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Plantation Establishment Techniques in Tropical America

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Tropical plantation management is not unlike its counterpart in temperate areas. Management principles are the same, although the applications may be somewhat modified, depending on the particular species, site, and product desired. Because there is no cold dormant season, tropical planting must be done at the beginning of the rainy season. Although container seedlings are generally planted, bareroot planting of pines is done on a large scale in eastern Venezuela, and bareroot stump plantings are made with some of the large diameter hardwood seedlings in several countries.

Applied research and pilot plant trials are an absolute necessity for selecting the best locally adapted planting material, as well as for improving plantation productivity through genetic improvement. Intensive site preparation and fertilization are common practices in operational plantations in the Tropics and are generally required for successful establishment and growth. The greatest difference between North American and tropical planting practices is the need for post-planting weed and grass control in the Tropics. Most tropical plantations are made with exotic species, which are usually pest free initially. Pest problems eventually do occur, however, but with good research and help from experts, threats from pests can be minimized or, in some cases, even eliminated. Tree Planters' Notes 43(4):125-132; 1992.

A substantial number of North American foresters who have had the opportunity to work in the Tropics have created certain myths about tropical plantations. Certainly not done with devious intentions, lecturers and guest speakers invariably show slides and examples of the fastest growing, best-formed tropical trees to impress their temperate-zone forestry colleagues. Such impressive growth can and does exist, but there is a need to put all things into perspective and present a realistic picture of tropical forestry to improve concepts of tropical plantation management.

There is no abrupt and definite difference between temperate and tropical forest management; rather it is a question of adaptation and making modifications to fit the particular conditions confronted. For a forester trained in temperate forestry, the concepts learned can be applied to tropical forestry, albeit with differences in emphasis and intensity of management.

Soils and Site Preparation

Tropical soils vary considerably from site to site, as do temperate soils, but soil management principles are basically the same. Generalizations about adverse tropical soils, such as the laterites, have led to many misconceptions (Sanchez and Buol 1975). Tropical soils are usually described in popular programs and articles as fragile and poor in nutrients, and this is often accepted. Indeed there are poor soils, but others are excellent and fertile. For example, laterite soils can become very hard once the forest cover is removed, but in fact, only 2%> of tropical American soils are laterites (Sanchez and Buol 1975). In my experiences in the Southeastern United States and the Tropics, I have not found working with tropical soils to be different from working with the soils of the Southeastern United States.

Phosphorus is quite often deficient for tree growth in tropical soils, as it is in some soils of the Southeastern United States. Boron is another element that is frequently deficient in tropical soils, particularly in volcanic ash soils and soils of basaltic origin. Applications of both elements are routinely made at the time of planting because they are necessary to obtain acceptable tree growth. Growth responses to fertilization can be dramatic on nutrient-deficient soils in the tropics (Ladrach 1980).

The majority of forest tree plantations in tropical America are established on degraded lands, such as brush land, old pasture land, or abandoned agricultural lands, because it is relatively easy to convert degraded lands to plantations at reasonable costs. It is also advantageous to reforest lands near conversion plants and mills, where there is an availability of manual labor. The popular concept that natural forests are being replaced wholesale with plantation species is incorrect (Zobel et al. 1987).

Site preparation is needed before planting tropical trees to control competing vegetation and to loosen soils, thereby improving structure and increasing macropore space. This facilitates water movement and/or water retention. Site preparation for tropical plantation establishment is generally much more intensive than that used for North American plantations. When planting fast-growing tropical species, particularly hardwoods, the difference between doing first-class site preparation and only mediocre site preparation usually determines success or failure. Without proper control of competing competition, the genetic potential of fast-growing species is not realized.

Fire is an historical and integral part of the ecology of the monsoon climates and it is commonly used to remove weeds, grass, and brush as a first step in site preparation. On sandy soils in central Brazil, as in the sands of northern Florida, chop and burn site preparation is a better alternative ecologically to windrowing and disking because the former leaves the scant surface organic matter and ash in place to be utilized by the plantation and to protect the soil.

On level well-drained soils with heavy textures, mechanical site preparation is often employed, using tractors with harrows and disks. On low wet sites, drainage and bedding are needed to remove excess water and to increase the amount of aerated soil available to seedlings or rooted cuttings for good root growth. Even on nonflooding sites, bedding has been shown to be very effective in promoting early tree growth (figure 1). Subsoiling is effective for improving tree growth on soils compacted from years of grazing or that have a natural hardpan, and this practice is becoming commonplace.

Although proven not to be the best site preparation on steep lands, manual scalping of planting spots with hoes is often used prior to planting (Ladrach 1983, Lambeth 1986). Weeds and grass between scalps are often controlled on steep sites with machetes or hoes.

Herbicides such as glyphosate have proven to be highly effective for site preparation on sites where there is heavy weed, grass, or brush growth. Aggressive commercial grasses are often encountered on old field sites and, if not controlled, will severely suppress or destroy plantations. Responses to herbicides have been dramatic. A common practice is to apply herbicides to grasses only in the planting spot (diameter of 1.0 to 1.5 m) before planting. Then the seedling is planted in the dead grass to avoid erosion. On volcanic ash soils in the Andes Mountains, where soil compaction is not a problem, herbicides alone are an effective means of site preparation. This method has been used when planting eucalypts, pines, and cypress in grasslands (Ladrach 1983). Where the competing grasses and weeds are tall, they are first reduced mechanically, manually, or by burning before herbicides are applied to the emerging grass.

A

Figure 1—*A 1-month-old planting trial of* Eucalyptus grandis *in Cojedes State, Venezuela. This upland pasture site was plowed and disked before planting. Tree growth is modest, but grass and weed competitors are abundant* (**A**). *An adjacent plot that was bedded after disking. The 1-month-old trees are over twice as tall and weed competition is greatly reduced* (**B**).

B

Planting Methods

Because there is no cold season in the tropics, most tree seedlings do not undergo a true dormant condition, which is the best time for planting in temperate regions. The majority of the large-scale plantations in the tropics are established in areas that have a monsoon or wet/dry climate, rather than a rain forest climate where no real dry season occurs. The most common error in tropical forestry is to delay planting too near to the beginning of the dry season. The key is to plant the seedlings as soon as possible after reliable rains begin so that they have sufficient time to develop hardy root systems before entering the dry season. Hardwood species planted early in the rainy season can have double the height at the end of the first rainy season as trees planted midway through the rainy season or just before the dry season, and much better survival at the end of the first dry season.

Where there is a short or nearly non-existent dry season, as is the case for the Caribbean side of much of Central America and in some of the Caribbean islands, planting is sometimes done throughout the year. More commonly, the planting season consists only of a few months during which there are reliable rains preceded by a severe prolonged dry season. Near the equator, there are often two rainy seasons and two dry seasons. In the subtropical regions, there generally is only one wet and one dry season per year.

Deciduous hardwoods such as teak *(Tectona grandis* L.), Spanish-cedar *(Cedrela odorata* L.), and gmelina *(Gmelina arborea* Roxb.) shed their leaves as a means of surviving extended dry seasons. Caribbean pine *(Pinus caribaea* var. *houndurensis* Barr. and Golf.) has adapted to extended drought conditions and nutrient-poor soils. Legumes, such as mesquite *(Prosopis juliflora (Sw.)* DC), leucaena *(Leucaena leucocephala* (Lam.) de Wit), and several species of *Acacia,* can grow on dry, alkaline soils. Many species of eucalypts have been found to grow fast under a variety of ecological conditions and are preferred for pulpwood production, where maximum biomass production is required. Some species, like river-redgum eucalyptus *(Eucalyptus camaldulensis* Dehn.) are very drought hardy.

Some eucalypt species are planted during the last few weeks of the dry season and irrigated to keep them alive until the rains begin and to gain additional growth. Each tree is irrigated at planting with about 3 liters of water from a tractor and water tank, manually applied with gravity-fed hoses attached to the tank. Additional waterings are done weekly or biweekly until the rains begin. This has been shown to increase height growth at the end of the first growing season by more than 50% (Minas Gerais, Brazil) compared to normal planting, done after the rains have begun (Rodrigues 1991).

Nearly all tropical tree planting is done by hand. Only a few organizations use machine planting. There are several reasons for hand planting:

1. Often, seedlings produced in nurseries are grown in containers and are not easily adapted to machine planting.
2. Many planting sites cannot be traversed by tractor, especially in mountain and hilly areas.
3. Planting machines are mostly imported and expensive. It is often much more economical to hand plant.
4. Many companies maintain a policy of utilizing manual labor whenever possible as a social benefit of reforestation, because unemployment is high in most of the marginal agricultural areas where reforestation takes place.

Eucalypts are invariably handled as container seedlings. Plastic bags, 12 X 15 cm flat, are frequently used, as are ribbed, tapered tubes, 3 to 4 cm in diameter and 15 cm long. Tubes are frequently held in plastic or metal frames in the nursery with air pruning of roots extending through the bottom of the tubes. Planting should be timed so that when the seedlings are ready in the nursery, conditions are suitable for transplanting them to the field. Eucalypt seedling growth should never be slowed in the nursery or seedlings left to grow too large for their containers. Thus, another reason for initial irrigation of eucalypt plantings is to assure survival in field plantings when the nursery stock is ready and must be planted even if the rains are delayed.

Pines are grown as container seedlings in most planting programs, but in a government project in eastern Venezuela, 30,000 ha of Caribbean pine seedlings are planted annually as bareroot seedlings (Ladrach 1991). Excellent nursery management and careful control of planting logistics are necessary to have successful bareroot planting in this region of droughty, sandy soils, where there is a prolonged dry season of 4 months or more each year. Seedlings are lifted, graded, root-dipped in a clay slurry, and machine-planted the same day. In the bareroot nurseries, the minimum acceptable root collar diameter is 4.5 mm because trees of this size or larger have good initial growth and survival. Smaller seedlings are culled.

Broadleaf species that produce large diameter seedlings are frequently planted bareroot as stump seedlings (pseudoestacas) or in containers. Some of the more important species are gmelina, teak, *Bombacopsis quinata,* and *Tabebuia* spp. Seeds are sown at wide spacings in the nursery, between 30 to 40 per m^2, to produce large-diameter seedlings. Seedling root collar diameters over 1.5 cm have been found to have the best survival in field plantings (Urueña 1991). Seedlings are lifted and pruned before planting. In some nurseries, the seedlings are lifted in the early evening, graded, pruned to a 20cm top and 15-cm root, roots dipped in clay slurry and the stump seedlings put in crates for shipment to the field (figure 2). The stumps are then planted the next morning.

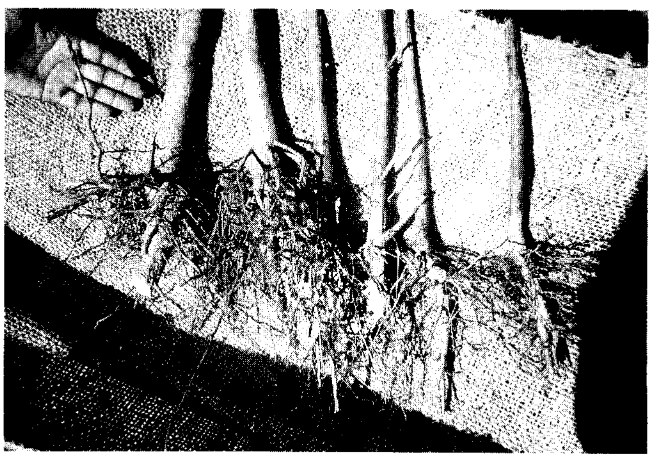

Figure 2—*Stump seedlings, or "pseudoestacas," of* Gmelina arborea *prepared for planting. Their roots are dipped in clay slurry.*

Bombacopsis, a special case. *Bombacopsis quinata* is a broadleaf species native to northern South America and part of Central America. It has different common names in different countries: saqui-saqui (Venezuela), ceiba tolúa, ceiba roja (Colombia), cedro espino (Panama), and pochote (Costa Rica). It is one of the most unusual species being planted commercially. *Bombacopsis* trees have thick, sharp spines growing along the entire stem and branches, throughout their lives. Young seedlings in plantations have a straight stem and a moderate growth rate, making them a promising species for the production of veneer and lumber. The species does not self-prune, and thus requires pruning for clear wood production. Old-growth trees in the natural forest can attain diameter at breast height values of well over 1 m.

Seedlings grown bareroot in the nursery shed their leaves during the dry season and are not irrigated during this time. The seedlings can be lifted during the dry season and either planted as full-length seedlings or as stump seedlings. Test plantings have shown that growth is best and survival is very good when the stump seedlings are planted bareroot during the dry season, without irrigation, a month before the rains, as opposed to planting when the rains begin (Kane 1989). This ability to survive and grow well when planted in absolutely dry soil is unique among commercial forest tree species.

Bombacopsis sprouts well, and large branches planted in moist soil will take root. Thus, it is a species that is suited for planting as rooted cuttings, once genetically improved stock has been selected and tested. In Central America it is known as an upland dry site species, but it also can grow in low river terraces and wet environments during the rainy season. It will withstand extreme droughts during the dry season, as in plantings on the Caribbean Coast of Colombia (figure 3).

Figure 3—*An 8-year-old plantation of* Bombacopsis quintana *in Pizano, northern Colombia, that has just been thinned. These trees are grown for plywood.*

Bombacopsis has been relatively unknown outside its natural range, but is now being planted commercially in Colombia, Costa Rica, and Venezuela. Growth rates are not as high as those of many eucalypts, or gmelina, but the wood quality and ease of management in plantations makes it a highly desirable species for producing solid wood products with rotation ages of 20 years or less. Some predict that *Bombacopsis* will become a very important commercial species within the next few years, as sources of natural tropical hardwoods for veneer and lumber are being rapidly depleted.

Post-Planting Weed and Grass Control

One major difference between tree planting in the American tropics and in North America is the post-planting removal of competition to seedlings. Aggressive growth of grasses and weeds in much of the Tropics makes post-planting weed control an absolute necessity for the establishment of successful tropical plantations. Climbing vines, such as the morning-glories *(Ipomoea* spp.) and campanitas *(Thevetia* spp.), can severely damage young trees and must be cut several times a year during the first years to keep them from deforming or even crushing trees to the ground.

Many of the old field sites are covered with exotic commercial grasses. Many of these grasses have spread beyond the original pastures and have become serious pests. Kikuyu grass *(Pennisetum clandestinum* Hochst. ex Chiov.) from Africa, was introduced into the Andean Region more than a century ago and has effectively colonized nearly all open highlands over 2,000-m altitude. This grass has large roots and is a fierce competitor for soil moisture and nutrients, as well as being allelopathic, that is, it produces in its roots growth inhibitors to other vegetation. Tree growth is severely retarded if this grass is not completely controlled around young trees.

Herbicides have been found to be more effective than manual weed control for the commercial grasses because they kill the allelopathic grass roots as well as the tops. In a planting of bluegum eucalyptus *(Eucalyptus globulus* Labill.) in Colombia, glyphosate (Roundup) was applied to kikuyu grass around 1-m-diameter hoed planting scalps at time of planting and again at 7 months later. After 2 years, tree volumes were increased by more than 250% by the use of herbicide, compared to trees in plots where weeds were controlled by hoeing (Lambeth 1986) (figure 4).

Molasses grass *(Melinis minutiflora* P. Beauv.) is another commercial highland grass in the Andes that is highly allelopathic to tree seedlings and must be controlled in young plantations. In a test of paraquat (Gramoxone) on molasses grass in the planting spot, at time of planting and at 2 years, the fifth-year growth of rosegum eucalyptus

A

Figure 4—*In a 2-year-old planting trial of* Eucalyptus globulus *by Smurfit Cartón de Colombia, trees planted in 1- × 1-m scalps in an old field of kikuyu grass in the Andes Mountains averaed 3.4 m in height* (**A**). *In an adjacent plot in the same trial, glyphosate (Roundup) was applied to the grass before the seedlings were planted and again after 7 months. Trees planted in this plot averaged 7.1 m in height* (**B**).

B

(Eucalyptus grandis W. Hill ex Maid.) was increased by 70%, from 158 m^3/ha to 269 m^3/ha (Osorio 1988). Herbicide control of molasses grass in a 3-year-old plantation of Mexican or Guatemalan cypress *(Cupressus lusitanica* Mill.) resulted in a 50% increase in average tree diameter within 1 year, compared to control plots with good weed control by hoeing (Cannon 1981).

Tall imported grasses also compete fiercely with young tree seedlings in the lowlands. In Venezuela, a 2-year-old plantation of gmelina established in guineagrass *(Panicum maximum* Jacq.) that was mowed twice after planting had an average height of approximately 2.5 m, with highly variable growth and poor survival, whereas this tree grown in a nearby test plot with continuous manual grass control averaged 7 m tall, with good survival (personal observation). Similar responses to control of guinea grass were also observed for teak plantations in the same area.

Brachiaria grasses are highly detrimental to tree growth and are, perhaps, the most allelopathic to trees among the commercial pasture grasses in the American tropics. Visible and dramatic reductions in the growth of *Eucalyptus urophylla* and river-redgum eucalyptus have been observed in Minas Gerais State, Brazil, where *Brachiaria* has invaded young tree plantations from adjacent pastures (personal observation).

Tropical pines likewise have shown a strong response to complete grass and weed control at time of planting and during the juvenile years. Native savannah bunch grasses such as *Trachypogon* spp. in Venezuela and Brazil are not as competitive with tree seedlings as are the introduced pasture grasses, but if not eliminated, they quickly remove soil moisture during the dry season and significantly reduce first-year survival.

Genetic Tree Improvement

The majority of the plantations in the American tropics are planted with exotic species, that is, species planted outside their natural ranges. This creates a sizeable adaption risk, because often there is little or no knowledge of how the exotic species will perform in a new environment, especially over several years or several rotations. Species and provenance trials are necessary to determine what should be grown on specific sites. Large growth responses have been demonstrated for rosegum eucalyptus and *Eucalyptus urophylla* S.T. Blake in Brazil; for Mexican weeping pine *(Pinus patula* Schl. & Cham.), Mexican mountain pine (*P. tecumumani* Schwerdtfeger), and kesiya or Khasi pine (*P. kesiya)* in Colombia; for Caribbean pine in Venezuela; and for other species by selecting the correct provenance(s) for planting (Brandáo 1984; Ladrach 1993, Zobel et al., 1987). In some areas it is possible to double yields by selecting the correct provenances of eucalypts (Ojo and Jackson 1973).

Once operational plantations are established, additional growth can be gained by selecting the best trees in the best plantations and using them as seed trees. These locally adapted trees, called land races, can increase growth substantially over imported seed (Zobel et al. 1987).

All successful forestry programs soon initiate research to select the best trees and establish them in seed orchards as well as assess their genetic potential in progeny tests. Clonal seed orchards have been established for many species in many countries. Although many forest plantations in Latin America are still made with unimproved seed, a substantial number now use genetically improved seed or genetically improved clonal material for reforestation. Major gains have been made in genetic tree improvement in the tropics, and with the fast growth and short rotations, tropical tree improvement is expected to advance more rapidly than that in temperate areas.

Planting of rooted cuttings from superior trees is becoming a common practice, particularly with the eucalypts. Clonal planting is superior because it captures and exactly duplicates both the nonadditive and additive variation in genetic traits of improved trees (Zobel 1992). Growth rates have more than doubled in Brazil through genetic improvement and clonal planting of rosegum eucalyptus (Brandáo 1984). Similar efforts in Colombia and Venezuela are expected to produce gains on the order of 60% (Lambeth and Lopez 1988, Jurado-Blanco and Lambeth 1991). Costs of nursery production of rooted cuttings have been reduced to the point where they are competitive with seedling production (Campinhos 1984).

Pest and Disease Problems

Initially, exotic plantations have the advantage of being pest free until such time as local pests adapt to the introduced trees or pests are introduced into the new environment (Zobel et al. 1987). Eventually, pests will occur in exotic plantations and they must be expected and dealt with. A few examples of the pest problems in the tropics, along with the controls utilized follow.

Leaf-cutting ants *(Atta sexdens, Atta laevigata, Acromyrmex landolti)* are serious pests of both pines and hardwoods, and ant control is standard in some parts of the Tropics (Jaffe et al. 1982). Ant control is particularly important in the establishment of Caribbean pine plantations in the sandy soils of the eastern grasslands of Venezuela and for eucalypts in north central and northeastern Brazil. Initial disking will reduce populations of leaf-cutting ants, but follow-up applications of insecticide are required to control ant damage.

Defoliating insects from adjacent natural forests often adapt to plantations of exotic species and be come very serious pests. Larvae of Lepidoptera can become defoliators that reach epidemic proportions in exotic plantations; attacks by larvae of the lepidopterans *Glena bisulca* and *Oxydia trychiata* in Colombia have caused complete defoliation and major losses in plantations of Mexican cypress and Mexican weeping pine (Lara 1985). *Glena* spp., *Thyrinteina arnobia* Stoll, *Sarcina violascens,* and *Eupseudosoma* spp. are defoliating pests of *Eucalyptus urophylla* in Brazil (Anjos et al. 1987, Zanúncio 1989).

Natural control of defoliators has been effective. By leaving areas of natural forest within the plantations, such as creek bottoms and gallery forests (narrow strip forests along rivers flowing through open range), populations of natural parasites and predators of the defoliators are maintained and control the populations of the defoliators so that they do not become epidemic. Maintaining adequate spacing or thinning stands that are overstocked increases tree health and reduces the likelihood of attack by defoliating insects. In Minas Gerais State, Brazil, a 2-year-old plantation of *Eucalyptus urophylla* planted at 2 x 3 m (1,660 trees/ha) was attacked by defoliating lepidopterans during a prolonged dry season, but adjacent plantations at a 3 x 3 m spacing (1,110 trees/ha) were not affected (Joáo Flavio da Silva, personal communication). In plantations of neighboring reforestation companies, where a 50-m-wide strip of natural open woodlands was left at regular intervals through the plantations, no attack was encountered at the closer spacing. Similar results have been observed for conifer plantations in Colombia, where wide spacings and a policy of leaving natural forests along creeks and protecting residual natural woodlots within the planting areas has virtually eliminated the threat of the defoliating moths.

A serious stem canker attack occurred in rosegum eucalyptus plantations in Brazil beginning in the late 1970's. Although not usually fatal, except to very young trees, the canker causes tree deformation with bark ingrowth and increased resin deposits, making the wood undesirable for bleached pulp. Several hundred thousand hectares were affected by this canker *(Cryphonectria cubensis),* and it was thought that some eucalypts would not be suitable for commercial pulp production. It was found that some progenies were fully resistant to the canker. As a result, most companies are now planting clonal material from resistant families and have virtually eliminated this canker from their plantations (Hodges et al. 1976, Hodges and McFadden 1987).

Grazing animals can also be pests in tree plantations. Agroforestry projects often include grazing and trees in the same field. The use of trees as shade for grazing animals is quite acceptable, where the principal crop is the animal, not the tree. When trees and grazing are attempted together as a mixed crop, there is a mutual reduction in the productivity of both and it is only justified for very high value sawtimber stumpage on good grazing land (Clinton and Mead 1990, Knowles et al. 1991). In the case of gmelina, not only is there a decrease in growth caused by the animals, but tree form is invariably poor in plantations that have been grazed during the years of establishment.

Conclusions

Plantation forestry in tropical America is concentrated on marginal agricultural lands and savannah lands, as opposed to cutover forest lands. Successful planting requires intensive site preparation, and fertilization is a common practice when establishing plantations. Herbicides are used by many organizations for grass and weed control prior to and after planting. Containerized planting stock is widely used, but bareroot planting and stump planting is used for some species. Hand planting is common throughout tropical America.

The majority of the plantations are established with exotic species and seed selection by provenance is important to maximize tree growth. Genetic tree improvement is an integral part of forest research of successful planting programs, and clonal seed orchards have been established for many species.

Although exotic plantations often have the advantage of being pest free initially, there are insect and disease problems in some plantations and their control is an important part of forest management.

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