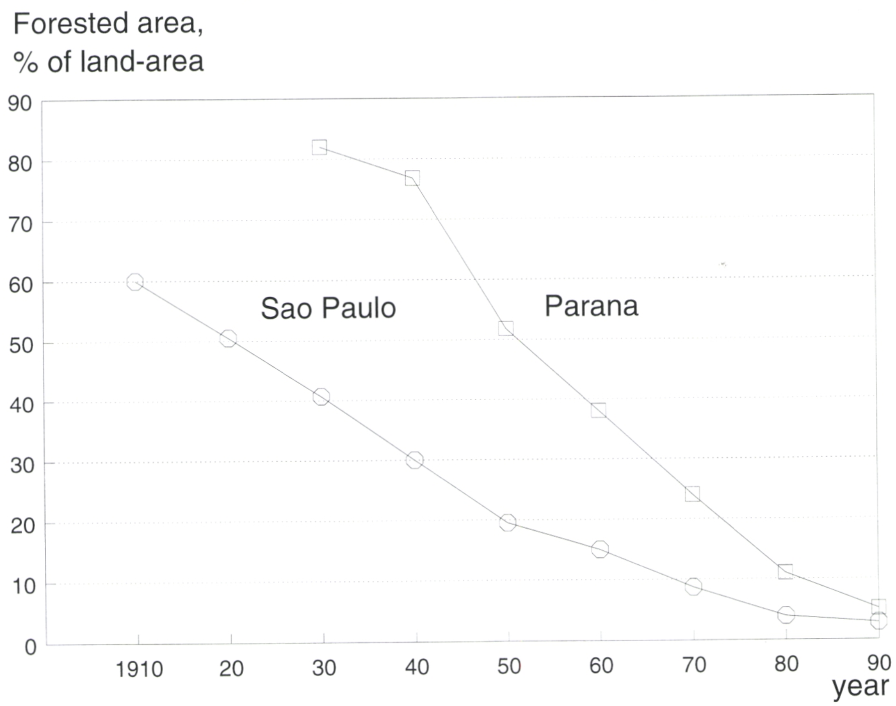

Figure 4. Depletion of forest area in Paraná and Sao Paulo states during 1910-1990 (Nock 1981, Stöhr and Hoogh 1979).

The initial forest area in both Paraná and Sao Paulo has diminished extremely rapidly during this century. About 5% of the original forest cover is left in Paraná and only 2-3 % in Sao Paulo. Felling was most active during the post-war years, during the period 1945 - 1970. Reasons for the heavy logging action lie in clearing of land for growing coffee, sugar cane, soybean, and other food crops, cattle grazing, human habitation, inappropriate commercial felling of forests, firewood procurement, and industrialisation.

The genus *Araucaria* is related to the genus *Pinus*. Along with the species belonging to the genus *Podocarpus*, *Araucarias* are one of the oldest and one of the few conifers of South America. There are two species of *Araucaria* on the continent; *Araucaria araucana* (Mol.)(E. Koch) in the south of Argentina and Chile, while *A. angustifolia* occurs on the tablelands of southern Brazil (see Fig. 1). Brazilian or Paraná pine (*Araucaria angustifolia* (Bert.) O. Ktze) is the symbol of the state of Paraná, but it is also a typical example of a threatened tree species in the light of the demise of forests in southern Brazil (Wainio 1888, Seitz 1983).

Figure 5. In the original, virgin forest the Paraná pine (*Araucaria angustifolia*) is a handsome tree with a umbrella - like top attaining heights of 50 meters. (Photo: Jari Parviainen)

A. angustifolia occurs in regions with a subtropical climate. This tree species is at its best when the mean temperature stays below 18°C. Annual precipitation should be in excess of 1250 mm. These conditions are met in the states of Paraná, Sao Paulo and Santa Catarina at altitudes of between 400 and 1500 m a.s.l. (Maack 1968, Fernandes 1991).

Forests with Araucarias have been mercilessly exploited as their wood is highly valued (Fig. 5). The wood of the Paraná pine enjoys great demand because of its suitability as sawnwood, for ornamental purposes, furniture, tooth picks, as well as raw material for the pulp and paper industry. The top of the tree with its branch whorls provides excellent raw material for ornamental wood articles such as lamp stands, lamp shades and candlesticks. Even the seeds of Araucaria are under threat - they are edible because of their large size. Araucaria seeds are seasonally available at local market places just like wild berries.

4. Reforestation programmes and forest industries

The drawbacks of diminishing forest resources were recognised already in the early years of this century. Planting trials with fast-growing tree species were commenced. Railway transportation with its steam locomotives required fuelwood as the source of energy. Eucalyptus were introduced from Australia and they proved to be excellent in growth and soon became the most popular plantation species.

By the year 1966, southern Brazil had a combined forestry plantation area of ca. 600 000 hectares. The first *Eucalyptus* plantation were established by the Brazilian naturalist Andrade in 1903 in the state of Sao Paulo. The first *Araucaria* and *Pinus* plantations were established during the period 1943 - 1956. At first, the experiences were variable - at times the plantations were highly successful, at other times they failed miserably. The failures were attributable to inappropriate choice of sites, poor provenances, erroneous planting and tending methods, and damage by insect pests or fungi.

A significant stimulus to stepping up of reforestation came in the 1960s (Nock 1981). In 1966, as a means of preventing the diminishing of the country's forest cover, the Brazilian Government launched its programme of subsidies for forest regeneration activities. This entailed the formulation of a tax-incentive system, according to which industrial enterprises and private individuals were permitted to invest as much as 50% of their taxable income in forest regeneration projects approved by the Government. On the other hand, forestry industry enterprises were obligated to plant at least four trees for every cubic metre of wood they processed.

Thanks to Government subsidies, the reforestation area quickly expanded. Following the examples of successful plantation establishment, new plantations began to appear in central and southern Brazil. By the end of 1990, there were a total of 7.0 million hectares of plantation forests; of this amount, 6.0 million hectares had been planted with Government support. Self-financing by companies accounted for ca. 1.0 million hectares of plantations (Sucheck 1991).

Establishment of forest plantations in Brazil during the period 1967-1989.

Period	Government subsidied	Owner-financed	Total
		hectares	
1967 - 1969	296.539	41.146	337.685
1979 - 1979	3.113.396	178.871	3.292.267
1980 - 1989	2.447.326	704.872	3.152.198
-	5.857.261	924.889	6.782.150

Financial support by the Government for forestry planting has since ceased. As a consequence, there has been a dramatic fall in the rate at which plantation forests are being established. In the peak years, the early 1970s, some 350 000 - 400 000 hectares were planted annually. In recent years, the annual achievements in plantation establishment have been barely 100 000 hectares. The cessation of Government support means that new plantations must be financed by companies. This in turn means that increasing attention is being focused on profitability of such ventures and on assessing the potential of alternative sites.

In the case of the state of Paraná, the period 1990 - 1993 saw the establishing of 24 000 hectares of plantation forests, a mere quarter of the annual planting area in the peak years. This fall in the planting of new forests is bound to have a dramatic impact on the future of forestry in the region, because when the growing stock attains maturity (at ages less than 20 for pine and at age 6-7 years in the case of eucalyptus see Fig. 6) there will be less and less wood available while demand is increasing with the rise in the standard of living.

The majority of Brazil's plantation forests are located in the southern tablelands and along a narrow coastal strip (Fig. 7, Sucheck 1991). Pine plantations have been largely established in areas formerly occupied by araucaria forests. Eucalyptus plantations, on the other hand, are located in the rainiest and warmest parts of the states of Sao Paulo, Minais Gerais and Espirito Santo.

Figure 6. An unthinned 18 years old mature pine (*P. taeda*) plantation by end cutting in the state of Santa Catarina. (Photo: Jari Parviainen)

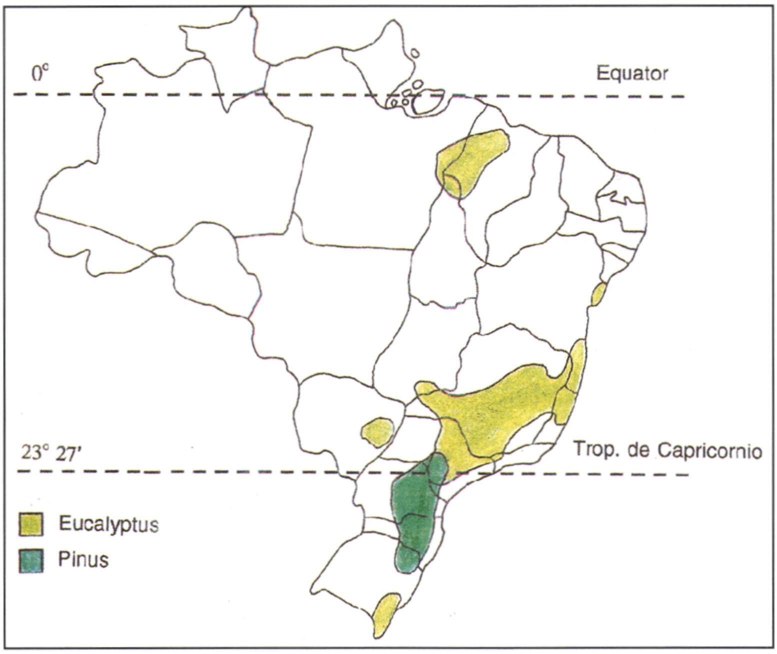

Figure 7. The location of forest plantations in Brazil.

The most essential aspect favouring the planting of fast-growing tree species has, however, been the strategy of the country's forestry industries. The establishing of plantation forests has led to a complete change in the traditional idea of practising forestry industry, because the planting of these forests has brought the forests into the proximity of industrial plants. The conventional practice, e.g. in the Nordic countries, has been to locate industry near plentiful forest resources with production relying on wood procurement from across a vast area.

Due to their rapid growth, plantations can be established to surround forestry industry plants. Consequently, the location of factories can then be selected in accordance with favourable infrastructure, good transport connections, labour availability, and the availability of land suitable for forestry. Company-owned plantations with the forests close to industry offer considerable advantages to the wood procurement and transportation. Costs can be minimised. Annual felling of timber can be concentrated on a single block, this is then replanted, and a new block is harvested the next year. The location of forestry industry plants in Brazil corresponds very closely to the location of plantations (see Fig. 8).

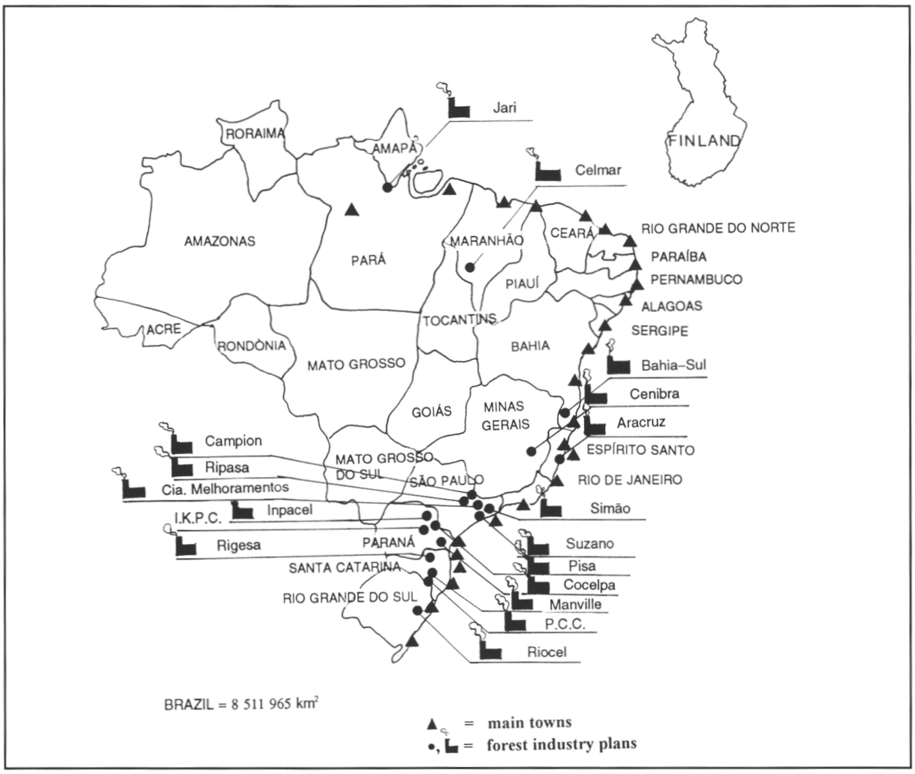

Figure 8. The location of forest industry plans in Brazil (see Murakami 1987).

Locally, plantation forestry may be seen to possess the following benefits (Nock 1981, Carvalho1988, Hakkila 1994):

- Conifer wood is in short supply in Brazil. Apart from araucaria, there are no other commercially significant indigenous conifers.
- The profitability per unit area of growing conifer plantations is manyfold when compared to utilising natural forests. This is an aspect of decisive significance to most investors.
- The present level of expertise is adequate for large-scale tending with less effort than when dealing with structurally more complex natural forests.
- Nursery production, establishing of plantations and wood harvesting from plantations allow the adoption of appropriate and tested know-how from abroad.
- The multiplier effects from the viewpoint of rural development:
  1) establishing a forestry plantation is another optional land-use form as increasing amounts of land are required for residential purposes and road construction, especially in the vicinity of towns;
  2) forestry plantations bring about not only high monetary yields to investors, but also jobs and income to people in forestry and forestry industry; and
  3) the jobs connected to plantations also alleviate the problems ensuing from internal migration as those employed by forestry settle down in rural areas.

Alongside the forestry planting programmes, the Brazilian authorities have produced production programmes for the country's forest industries. The aim has been to eventually achieve self-sufficiency in pulp and paper products and bring about a situation where exports of forestry industry products exceed the corresponding imports. In 1987 it was estimated that a total of ca. 16.5 million hectares of forest should be planted in Brazil by the year 2000 (Kengen 1987, Murakami 1987). Regardless of what may be done during the following remaining years, this goal will not be reached as only half of it has been implemented to date.

Nevertheless, the country's plantation forests have created a powerful forestry industry sector in Brazil. Brazil may be the world's foremost example of forestry-industry reliance on plantation forestry. In 1990, Brazil's paper and paperboard production reached the 5.0 million tonnes level. Pulp production has also reached this level (Sucheck 1991). In 1994 the corresponding figures for Finland were 11 and 10 million tonnes.

In 1990, Brazil's exports of both pulp and paper amounted to 1.0 million tonnes. Although Brazil concurrently imported newsprint and LWC paper, the country's own forestry industry production and export volumes clearly exceeded imports. At the same time, the export earnings of Brazil's forestry industries exceeded imports of the corresponding product categories by ca. USD 900 million. Thus, the 1980s were a period during which Brazil became a significant exporter of pulp and paper products, and world-class competitor in this sector (Rezende & Neves 1988, Sucheck 1991). Countries rivalling Brazil in terms of its leading product (eucalyptus pulp) are Spain and Portugal in Europe, and Chile in South America. When compared to Brazil, the wood production possibilities for regarding eucalyptus-based products in Spain and Portugal are, however, clearly less advantageous; e.g. due to slower growth and shortage of suitable land in the latter countries. The area of eucalyptus plantations in Chile is increasing, but the potential for expansion is limited by climatic conditions and insufficiency of land suitable for eucalyptus.

5. Establishment and management of plantation forestry

51. Choice of species and the goal of plantations

Over 60% of the plantations are of Australian *Eucalyptus* species (e.g. *E. saligna, E. viminalis* and *E. grandis*). Eucalyptus plantations serve the needs of pulp production and energy generation as charcoal. Nowadays, eucalyptus wood is also used by the constructing and furniture industries. Next in line after the fast-growing species of the genus *Eucalyptus* are two pine species, loblolly pine (*Pinus taeda)* and slash pine *(Pinus elliottii)* from the southern and south-eastern parts of the United States, which account for ca. 35% of all plantation forests (Sucheck 1991). Due to their high yields, other exotics of interest are kiri (*Bawlownia* sp.) and *Gmelina arborea*, of which there are local trials.

In accordance with the current Brazilian forestry legislation, the requirements for tax exemptions state that 10% of the forest area within a particular reforestation project must be set aside for native flora and additionally 1% of the area must be planted with indigenous tree species. Despite these requirements, exotic tree species have replaced native species almost entirely in plantations. A mere 1 - 2% of the total planting area carries araucaria (Bönish & Moreira 1988). Araucaria plantations amount to less than 10% of the reforestation area in the state of Paraná, the principal region of the original araucaria forests. Planting of native broadleaved species, e.g. bracatinga (*Mimosa scabrella*), imbuia (*Ocotea porosa*), cedro (C*edrela fissilis*) and *Ilex paraguariensis*, within the state of Paraná has been modest and confined to certain special areas.

Why is it that in Brazil exotic tree species have replaced native species? The single most important answer lies in the rapid growth of the exotics. The growing conditions in southern Brazil have proved to be especially suitable for certain eucalyptus and pine species. Their growth in Brazil can be as much as several times greater than growth under their native conditions. This has also resulted in quick returns on investment in fast-growing forestry plantations. Investment in plantation forestry has been an attractive alternative.

Experiences with planting and growing of native tree species have been few in number. They have not proved to be fast-growing when established as plantations. Araucaria plantations have attained maturity as late as at age 40 - 60 years, with sawtimber requiring perhaps even 80 - 100 year rotations (Bönish & Moreira 1988).

52. Establishment and management

Pine plantations are established using regular row-to-row and tree-to-tree intervals (Fig. 9). Usually there are at least 1600 to 2000 trees per hectare (Parviainen 1981a and b). The first commercial thinning yielding pulpwood is possible at age 7 - 8 years. At this stage roughly one-third of the stems are removed. The following thinnings are done at intervals of 4 years. If the aim is simply to produce pulpwood, the rotation is less than 16 years in length without thinnings. Sawtimber requires rotations of 25 - 30 years.

Following planting, weed control (mechanical or chemical) is carried out 2-3 times on the regeneration sites before the seedlings have reached an adequate height to enable their unobstructed further development.

Planting is carried out either manually or using machines (Fig. 10). Daily productivity in manual planting is 800-1000 seedlings; in mechanised planting it is usually 4000-5000 seedlings for a team of three.

In the case of plantations owned by the pulp and paper industry, the principal goal at present is pulpwood production. The idea is to apply rotations of roughly 17 - 18 years with no thinnings. At final felling, the breast height diameter of the trees is ca. 25 - 30 cm. This corresponds to tree ages of 80 - 100 years in Scots pine stands in southern Finland.

The annual growth of pine plantations in southern Brazil may be as high as 25 - 35 m^3 hectare. Compared to the growth possible in pine stands in Finland, this is five times greater.

Figure 9. Young eucalyptus and pine plantation, (*P. taeda*) in the State of Santa Catarina. (Photo: Jari Parviainen)

Figure 10. Planting of eucalyptus containerised seedlings using a machine for spreading the seedlings followed with manual planting. (Photo: Jari Parviainen)

Pulpwood plantations of eucalyptus are established using wide spacing; the tree-to-tree interval along rows is often 1.5 - 2.0 metres and the row interval is 3.0 metres. An additional fertiliser treatment is applied in connection with planting. Felling is carried out at age 6 - 7 years when the mean wood yield peaks. The next generation of trees is a coppice plantation obtained through stump sprouting. Seven to eight years later the coppice stand is felled. With the third generation of trees harvested, the site is cleared and a new stand is established by planting (Sucheck 1991).

Eucalyptus plantations achieve even greater yields than pine plantations. Commonly, eucalyptus yields are 30 - 50 m^3 hectare per year (Fig. 11). On extremely good sites and under humid conditions annual per-hectare yields as high as 70 - 80 m^3 have been reported for the first generation f. ex. by Aracruz Company in Espirito Santo. The fast growing stands of eucalyptus are known to achieve annual height increments of as much as 6 - 8 metres. This means a few centimetres of shoot elongation per day. In other words, you almost can see them grow as you watch them.

Figure 11. Five year old mature eucalyptus plantation for pulp wood in the State of Espirito Santo. (Photo: Jari Parviainen)

There are some problems associated with plantation forestry, which become accentuated when exotic tree species are introduced. For the present, Brazilian plantations have not been afflicted by insect or fungal epidemics. Although the species of fauna and fungi potentially occurring in the plantations are known, detailed knowledge of their ecology and appropriate means of controlling them are lacking. Consequently, in a case of damage, the possibilities for effective control or prevention of its spread are poor. According to the results of soil studies, especially eucalyptus plantations are suspected to promote the drying up of the soil and its acidification, and to markedly consume soil nutrients. Some experiences reported by industry indicate that third-generation eucalyptus stands, unless fertilised, yield only 30-40% of the amount of wood produced by first-generation stands. In other words, fertilisation is required to maintain an adequate nutrient status.

Forest fires pose a more serious threat to plantation forestry than do biotic damaging agents. Since conifers are grown closely spaced, the lowermost branches soon die and the needles are shed. It often happens that the dry mattress of needles on the forest floor exceeds 10 cm in thickness. Dry branches and needles ignite readily. Also the eucalyptus plantations are very susceptible for fire because of dry leaves and bark sheets on the ground. The forest industry companies have devised fire prevention systems for containing fires.

53. Timber harvesting

Timber procurement is composed of three main phases: cutting, off-road transport and on-road transport (Hakkila 1995). From pine plantations timber is harvested primarily by using motor-manual cutting and the tree-length system. Felling and delimbing the trees is carried out with a chainshaw at the stump. Sometimes the delimbing takes place after the off-road transport at the landing (Fig. 12). Bucking to assortments is made with chainshaw either at the landing prior to truck transport or alternatively at the mill yard (see Hakkila et. al. 1992 a and b).

The log-length system is used mainly in the eucalyptus plantations (Fig. 11). The chainshaw operator carries out all the phases of cutting at the stump. A team of two workers, one felling and bucking with a chainshaw and the other delimbing with ax, is a quite common work arrangement.

The off-road transport of plantation timber is based in Brazil primarily on the use of farm factors. Farm tractors can be equipped either for ground skidding full trees and stems or forwarding logs, depending on the harvesting system applied. The use of load-carrying tractors, i.e. forwarders for off-road transport is still rare in Brazil (Hakkila et. al. 1992 a).

The transport from the road side to the mill is in operation year-round. Pulpwood trucks are usually equipped with one or even two trailers. The companies usually use separate tractors for loading trucks at the landing.

Logging mechanization project

The results and recommendations of the Finnish-Brazilian logging mechanization project were published in the report, Feasibility of logging mechanization in Brazilian forest plantations, Metsäntutkimuslaitoksen tiedonantoja 404/1992 by Hakkila, Malinowski and Sirén. The conclusions were:

Apart from the differences in climate and infrastructure between the Nordic countries and Brazil, the physical operating environment in the southern Brazilian forestry plantations is rather similar to those of the geographically far-removed northern regions. Although Brazilian pine and eucalyptus logs are usually made considerably shorter than pulpwood logs in Finland, they do not otherwise differ greatly from the Nordic countries' timber from the procurement and processing point of view.

A major difference is that in Brazil special forest tractors are replaced by conventional farm tractors owing to the easy terrain conditions, lower investment costs and partly, protective trade policy. A distinctive difference is also the lack of harvesters and other multi-function machines, which in the early 1990s revolutionized timber harvesting in northern Europe (Hakkila 1988, 1995). However, differences occur between pulp companies in the equipment and efficiency of logging, and many companies are already testing the suitability of mechanized cutting for the Brazilian plantations.

Timber harvesting should also be analysed on the ecological point of view. The practical experiences show that the logging technology applied in southern and south-eastern Brazilian plantations does not generally create alarming adverse consequences such as erosion, improverishment of soil, rutting or excessive damages to standing trees. However, risk of erosion exist in steep terrain and soil compaction may occur under feller-bunchers, transport tractors and trucks trafficking on the logging site. Compared to a combination of loader tractors and transport tractors in timber transport from clear-cutting areas of eucalyptus, a self-loading forwarder with a long-reach crane would cause less damage to soil and stumps and thus improve the coppicing of a new tree generation. Emphazise should also be paid on the training of the staff at all levels of the organization in order to quarantee the successful working chains and planned operations.

Figure 12. A grapple skidder, equipped with a safety frame, delimbing whole pine trees by backing its load throught a delimbing gate at a landing site in the state of Santa Catarina. Bucking to assortements is made manual by chainshaw. (Photo: Jari Parviainen)

Figure 13. A typical Finnish one grip harvester operating by clear cutting in a mature eucalyptus stand in Brazil. (Photo: Olli Eeronheimo)

It follows according to the conclusions of the joint research project that the Nordic small-log technology is mostly adaptable to Brazil's plantation-grown timber. The modern Finnish log-length system, based on the use of one-grip harvesters and load-carrying forwarders (Fig. 13), offers a cost-competitive and environmentally sound alternative for the long term development of timber harvesting from the Brazilian pine and eucalyptus plantations.

6. Results of joint studies on nursery production and planting

61. Factors affecting the choice of seedling production method in tropical and subtropical conditions

Biological, technical and economic factors affect the choice of seedling production method. The basic solution consists of a choice between the production of containerised seedlings or bare-rooted ones. Since the production of bare-rooted seedlings is highly suitable for mechanization, it has been possible to develop this approach into large-scale mass production. Economic considerations in Finland and the other Nordic countries have forced these countries to develop production lines for containerised seedlings that are as rationalized, mechanized and automated as possible (Parviainen 1984, 1986, Fig. 14). Thus, in a way, containerised seedlings have become a product of a biological conveyor belt system. In many respects the production of eucalyptus-cuttings in nurseries of Brazilian companies resembles the methods used for containerised seedlings in Finland (see Campinhos et. al. 1984).

The factors which the seedling producer takes into account when deciding which production method to adopt can include easy handling, transport and planting of the seedlings, rationalization of the nursery work, possibility to lengthen the planting season, and the unit price of the seedlings. However, the most important criterion when choosing the type of seedling is the success of planting in the field. The person responsible for the regeneration should know which factors will promote the subsequent success of the seedlings in the field. A central factor is the quality of the seedlings (Duryea and Landis 1984, Schmidt-Vogt 1984, Leikola 1984, Parviainen 1986).

Figure 14. Production of VAPO-pine seedlings in the plastic greenhouse in Finland. The roots and the peat sheet are pruned vertically on four sides using circular sawblades. (Photo: Leo Tervo)

The following factors at least have to be taken into account when choosing seedling production methods under tropical and subtropical conditions (see Evans 1982, Carneiro 1986, 1996):

Biological factors:

- The survival of containerised seedlings in plantings is usually good. Containerised seedlings permit the planting season to be extended. Their use is safer under unusually dry conditions than the use of bare-rooted ones. Containerised seedlings also permit replanting to be done during the same growing season.
- Bare-rooted seedlings require careful timing of the lifting and planting work, as well as favourable weather conditions after planting, if survival is to be ensured. Bare-rooted seedlings give poor results under difficult climatic conditions.
- The seed requirements can be precisely estimated in the production of containerised seedlings. The production of some species of tree seedling in only possible through the use of containers.

- Ensuring statisfactory root development. The root deformation should be avoided by selecting a method which does not permit spiralling the roots.

Technical factors:

- Manual or small scale containerised production can be carried out without any demanding technical investments. High automated containerised production requires a production line, which consist of filling, sowing, transport, sorting and packing units. The seedlings are raised under controlled environment either in the plastic greenhouse (watering, fertilization and ventilation regulated) or in the shaded area on open field (watering and fertilization regulated).
- Arranging the production of bare-rooted seedlings often requires certain mechanization. Machines are required for site preparation, harrowing, forming the sowing beds, sowing, cutting and lifting (e.g. tractor - mounted equipment).
- Containerised seedlings are difficult to handle and heavy to transport. The transport costs are high over long distances.
- The transport of bare-rooted seedlings is relatively easier than that of the containerised seedlings, particularly when the distances are long.
- Containerised seedlings require as many containers as seedlings. The material used as the substrate in the containers should be of as uniform quality as possible.

Economic factors:

- The high automated continerised production requires much higher investment of money than that of the bare-rooted seedling production.
- The manual production of containerised seedlings is usually more labour-intensive than that of bare-rooted ones. This often raises the production costs above those of bare-rooted ones. However, the development of methods for containerised seedlings has reduced costs.

When making a choice about the type of container, the following criteria should be taken into account (see Carneiro 1991, 1996):

- distribution of the root system and damages;
- dimensions (form, height and diameter);
- possibility of re-use;
- cost;

- handling
- durability (whether it decomposes during the seedling production phase or not, hard plastic, paper, styrox etc.);
- ease of transport to the plantation field;
- availability on the market;
- possible toxicity for the seedlings.
- design and construction (ridges, ribs, grooves)
- colour of the material (temperature)

Seedlings and planting form only one phase in artificial regeneration. Regeneration should be considered as a chain of events, starting from clear cutting and ending with the successful establishment of the plantation. The choice of whichever regeneration chain is determined on the basis of economical calculations that take into account all relevant aspects. The introduction of computer technology (Parviainen 1986, 1988, 1992) has increased the capacity to examine the regeneration process as a whole. It makes possible, for instance, to include in the selection process such aspects as the risk of failure, the technical quality of the trees, the variation in the planting density and the tending of harvesting requirements.

The containers can be classified into the three types (see Fig. 15):

1. Semi-pervious or pervious containers not removed at planting. The containers have an external wall, have to be filled with substrate and planted with the seedlings. Paperpot, peatpot, veneer, jacatron, bambus, etc, could be mentioned as examples. The plastic bag is the one exception which cannot be planted with the seedling. The rigidity of the wall allows for easy handling and transport and, to a certain extent, can help to decrease desiccation in dry soils. The disadvantage on dry soils is that the contact surface between the root system and the soil is limited, if the container wall does not decay quickly. The roots sometimes come out through the bottom of the container.

2. Impervious containers removed or split at planting. The container also require filling with substrate. The soil blocks with root systems are removed from the container before planting out. These seedlings, however, must be kept in the container long enough for the root mass to penetrate the block completely in order to facilitate extraction. This period varies with tree species and the dimensions of the container. The container walls are not normally perforated by the roots unless they have been specially designed for this purpose, the container having gaps between the cavities through which the

roots can penetrate. This prevents deformed development of the root system. Styroblock, multipot and in Brazil very common Tubete can be mentioned as examples.

3. Pre-filled containers. This type of containerised seedling incorporate the advantages of the two previous types: they are the container and the substrate at the same time. They are planted with the seedlings, are normally hard enough and permit fast development of the roots. It should be pointed out that a long production period causes the roots to penetrate the root space of adjacent seedlings. In Brazil the "torrao paulista" (Sao Paulo block) can be mentioned as an example. In other countries some other blocks are being used, in Finland a method based on pressed and dryed peat sheets (VAPO method) is developed (Parviainen and Tervo 1989). With the VAPO-method it has been possible to combine a rapid root regeneration potential and favourable morphological root system development by pruning the roots and peat sheet. Pruning is carried out with the use of circular saw blade by forming a peat block.

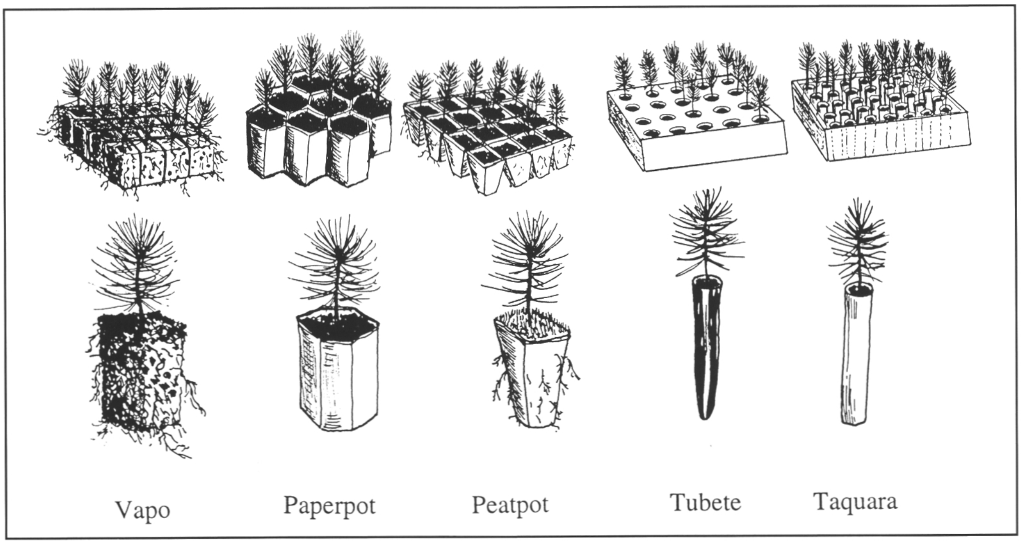

Figure 15. Examples of the compared containerised tree seedling methods in the nursery and field experiments.

62. Nursery production of planting stock and forest tree breeding

The tree seedling production methods in use under Brazil are described in Portuquese in detail in the nursery manual written by Carneiro (Producao e controle de qualidade de mudas florestais 1996). For that reason only the main features are illustrated in this report.

The fact that industry strives to cut its costs in forest regeneration means that the production of containerised seedlings will rise. While the field survival of bare-rooted seedlings is good, generally in excess of 90%, the drawback in using them is in the shortness of the planting season. The aim is to extend the planting season, one month for bare-rooted seedlings, to several months by using containerised seedlings.

In the states of Paraná and Santa Catarina, nursery production covers both bare-rooted and containerised planting stock. The general practice when planting eucalyptus is to use containerised stock. The trend is towards increasing containerised production also by pine seedlings. Consequently, the companies are seeking reliable new methods of producing containerised planting stock. However, more extensive raising experiments are needed before the methods can be adopted on a wide scale.

Seed orchards from the fastest growing provenances have been established for pine. Pine seedlings are germinated and raised in the open as bare-rooted stock, or alternatively germinated in polythene tunnels and then moved out. Bare-rooted pine seedlings do not require transplanting. The seeds are sown mechanically into beds. Undercutting the roots replaces transplanting. The production period for both bare-rooted and containerised stock is a little short of one year. Bare-rooted pine seedlings sell for roughly half the price of containerised seedlings (Fig. 16 and 17).

In humid conditions Eucalyptus-seedlings are mainly produced by cuttings. The cuttings are made by branch cuttings from special "mother" tree production. After a few weeks rooting period plants are ready for planting out (Fig. 18 and 19).

Figure 16. Seven months old bare-rooted tree seedling nursery bed of pine ready for lifting and planting in the state of Santa Catarina. (Photo: Jari Parviainen)

Figure 17. A typical rootpruned bare-rooted 7 months old pine (*P. taeda*) seedling just before planting out. (Photo: Jari Parviainen)

Figure 18. Thinning of 4 weeks old eucalyptus seedlings in the Tubete-containers in order to develope more sturdy seedlings. (Photo: Leo Tervo)

Figure 19. Prickling of eucalyptus cuttings into the Tubete containers for rooting. (Photo: Jari Parviainen)

In addition to success in the silvicultural sector, the success of fast-growing eucalyptus plantations is the result of intensive forest tree breeding. At first, the idea was to seek out fast-growing provenances through genetic improvement and then to cross these and obtain additional growth in the form of hybrid provenances. In the second stage, seed selection focused on provenances of a specific kind of fibre for the pulp industry. Paper quality criteria were kept to the fore in this endeavour. With the provenance material thus selected, the next step was vegetative propagation, the production of cuttings. Entire plantations can be established based on clonal forestry, - individuals of the same mother tree (Oda & M. Menck 1988, de Oliveira 1988, Vailant 1988).

Micropropagation and tissue cultivation are the very latest biotechnology technique used in producing forest tree planting stock. For the present, however, these two methods are at the experimental stage. Furthermore, it does seem that micropropagation methods are clearly more expensive than cutting production and the conventional seed-based raising of seedlings.

The annual production volume of a typical Brazilian forest tree nursery varies between a few million and over ten million seedlings. The Rigesa Company in Santa Catarina State has a nursery production of 2 million eucalyptus seedlings and 4-5 million pine seedlings (*P. taeda*). The company is very active in developing new, more advanced production methods. Klabin Company in the Paraná State has a nursery production ca. 14 million seedlings per year. Some major investments have been carried out at the company's nursery: filling and seeding of the containers has been mechanised and the South-African made filling and sowing machine is capable of dealing with even tiny eucalyptus seeds one seed at a time. The seedlings are initially raised in polythene greenhouses. A month later they are moved to the shaded area. There the containers are given more room by moving 50% of the containers to another base.

63. Experiments and tests of different tree seedling methods

Canquiri experiment

The first experiment to compare the different containerised seedling production methods was arranged in 1986-1987 in the seedlings nursery of the University of Paraná in Curitiba. Six different Finnish and Brazilian methods for raising slash pine (*P. elliottii*) was studied. The raising period lasted eight months. The total number of seedlings in the experiment was over 5500 (Carneiro and Parviainen 1988, Parviainen et. al. 1992).

The morphological characteristics of the containerised seedlings did not differ from those of bare-rooted ones. The mean height of the tallest seedlings was 13-14 cm. Seedling development was especially poor in containers with a small volume. The Finnish paperpot and VAPO methods at least are suitable for the mass production of seedlings under South Brazilian conditions. When using the popular *Tubetes* method, the root system of the seedlings is weak resulting in varying success when planted.

With the same seedlings a planting field experiment was established in 1987 on the experimental farm of the University of Paraná (Canquiri). The aim of this experiment was to follow the survival and development of the seedlings under field conditions.

The study deals with the first three and half years of development of the seedlings after planting out. The trees were measured and 3 sampling trees/treatments were taken for root systems analysis in February 1991. Seven different production methods were compared (The Finnish ones: paperpot type Fh 5010, paperpot type Fh 5015, peatpot FP 620 and VAPO, The Brazilian ones: Tubete, Bare-rooted and Taquara, see Fig. 15).

The results show, that the paperpot seedlings of type Fh 5015 were tallest and VAPO seedlings the shortest after three and half years growth (Fig. 20). There was no statistical difference in the height growth of the last growing season, stump diameter, diameter at breast height and number of whorls between compared nursery stock types (see Parviainen et al. 1992).

The straightest stems were observed for VAPO and peatpot seedlings (Fig. 20). A normal tap root was observed for almost all bare-rooted and VAPO seedlings. No normal tap roots were observed for seedlings of paperpot type (Fh 5015), peatpot (FP 620), tubete, and taquara. The development of lateral roots was the most uniform with VAPO seedlings.

Results indicate that there are differences in the early development of different seedling types. Thus the results confirm the conclusion (see e.g. Schmidt-Vogt & Gürth 1977) that the size of seedlings at the time of planting effects the early development of the seedling.

The experiment gives suggestions as to what direction the root systems develop (Fig. 21). The VAPO seedlings have the most natural root system development. The share of trees with a bent or crooked stem of all planted trees was 5-15 % at the maximum. These trees can be removed in the first thinning, but if the trees remain in the stand up until to the end-cutting, crookedness may cause more waste wood by degrading the logs.

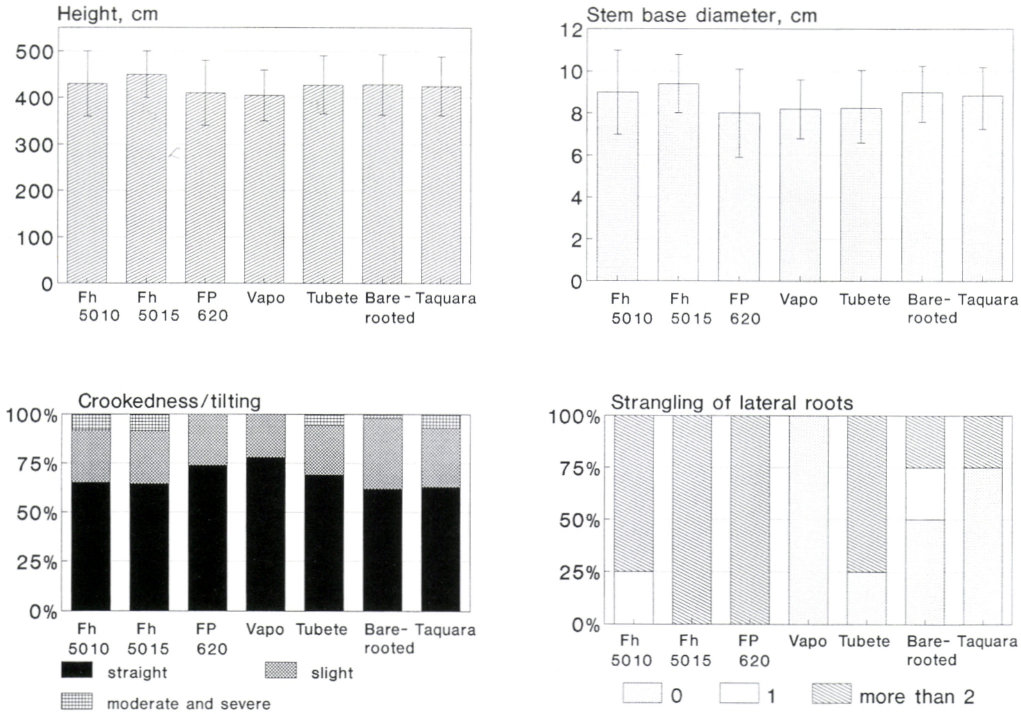

Figure 20. The main results of the Canquiri experiment with pine three and half years after the planting out in the field.

Figure 21. Lifting of the sample trees for analysing the root systems at Canquiri experiment (Photo: Taneli Kolström)

Experiments by forestry companies

To test the preliminary results in the large-scale, practical nursery operations several raising experiments as well as planting trials were arranged during 1991-1995 by forestry companies in South-Brazil.

A pruning machine and a certain amount of peat blocks and trays were donated to the University of Paraná by the Finnish company VAPO. The pruning machine was firstly installed at RIGESA's nursery.

Because of the limited availability of the material, especially of peat blocks and trays, it was not possible to establish extensive experiments in different regions. The main experimental area is at RIGESA, but preliminary tests have been run with the cooperation of other companies located in three southern Brazilian states:

State of Sao Paulo: RIPASA.

State of Paraná: AGLOFLORA, BANESTADO, INPACEL, KLABIN, and PISA.

State of Santa Catarina: RIGESA.

In addition to nursery phase, most of the experiments and tests included monitoring seedling development after field planting. As forest experiments need several years before final appraisal can be carried out, the results obtained so far are preliminary and not conclusive. However, they do give some indications of the performance of the VAPO system compared to the *Tubete* system.

RIGESA experiments

The main experiments for comparing the VAPO system and the methods normally used in Brazil to produce pine seedlings were established at RIGESA, where there was a pruning machine in operation.

The first experiment comprised five treatments: VAPO (open sky), VAPO (shaded), *Tubete* (open sky), *Tubete* (shaded), and bare-rooted seedlings (Fig. 22). The species studied was loblolly pine (*Pinus taeda*). After a six-month growing period in the nursery, the seedlings were planted in July 1991 in the field at two different sites, "Matão" (sandy soil), and "Paredão" (clayish soil).

The results based on the most recent measurement of the trees (9 May 1995) after 4 years growing period on both sites (data on diameter at breast height (dbh), total height, and survival percentage) were as follows (Fig. 23). Under favourable growing conditions no differences in survival or height growth between the compared nursery stock types could be observed. On dry soil types the large volume containerised seedlings had the highest survival and the fastest height growth. The results confirm the earlier observation that seedling size has a strong influence on the initial development of the plantation.

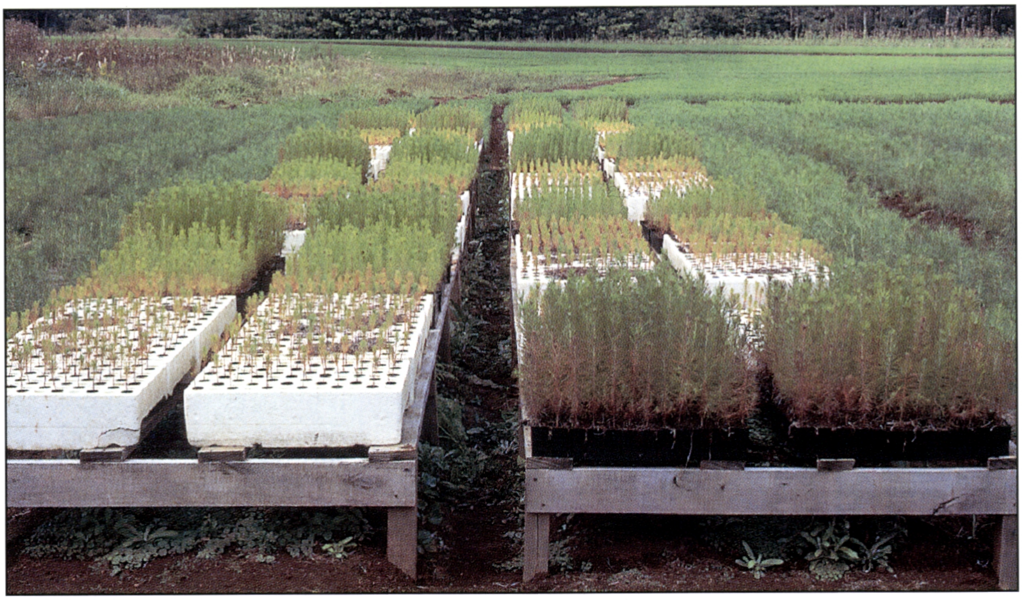

Figure 22. The compared containerised tree seedling methods at Rigesa Company's nursery before the planting out in spring 1991. (Photo: Leo Tervo)

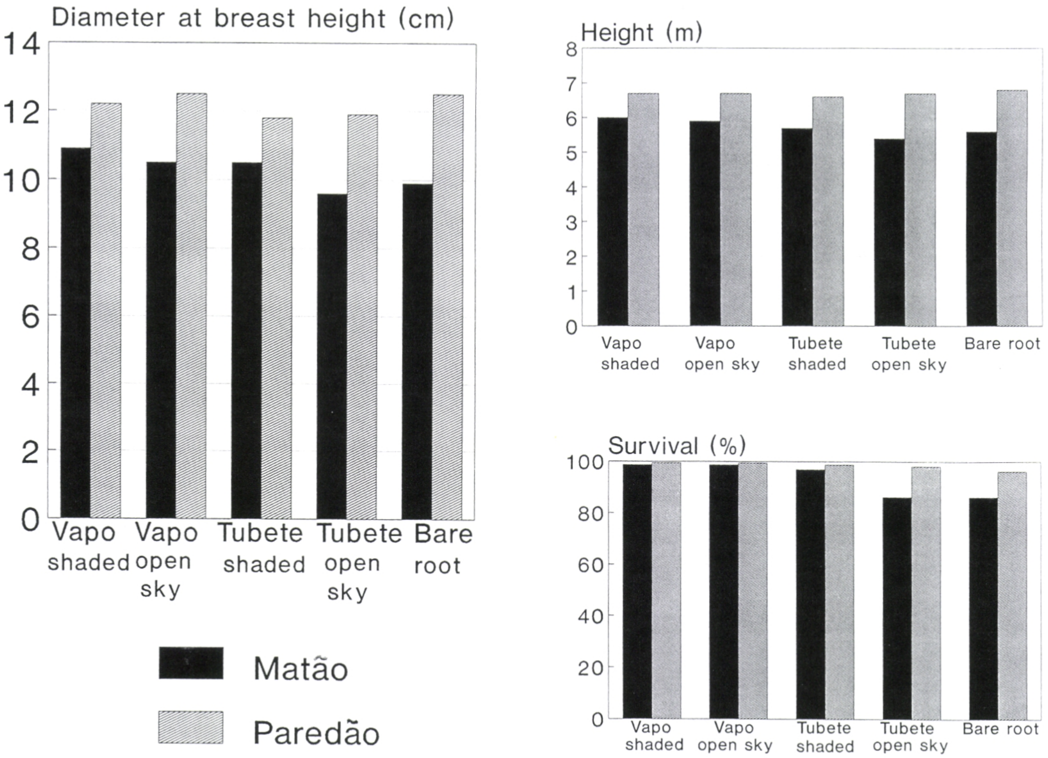

Figure 23. The main results after 4 years period in the Rigesa experiments with pine at Matão (sandy soil) and Paredão (clayish soil).

Another similar but far more comprehensive experiment was recently established at RIGESA by Adalberto Brito de Novaes, a graduate student at the Federal University of Paraná Forestry School. The experiment will provide him with the material for his doctoral thesis. The final results of this experiment will be available by the end of 1997.

The experiment compares five different methods of seedling production (VAPO 10 cm, VAPO 7 cm, *Tubete* normal density, *Tubete* lower density, and bare-rooted) using loblolly pine (*Pinus taeda*). The nursery phase was established in October 1994 and the field planting in April and May of 1995. Besides comparing the growth rate and survival in the field, a detailed analysis of the quality and morphological parameters of the seedlings, including root system development, will be carried out. Preliminary results indicate a much better root system development of the VAPO and bare- rooted seedlings in comparison with to *Tubetes*.

INPACEL experiment

INPACEL is a pulp and paper company located in the northern part of the state of Paraná. The objective of the experiment established by INPACEL was to compare the development of seedlings grown according to the VAPO system and the *Tubete* system after field planting. The species used was *Eucalyptus grandis*. The seedlings were planted in the field in January 1994. During a period of 16 months after field planting no differences were observed in the initial development between the VAPO-seedlings and the Tubete seedlings.

The results of this experiment are of preliminary nature. A complete analysis will be carried out at the end of the plantation rotation of 6 to 7 years.

AGLOFLORA experiment

AGLOFLORA is the forestry branch of *Placas do Paraná*, a particleboard manufacturer, located in the central-eastern part of the state of Paraná. The objective of the experiment was to compare the post-planting development of seedlings of loblolly pine (*Pinus taeda*) produced using the VAPO system and the *Tubete* system.

The seedlings were planted in the field in March 1994. The first measurements were made in March 1995, one year after planting. As the trees were too small for having their breast height diameter measured, only total height was measured. The results (in average, three replications) were for VAPO 1,43 meter and for Tubete 1,03 meter (Fig. 24).

The results of this experiment are also of a preliminary nature. However, the faster height growth of the VAPO seedlings saved at least one weed control operation, thereby reducing maintenance costs. A complete analysis, including the economic aspects, will be carried out at the age of three years further tending of young trees becomes unnecessary.

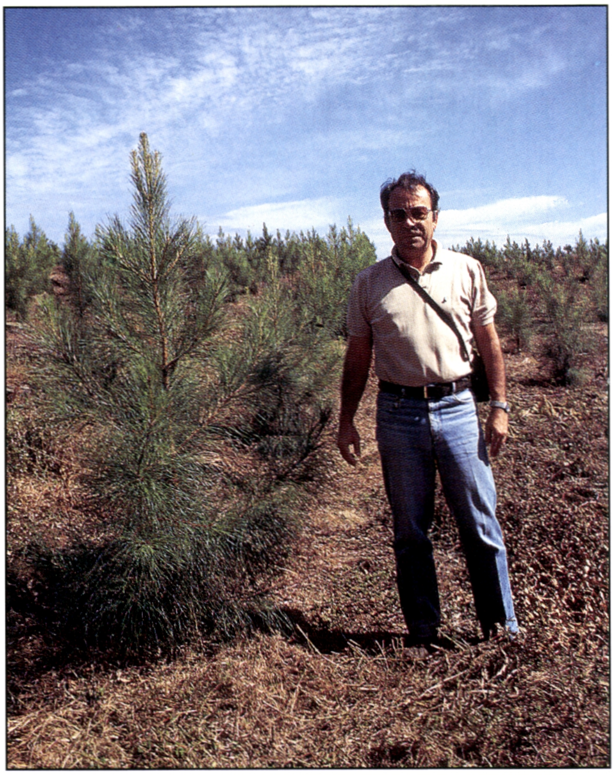

Figure 24. The field experiment at Agroflora company one year after planting out (Photo: Leo Tervo)

RIPASA test

RIPASA, a pulp and paper company located in the southern part of the state of Sao Paulo, received only two peat blocks for conducting preliminary tests on seedling production using the VAPO system. They sowed *Eucalyptus grandis* in one block and *Cupressus sp.* in the other. The only result got so far is that the seedlings grown in the VAPO system were ready for field planting after 70 days, compared to 90 days for the *Tubete* seedlings. No field measurements have been carried out so far.

Other companies and tests

Peat blocks were given also to the companies BANESTADO, KLABIN and PISA for conducting tests on seedling production. However, no data are available so far.

64. Finnish silvicultural systems for application in plantation establishment in southern Brazil

Raising of pine seedlings:

1. Success and initial development of plantings

When the climatic conditions are good and the soil is moist, bare-rooted and containerised seedlings do not significantly differ in regard to success and initial development. Ground vegetation control has to be carried out 2-3 times before the seedlings have reached an adequate height to enable their unobstructed further development. The development of sturdy containerised planting stock, such as those raised in VAPO pots, is faster than that of planting stock raised in small pots. This means that one grass control measure is avoided. In the case of supplementary planting, sturdy containerised planting stock is the appropriate solution thanks to their fast initial development.

When planting on dry soils and in dry climatic conditions, containerised planting stock are a safe choice. Survival of containerised seedlings is most reliable and their first years' height development is the fastest. The best result can be achieved using large seedlings, such as those raised in VAPO containers. Small containerised planting stock, such as Tubetes, are unreliable in their initial development and slow-growing. Further, the use of containerised stock enables the planting season to be extended.

2. Root system development

It has been found that the development of young stands and the quality of the tree stems depend on the nursery stock type. Some nursery stock types can result in seedling stands where more than 10% of the tree stems are of poor form. These poor-quality individuals have to be removed in thinnings. Also, strong winds may cause the seedlings to tilt if their root systems are deformed or not firmly attached to the soil.

Root deformation and the related crookedness and bending of stems may be caused both by the nursery stock and the planting method. Planting needs to be carried out with care. The planting hole has to be deep enough, the roots must be spread out in the hole, and the seedling has to be placed in an upright position on planting. The type of container must be so chosen as to ensure that no root deformation results during the nursery raising period. Research has shown that the most natural root development is achieved when using seedlings raised in VAPO containers; the roots of these seedlings are pruned at the nursery. With other types of containerised seedlings, care has to be taken to ensure that the raising period is not too long in relation to container size and that the container does not cause the spiralling of roots.

3. Production costs and technology used

The technical level employed in forest tree nurseries in southern Brazil varies a great deal. Advanced mechanised and automated production lines are in use at some nurseries, the methods are less labour-intensive. The production of bare-rooted planting stock can be initiated with low investment of money with the result that the production costs also remain lower. Since the planting stock produced by companies are transported immediately to the planting site without using contractors as suppliers and without resorting to storage, the delivery chain is inexpensive and it works. Machines or manual systems can be used in planting work.

The development of nursery production focuses mainly on the methods used in raising containerised planting stock. Although the general wage level is low, there is a trend towards raising the level of technology used. The most common method is that of raising Tubete containerised planting stock. Many nurseries are, however, carrying out reforms and considering the acquisition of new production methods. Experience has shown that Finnish methods of raising containerised planting stock are interesting new options for Brazil.

The difference in adopting the VAPO method of raising containerised planting stock when compared to conventional methods is that the VAPO method of raising planting stock does not require a production line for filling the containers, because the sheet of peat that the VAPO method is based on is in itself the substrate. The VAPO container requires a cutting machine and this is an investment. The VAPO container has three times the volume of a Tubete container.

The work stages in raising the planting stock do not essentially differ among the various containerised methods. Experience has shown that the VAPO containerised planting stock's raising period is 25% shorter than that of Tubete containerised planting stock. The irrigation and fertiliser treatments required by the containerised planting stock are easier to carry out with the VAPO containers than with the smaller containers.

Containerised stock can be planted out either by machines or manually. For the present, it is mainly manual planting with hoes that is used. The different container types do not differ in this respect.

Raising of eucalyptus seedlings:

1. The most appropriate solution is that of raising containerised stock as this enables the user to rationalise production. With eucalyptus seedlings, there is in practice no alternative to using containers. Once the seed have germinated, it is necessary to thin the containers leaving one seedling per container; and the surplus seedlings can be transplanted to empty containers. This thinning and prickling work involves high costs and also the loss of seedlings (culling percentage) is high. Another way is to use a separate germination box from which seedlings are then prickled directly into containers. This makes it possible to reduce the proportion of wasted seedlings.

2. Eucalyptus cuttings should also be planted directly into containers. The use of containers ensures efficient production and the raising and handling of the plants are easier to rationalise.

3. In favourable climatic conditions, the planting-out result with eucalyptus seedlings can be relied upon. Grass control is necessary as is periodic termite control.

4. The VAPO method of raising containerised planting stock is also a favourable alternative when producing eucalyptus seedlings. Wide-scoping experience is lacking for the present, but preliminary results indicate that their initial development has been favourable. It can be assumed that the VAPO container will prove to be especially appropriate for the transplanting of seedlings and for planting cuttings. Due to the rapid root development of seedlings in VAPO containers, root cutting has to be correctly timed so as to ensure the formation of a firm container. Before large-scale production of eucalyptus seedlings can be commenced using the VAPO method, more experiences need to be gained.

Conclusion

The choice of seedling production method depends on the company's objectives. To minimise the risks, the containerised option is a safe choice; success of planting is assured, the planting period can be extended, and nursery work can be rationalised. Bare-rooted stock are easy to produce and plant, and do not require high investments, but the climatic conditions for planting (i.e. survival) of bare-rooted stock have to be certain.

Finnish methods of raising containerised planting stock are appropriate for application in most regions of Brazil following minor modifications which depend on the tree species used.

7. Conclusions

As a whole, this Finnish-Brazilian project constitutes the first comparative trial conducted in Brazil involving containerised seedling production and the early development of the planted trees. The results of the planting trials indicate that there are differences in the growth and field development of different nursery stock. Early development in the field corresponds to the differences in growth observable already in the nursery stage.

The conclusion can be drawn that the Finnish paperpot and VAPO methods of growing containerised seedlings are appropriate for large-scale use in Brazil. The VAPO seedlings stood out from among the other tested seedling types due to their superior root development and successful nursery stage. The VAPO system is appropriate for producing both pine and eucalyptus planting stock.

The experiences gained in this cooperation project indicate that adopting of a new tree seedling production method as well as mechanisation of timber harvesting is a lengthy process, and calls for years of development and experimentation. In the course of such work, forestry organisations seek out the solutions most appropriate for their particular work environment and socio-economic situation. They also gradually adapt themselves as organisations to the new methods and are in a position to launch the necessary labour skill and supervisor training. Nordic silvicultural systems have also to be adapted to the local climate, specific tree characteristics and the professional skills of the forestry staff. Where socio-economic conditions and infrastructure allow, even the most advanced mechanised methods can prove to be both successful and cost-competitive.

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The Finnish Forest Research Institute,
Research Papers 594
ISBN 951-40-1503-7 ISSN 0358-4283