Forest Nursery Management in Chile

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The forest economy in Chile is based on products from artificial reforestation efforts on approximately 2 million ha. From these, about 1.5 million ha (75%) are planted with *Pinus radiata*, 400,000 ha (20%) with species of *Eucalyptus*, principally *E. globulus* and *E. nitens*, and the rest (5%) composed by other species such as *Pseudotsuga menziesii*, *Pinus ponderosa*, *Pinus contorta*, and some hybrids of the genus *Populus*. Annual planting rates have varied from a maximum of 130,000 ha in 1992 to approximately 28,000 ha in 1999. This year (2000), the planting period is unfinished but is estimated to be similar to the previous year.

The rate of seedling production in the nurseries has varied from a high of 400 million seedlings to 100 million seedlings during the present year. The number of nurseries has oscillated from 850 to only 100 during the present year. This variation in number is explained by the change in responsibility in the establishment of the plantings and the ownership pattern.

Until the middle of the 1970s, the State Forest Service (CONAF) was the principal tree planter in the country. They established agreements with small and medium farmers, planting 54,000 ha in 1976. This corresponded to 50% of the total plantings in the country as a result of the 1975 Foment Law for planting.

Presently, many small and medium companies, both private and state, that participated in the establishment of the plantings have disappeared from the market. Now, around 1.5 million ha of forest belong to only two companies. Of these, one company has concentrated seedling production in only one site. They own a central nursery of about 140 ha, with a production of about 25 million seedlings, and with the best possible technical level available in the country. The other company produces about the same number of seedlings divided across four nurseries. The rest of the seedling production in the country is distributed among small companies with less than 3,000 ha planted per year, and some private nurseries that, in total, produce less than 15 million seedlings. The state owns 18 small nurseries that, in total, produce less than 5 million seedlings.

The present document analyzes the principal activities and cultural practices currently applied for seedling production in the country. This includes different seedling propagation and production methods without considering the technologic level.

Propagation from Seed

About 60% of the *Pinus radiata* production is from seed. Approximately 70% of the seed comes from seed orchards, with the rest from plantings under management. In the case of the *Eucalyptus* species, 96% of the seedlings are produced from seed. About 40% of this seed comes from seed orchards and the rest from plantings. In the specific case of *Eucalyptus nitens*, about 20% of the seed is imported from Australia.

In general, the available seed has more than 97% purity, with more than 80% germination capacity. Due to the high annual seed production, only the summer and fall harvests of the same year are used. Seed storage for more than three years is an exception, and only includes species with marked periodicity in cone production.

Pinus radiata is produced principally in bareroot nurseries, but a small portion is also produced in containers. Species from the genus *Eucalyptus* are principally produced in containers; however, *Eucalyptus globulus* and *E. nitens* are produced in bareroot nurseries.

Bareroot seedling production starting from seed

In Chile, bareroot seedling nurseries are established on a variety of soils and climates within the most concentrated planting areas, ranging from 72° 00' 00" longitude - 32° 00'00" S latitude to 72° 00' 00" longitude - 42° 00' 00" S latitude. Most nurseries are established on *Dystric Xeropsaments*, *Umbric Dystrochrepts*, *Typic Rhodoxeralp*, *Typic Melanoxerands*, and *Ultic Palexeralfs* soils. The climate varies from maritime to Mediterranean, with annual precipitation from 350 mm to 2500 mm. The absolute minimum temperature at the canopy level varies from -1 to -12 °C, and the absolute maximum under the shade varies from 28 to 40 °C. The extreme temperatures are always registered in the central plains.

Pinus radiata

About 98% of the radiata pine seedling production from seed is in bareroot nurseries. Seed size varies from 17,000 to 46,000 seeds per kilogram depending on the family, seed orchard, and production area under management. After harvest and cleaning, seeds are classified by size. Even though the seed may come from the same family, the sized lots are treated as different lots for germination analysis, sowing depth and pretreatments. Sowing pretreatments are determined as a function of the viability, as well as germination capacity and germination energy relationship, varying from 24-hour soak in water at room temperature to 15-day stratification. A 24-hour water soak plus stratification is recommended for seed lots with differences greater than 15% between germination capacity and germination energy. A simple water soak is recommended for lower differences. All the nursery managers soak the seed in water for 24 hours to eliminate floaters. TMTD at a rate of 5 g/kg is applied to the seed to prevent damping-off.

Mechanized sowing is done at the end of the fall or early spring when surface (3 cm) soil temperature is less than 28 °C. Nursery beds are 1.2 m wide and include 8 rows 12.5 cm apart. The separation between seedlings varies from 4 to 8 cm depending on the soil productivity and the expected root collar diameter. Sowing depth varies from 5 to 15 cm depending on the size of the seed.

Most of the nurseries fertilize only with phosphorus during the establishment stage. There is a special interest to control damping-off, caused by *Pythium*, *Rhizoctonia*, *Fusarium* and *Phytophthora* fungi. These fungi are controlled by a combination of cultural practices and fungicide applications. Among the cultural practices are early sowings at low density and proper sowing depth, fungicide use in pre-emergence crops using specific products, or wide spectrum mixtures after emergence. Seedbeds are inoculated with native ectomycorrhizal fungi during the first crop of radiata pine.

Successive applications of oxifluorfen are applied as pre- and post-emergence weed control. Fluazifop-butil is applied in the specific case of grasses. Some nurseries use herbicides from the triazine group such as Simazine, Prometrine, and Atrazine. In general, nurseries are maintained free of weeds during the entire production process (9 months). Until now, none of the nurseries has used soil fumigants.

During the rapid growth stage, irrigation is applied when soil moisture decreases almost to the permanent wilting point. High levels of N, P, and K in the foliage are maintained before starting root management, which starts when seedlings have reached 80% to 90% of the target height. Root management consists of an undercutting at a depth of 12 to 15 cm, depending on the drought level of the planting site. In addition, wrenching is applied after one or two weeks depending of the environmental conditions at the nursery. Finally, a vertical root pruning is applied at the end of the root management period. During this stage, the principal sanitation problem in areas with high temperatures is *Macrophomina phaseolina*, a fungus that can only be controlled through cultural practices such as irrigation and mulching. In addition, there are some problems with insects such as Thrips and *Rhyaccionia buoliana.*

During the hardening stage, the amount and frequency of irrigation are reduced in areas with more than three months without precipitation. In areas with summer precipitation, nitrogen fertilization is discontinued, phosphorus is maintained, and potassium is increased. Also, the frequency of wrenching is increased. Top pruning is applied to control height growth. During the second stage, at least 250 cold-hours (≤ 7 °C at the level of the foliage) are accumulated before harvesting. For seedlings destined for high moisture areas, the levels of Cu are increased through the application of cupric fungicides.

The most sophisticated nurseries evaluate the root growth potential by using special chambers, which regulate temperature, moisture, and oxygen to the root level. With this parameter, the correct harvesting time and seedling quality can be determined. The principal sanitation problems during this stage are *Botrytis* sp. and *Mycosphaerella pini* (*Dothistroma pini*) in areas with more than 2000 mm precipitation.

Seedlings are harvested early in the morning or late afternoon to avoid a decrease in the water potential of the seedlings. For this reason, some activities are done manually, except for one nursery that harvests seedlings mechanically. In the case of fall plantings, seedlings are planted as soon as possible, no more of 48 hours after lifting. During the winter plantings, after accumulating 700 to 1,300 cold-hours, seedlings are stored up to 30 days at 3 °C. Prior to shipping, roots are treated with a superabsorbent, using a local product (MVH-102) that maintains good root moisture conditions for a longer time period after harvesting. The seedlings are transported to the planting site in boxes, which are loaded in trucks with wind and sun protection. The most technologically advanced nursery transports and stores seedlings in refrigerated trucks.

Eucalyptus

About 5% of *Eucalyptus* species are produced in bareroot nurseries. However, during the establishment stage, these are grown in 5 to 7 cm^3 containers using finely ground composted radiata pine bark. Direct seeding of nursery beds is not practiced because of the high cost of the seed of some species, the low efficiency in its use, and the necessity of special protection—a scarce and expensive process in the country. In addition, some nurseries do not have an efficient weed program management before sowing, which is necessary due to the high-speed germination of *Eucalyptus.* For this reason, all bareroot seedlings are grown in a mixed production process where only the rapid growth and hardening stages are done under the bareroot system.

Sowing is mechanized, and in some cases, pre-germinated seeds selected by specific density are used. *Eucalyptus globulus* seed is soaked only in water while *Eucalyptus nitens* seed are pretreated with stratification. Generally, germination of both species is done in rooms or greenhouses with temperature control. Seedlings are transplanted when they have the first pair of true leaves. Transplanting is either manual or mechanical depending on the size of the nursery. When the operation is mechanical, they use 1.2 m wide beds with either 6 rows, 17 cm apart or 7 rows, 15 cm apart. Within the row, seedlings are 6 cm apart, with an average density of 96 to 112 seedlings/m. This process has reduced the production cost up to 60% for *Eucalyptus nitens* and 40% for *E. globulus.* In the case of species that require two growing seasons in the nursery (for example, *Nothofagus alpina*), there was a 75% reduction in the production cost.

During the last soil preparation prior to the transplanting, one-third of the total phosphorus is applied. The rest of the fertilizers are applied during the rapid growth stage in an attempt to apply optimal levels of N, P, and K. In both *Eucalyptus* species during the nursery stage, seedlings do not form mycorrhiza with ectomycorrhizal fungi, but only with endomycorrhizal fungi mainly of the genus *Glomus.* In the case of *Eucalyptus globulus*, the irrigation is applied when the available water has decreased 50%. However, for *Eucalyptus nitens,* water is applied after reaching the permanent wilting point. Oxifluorfen is used to control broadleaf weeds while fluazifop-butil is used for grasses. The applications of herbicides are repeated every 30 or 60 days depending on the weather conditions.

During the rapid growth stage, when the *Eucalyptus globulus* reaches approximately 15 cm in height, root pruning starts with undercutting the tap root. After this, wrenching is applied every 10 days followed by lateral root pruning at the end of the process. In *Eucalyptus nitens*, the tap root is undercut when the seedlings reach 80% of the target height. Wrenching is less frequent and the root management less intense than for *E. globulus*.

During the hardening stage, irrigation is gradually reduced for two to three weeks until the applications are determined by the permanent wilting point. At the end of this stage, top and lateral branch pruning is applied to *Eucalyptus globulus* to induce cold hardiness. In *Eucalyptus nitens*, only lateral branch pruning is applied. During the harvesting, roots are treated with superabsorbent polymer and protected against wind and sun during the transportation to the planting site. One of the advantages of this seedling production methodology for *Eucalyptus* is the reduction of sanitation problems during the entire production process compared to other production methodologies.

Seedling Production in Containers Starting from Seed

During the last five years, about 2% of *Pinus radiata* seedlings were produced in containers as a result of the decrease in the production rate of *Eucalyptus* species. Some nursery managers were forced to use containers to justify the investments. Seed management is similar to bareroot seedling production. The size of containers varies from 80 to 130 cm^3, either in blocks or individual plugs. Chemical root pruning is applied through the use of latex paint containing copper. Sowing is mechanized, putting only one seed per container with an efficiency greater than 95%. Composted pine bark is used as the growing medium, with particle size varying from 0.5 to 10 mm of diameter. Some nursery managers incorporate slow release fertilizer in the growing medium before filling the containers. Others prefer to apply soluble fertilizers through the irrigation system (fertigation) using different formulae and concentrations. Some others prepare their own mixtures. Most of the production is outdoors, using supports of 80 cm in height, and taking advantage of the environmental conditions at the end of the summer and early fall to harden the seedlings.

In the case of the *Eucalyptus* species, around 90% of the seedling production is in containers. Until the middle of the 1970s, polybags placed on the soil containing different soil mixtures were used to produce the seedlings. After this, there was a change to 60 x 40 cm polystyrene blocks containing 104 conical cavities, 7.5 cm deep, with a volume of 56 cm^3. During the 1980s the size of these changed to 84 cavities per block, 10 cm deep, with a volume of 80 cm^3.

Currently, many nurseries use 60 x 40 cm blocks with 84 cavities, 16 cm deep, with a volume of 130 cm^3 and a manufactured density of 28 kg/cm^2 for the styrofoam. Most of the nurseries use 100% composted radiata pine bark. Others mix the bark with 15% peat, and some others use 50% composted pine bark and 50% perlite.

Sowing is mechanized, putting 2 to 3 seeds per cavity. If more than one seed germinates, thinning is performed before the beginning of the rapid growth stage. During germination, most of the nurseries use polyethylene greenhouses with controlled temperature and the moisture near field capacity. After seedling emergence, irrigation is decreased until the root system reaches the bottom of the containers. Some nursery managers move the seedlings outdoors under shade-house conditions, especially when harvests are done during late winter or early spring. For those harvests between the fall and winter, seedlings are moved outdoors after emergence is complete. During the rapid growth stage, in general, there are two management regimes. The first maintains the seedlings under constant nutrient and water stress for nine months with a target seedling height of 20 cm without top pruning. The second is different from the previous one because, during the rapid growth stage, the moisture is maintained around 50% available water and this phase finishes with optimal nutritional levels. Top pruning is applied to the seedlings at a height twice the length of the containers. In this way, seedlings are more cold tolerant in the nursery and can be planted between fall and winter.

During the hardening phase, frequency and volume of irrigation is decreased trying to maintain seedling water potential levels below

0.7 MPa. In both species, the principal sanitation problem of this methodology is the attack of *Botrytis*. The use of mycorrhizal inoculation is needed as a cultural practice.

Vegetative Propagation

Pinus radiata

Since the 1980s, as a result of the genetic improvement program, *Pinus radiata* has been propagated from cuttings. Currently, about 40% of the seedlings are vegetatively propagated. One company produces about 30 million seedlings, of which 80% are propagated from cuttings. The rest of the nurseries are increasing the vegetative seedling production every year. The cuttings are obtained from mother plants originating from seeds of 1.5 generation orchards. Seedlings are produced as bareroot or containerized cuttings with two variants: seedlings from normal sized cuttings and microcuttings.

Bareroot Production

The hedges are initially established at a density of 32,000 to 40,000 per hectare. These are harvested for five years and then replaced. The rounded form produces the highest amount and the best quality of cuttings. However, due to the difficult management, many people prefer a flat top and an irregular form for the rest of the hedge, especially after three years and with enough cuttings. A good 3-year-old hedge plant produces around 40 high quality cuttings.

Collecting the cuttings is a key step in the process, since first, second or third order cuttings can be obtained. Among them, there is no difference in the rooting capacity, but the last two types can produce 5% to 8% more bifurcated seedlings than the first order. When there is abundant material, only first order and long cuttings are used. During the harvesting, the material should always be protected against wind and sun. The base cut should be as straight as possible without damaging the cambium. For this reason a scalpel is preferred for these cuts. If necessary, cuttings should be stored at 3 °C and relative humidity above 75%.

For bareroot seedling production, the ideal cutting should be 4 mm in diameter and 12 cm long. Most of the nursery managers use 10 cm long and 3 to 5 mm diameter cuttings. Cuttings with larger diameters produce larger seedlings. Harvesting of the cuttings begins during late fall and continues throughout the winter. These are inserted in the nursery soil up to half of their length, 7.5 cm apart within the row and 17 cm apart among the rows. This is about 90 cuttings per lineal meter of bed. Later, these are covered with plastic white shade cloth to avoid damage from wind and sun. After rooting, the shade cloth is removed, leaving the seedlings outdoors. From here, rapid growth stage is initiated and the general management is similar to those produced from seed. The only difference is that root management starts with a lateral root pruning followed by wrenching and a vertical pruning at the end. Similar to seedlings produced from seed, nutrient levels are maintained in optimal conditions.

The hardening phase starts with irrigation restrictions. Most of the nurseries apply top pruning at the end of the summer when the diameter growth is still possible. Harvesting is initiated after 600 cold hours in some nurseries. Before this chilling requirement is met, only seedlings from seed are shipped.

Currently, there is still controversy about the rooting form and grade of the cuttings. Some people think that more roots at the base of the cutting indicates higher seedling quality and greater stability after planting. During this winter, about 15,000 ha of 1- to 3-years-old plantings were severely affected by the wind. On the other hand, others consider that the origin and vigor of the roots is more important for quality of the root system. They consider that the wind problem depends more on the interaction of the soil characteristics, such as moisture, texture, depth, and structure, than the structure of the root system.

Production in Containers

Some nurseries produce vegetatively propagated seedlings in containers. They use 8 to 10 cm long cuttings with a minimum diameter of 3 mm, and containers with a depth of 16 cm and a volume of 130 to 140 cm^3. The substrate is a mixture of composted pine bark and 15% to 20% of peat.

The establishment phase in the nursery is done under a plastic cover with controlled temperature. Normally, rooting is faster under these conditions than outdoors. The rapid growth stage is the same under plastic cover or outdoors. The hardening phase is outdoors.

The goal is to produce seedlings with a height of 25 to 30 cm and diameter greater than 4 mm.

When abundant material from one specific family is needed, the microcutting propagation system is used. Seed from the specific family are germinated, and once they are 3 to 4 cm long, a 2 to 3 cm long cutting is removed. The microcuttings are placed in a substrate composed of 50% composted pine bark and 50% perlite, obtaining roots in a period of 25 to 45 days depending on the environmental conditions in the nursery. Whenever the seed propagated seedling produces new growth with the required characteristics, additional cuttings are harvested. In this way, in a period of 12 months, dozens of seedlings can be obtained from cuttings that normally are designated for hedge gardens. This process is done on hot beds with a constant rooting medium temperature from 20 to 25 °C. The environmental moisture should be above 70% and the mother plants should have good nutritional levels, especially nitrogen.

Eucalyptus

Less than 3% of the total production of *Eucalyptus globulus* is by cuttings. In the case of *Eucalyptus nitens,* the total production is less than 1%. Similar to radiata pine, the cuttings are obtained from hedges originating from seeds produced under controlled pollination. The cuttings are 7 to 10 cm long with diameters of 2 to 3 mm, with an optimum of 9 cm long and a diameter of 3 mm. In some cases, cuttings are treated with IBA in concentrations varying from 4% to 8%. The purpose is to stimulate the rooting, which is strongly dependent on the origin of the cuttings. There are some families with 100% rooting and others with 0% rooting. As an average, rooting in the modern nurseries is around 50%. It is estimated that, in the next 5 years, about 50% of the *Eucalyptus globulus* production will be cuttings.

Currently, cuttings are collected from middle spring to late summer with the optimal period during the summer. The containers (140 cm^3) are the same used for *Pinus radiata.* The substrate used as rooting and growing medium is composed of 50% composted pine bark and 50% perlite, which is amended with slow release fertilizer before filling the containers. The rooting process is done on hot beds, with a rooting environment temperature from 20 to 25 °C and the environmental moisture above 70%. After the establishment stage, when the new roots are longer than the length of the container, seedlings are moved to a sun protected area for approximately 30 days. Seedlings are then maintained outdoors until the beginning of the fall, when they are protected with shade cloth. Soluble fertilizer is applied after the initiation of the rooting process. At harvesting, 6 to 7 months after the rooting, seedlings have root collar diameters of 5 to 7 mm and height around 25 to 30 cm, with 5 to 6 leaf pairs. The principal sanitation problems are eventual *Botrytis* attacks, which are controlled with frequent applications of fungicides.

Application of Biotechnological Methods on Seedling Production

Similar to all forestry activities in Chile, the application of biotechnology to forest species is done only by the big companies. The most advanced micropropagation program using forest species is controlled by the Arauco Group, which has developed advanced micropropagation protocols for *Pinus radiata* and *Eucalyptus globulus.* This group, through its research institution (BIOFOREST S.A.), has initiated the acquisition of technology to increase their best clones through somatic embryogenesis. This is the most advanced group in this field. Other companies, such as Forestal Mininco S.A., have established micropropagation laboratories for *Pinus radiata* and *Eucalyptus globules,* but have had problems with the acclimation process and field establishment.

In addition, universities perform basic research to apply vegetative biotechnology to forest crops. The Universidad de Chile and the Pontificia Universidad Católica de Chile conduct micropropagation and somatic embryogenesis research in *Pinus radiata.* This research has received financial support from a group of forest companies that are smaller than the previously mentioned companies. The Universidad Austral de Chile has established a research center (CEFOR), which includes a micropropagation laboratory for *Eucalyptus globulus.* However, they are restricted in the propagation of forest species because they are using protocols from Japanese companies. The Universidad de Concepción has had a complete forest biotechnology laboratory since 1998, where embryogenesis protocols for *Eucalyptus globulus*, *E. nitens,* and *Pinus radiata* have been developed. In addition, *in vitro* protocols for many native forest species have been completed. This laboratory has established acclimation protocols for *Pinus radiata* seedlings propagated *in vitro*, but *Eucalyptus* sp. protocols are still in process.

It is necessary to note that the massive seedling propagation *in vitro* is still developing in Chile. At present, only hedges are used to produce cuttings that will eventually be used to produce new seedlings. The principal reason for this is the high costs of this methodology compared to the traditional seedling production methods.