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The Rain Forest in Tropical America: Forest Dynamics, Reforestation, Seed Handling, and Problems of Management

Carlos Vázquez-Yanes and Alma Orozco-Segovia

Centro de Ecología, National Autonomous University of México
Mexico City

During our lifetime we are seeing the high evergreen rain forests of tropical America being destroyed at overwhelming speed. There is still a considerable lack of basic knowledge about forest dynamics and proper management for this complex type of plant community. The understanding of the natural regeneration processes that take place after spontaneous gap formations in the mature forest is shedding light on this matter. The role of the fast-growing but short-living pioneer trees that first colonize light gaps in the reestablishment of the forest environment may be decisive in the development of management and reforestation techniques using native species. Seed storage and handling is difficult for most valuable timber and fruit species due to the high moisture content and rapid metabolic rate of most rain forest seed species. This creates a lack in both the availability of seeds of native trees for reforestation and the creation and maintenance of nurseries. Much more research is needed in order to solve these problems. Tree Planters' Notes 43(4):114-118; 1992.

The high evergreen tropical rain forest is a fantastically diverse plant community. It covers an important part of the tropical American continent. The largest forest extends for millions of square kilometers across the basin of the world's largest river, the Amazon. Although there are several smaller rain forests in tropical America, most are severely disturbed and reduced by human activities. A particularly important one starts at the Pacific Coast of Ecuador and Colombia, covers the Isthmus of Panama, and continues along the Atlantic Coast of all Central America to Guatemala, entering North America along southeastern Mexico. In Mexico it mainly stretches along the coast of the Gulf of Mexico between the mountains and the sea, continuing north into the State of San Luis Potosi, crossing the Tropic of Cancer about 400 km south of the U.S. border. In Central America and Mexico an enormous part of the forest has disappeared during this century and only isolated patches remain along the range. Some of the largest still-forested areas are in Panama and Costa Rica, on both sides of the Mexican-Guatemalan border, and in the Mexican state of Oaxaca. In Mexico, only 10% of the original forest still survives; the rest has been transformed into pastures or fields for crops such as sugar cane, corn, and coffee. The State of San Luis Potosí has lost all of its rain forest in just 20 years (Dirzo and Miranda 1991).

An important part of the basic knowledge of rain forests comes from research facilities situated along this range. These include, to the south, the island of Barro Colorado, Canal Zone, in Panama (Smithsonian Tropical Research Institute) (Leigh et al. 1982), in the middle at *La Selva* in Northern Costa Rica (Organization for Tropical Studies) (Clark et al. 1987) and at the northern part, at *Los Tuxtlas* volcanic area in the State of Veracruz, México (National Autonomous University of México) (Gómez-Pompa and Del Arno 1985).

The main difference between the rain forest and most temperate forests is the striking abundance of different kinds of trees. Most rain forests are composed of many species with little or no dominance of any species. A mean square hectare of Amazonian rain forest may have more than 200 different species of trees, with over 150 species in a Costa Rican forest and less than 100 species in a Mexican rain forest (Bongers et al. 1988).

The difference in richness of the forest between the south and the northern part of the range may be due to the age of the community. The present-day Mexican and northern Central American rain forest is of relatively recent origin because during the last ice age, about 10,000 years ago, the climate was drier in this region than it is now. It is even possible that the rain forest did not exist at that time or that it was much smaller and its expansion to the north began after the ice age (Toledo 1982).

The structure of the rain forest is highly complex. Any diagrammatic profile of the forest shows a complex array of plants yielding multiple strata. The lowest stratum is formed by herbaceous plants, small palms, seedlings of trees, and small saplings at ground level. Next, there is a layer of shrubs, small trees, and palms. Above these are medium size trees and occasionally more palms. Towards the top stratum there is the canopy of large trees (from 25 to 40 m in height, depending on the place), and over the canopy there may be scattered gigantic emergent trees that may reach over 70 m in the most luxuriant parts of the range. Growing on all tree sizes from small to large is an abundance of cryptogamous plants, climbers, epiphytes, and strangling trees that contribute to the complexity of the structure of the community (figure 1) (Richards 1952).

Figure 1—*Tree branches are densely covered with epiphytic plants, which increase their weight and make them more vulnerable to storms and wind.*

A limiting factor for the small plants in this system is the sparse level of radiant energy at the lowest stratum inside the forest. The available light for photosynthesis is reduced to a minimum, and many plants cannot grow sufficiently under this light. Only those situated under the reach of occasional sunfleks may receive enough radiant energy for growth. For most woody plants, the only chance to become successfully established and grow toward the canopy is an opening or a gap in the forest canopy that allows more energy to reach the ground level of their community (Chazdon 1988).

Rain Forest Dynamics

Canopy gaps are natural disturbances that occur randomly in the rain forest. The occurrence of gaps and their filling process explain much of the structure, regeneration mechanisms, and tree growth behaviors that characterize the rain forest of Central America and Mexico, which have been well studied (Brokaw 1985).

Gaps are not uncommon. It has been calculated that about 1% of the canopy area becomes a gap yearly (Popma et al. 1988). Branches and entire trees in the rain forest normally do not die of old age. The shallow roots that characterize these trees; the weight of their load of epiphytes and climbers; the water during the heavy rains; and the damage produced by termites, fungi, and other parasites make trees vulnerable to strong winds. Trees then fall violently to the ground during a storm, creating an opening in the canopy (figure 2).

Figure 2—*Most trees fall to the ground long before they are old enough to die of old age, creating a canopy gap.*

The sudden penetration of more light to the lower levels of the forest has consequences for all the plants in the newly created opening (figure 3). New branches of surrounding trees may grow toward the opening; arrested or slow-growing seedlings, saplings, and treelets may start growing much faster; some light-sensitive seeds may germinate; and even some understory plants may finally get enough energy to produce flowers and fruits. Gaps create new opportunities for many plants, allowing the renovation of the canopy and reinforcing the maintenance of the species diversity of the forest (Bazzaz 1984).

Figure 3—*The forest ground is covered by arrested or slow-growing seedlings of many tree species waiting for an opportunity (light gap) to grow toward the canopy.*

Large gaps in the rain forest are characterized by the emergence of special kinds of tree that are not present in mature forest patches. The **pioneer trees,** sometimes called **weed trees,** are characterized by their very fast growth and short life span; formation of very-low-density wood; an umbrella-like crown of strictly heliophilic leaves (requiring full sunlight); and a massive production of small seeds (figure 4). They survive in the medium to large gaps for 20 to 30 years until slower-growing mature-phase trees shade them. The best known pioneer tree of the Americas is the balsa tree, which produces a light wood that is very useful for wood carving and other modeling (Gómez-Pompa and Vázquez-Yanes 1981).

Pioneer trees are also common in some secondary fallows produced in disturbed areas when the soil and seed sources allow. They also grow along trails and roads built through mature forests and frequently along river banks.

Some authors consider pioneer trees healing vegetation (Gómez-Pompa and Vázquez-Yanes 1981). In fact, these trees help to restore the microclimatic conditions of the forest and the organic matter of the soil in the large openings. Due to the characteristics of their crowns, they do not produce deep shade, and therefore may favor the establishment and growth of mature-phase tree seedlings, which would ordinarily not survive. Although there has been little research about this subject, it is obvious that pioneer trees are going to play an important role in management and reforestation with native species. They might also contribute to the recuperation of soil fertility and microclimate, which would help the development of mature forest trees in

Figure 4—*Pioneers like these tall slender cecropia trees are large gap colonizers, which play an important role in the healing process of the forest.*

areas that are now devoid of original vegetation (Gómez-Pompa et al. 1990).

Reforestation Practices

The understanding of the natural regeneration processes of the rain forest will provide the basic information required for the proper management of the rain forest, which until now has been exploited in all the American tropics in an extremely destructive way. Timber resources of the forest, like the valuable minerals of a mine, can be exploited until depletion. If we continue this practice, the disappearance of the remaining valuable trees of the forest in most of the tropics is only a few years away (Wilson 1988).

Logging in tropical America is still seen by many conservationists as the beginning of the end of the rain forest. Loggers remove valuable timber by opening roads into the forest. Slash-and-burn farmers then move in using the same roads. Because of the lack of proper management techniques, the rain forest can be still considered a nonrenewable resource (Gómez-Pompa et al. 1972).

The exploitation of valuable timber species, such as mahogany *(Swietenia spp.),* in the tropical American rain forest has been very damaging. This species is now risking extinction in parts of its distribution. Some attempts have been made to develop nurseries to produce saplings of mahogany in nurseries in order to replant the forest. Although a common practice in temperate forests, the results with mahogany have been very often very disappointing in plantations because insects destroy most of the saplings. This is a good example of how the extreme complexity of the biotic interactions in the rain forest requires much more research before we will be able to develop proper management techniques for many species.

In the American tropics, reforestation with native species of the rain forest is seldom attempted. More often, exotic trees such as eucalyptus, gmelina, and the tropical pines from the Caribbean islands and Asia are used in order to create a fast-growing monoculture forests for timber and cellulose. These managed forests totally replace the native plants and animals and offer a striking contrast to the native forests in terms of levels of biological diversity.

Tree Seed Problems in the Tropics

The seeds of different plant species are exposed to the environment with a wide range of moisture contents, metabolic rates, and variable dormancy mechanisms, which influence their viability in the soil or in artificial storage (Priestley 1986). These seed attributes are closely related to the characteristics of the environments in which the plants live.

The availability of seeds for reforestation of the rain forest is one of the main problems that must be solved in order to develop techniques of management for native species. Most rain forest trees produce big fleshy seeds that germinate quickly and give rise to seedlings with extensive root and foliar surfaces. These traits might be related to the almost continuously favorable conditions for germination that characterize the rain forest as well as the intense competition for light among plants existing at ground level beneath the canopy and the high level of seed predation and deterioration created by the continuous high temperatures and moisture levels of the environment (Foster 1986).

Most rain forest mature-phase seed species are characterized by the lack of a period of dormancy, a high moisture content, and rapid respiration rate (Garwood and Leighton 1990). This combination of characteristics fits the tropical recalcitrant type of seeds first described by Roberts (1973) and redefined by Bonner and Vozzo (1987). By definition, they are hard or impossible to store for long periods of time. Survival of the seeds in the field is often unpredictable because it depends on the balance between water absorption from the soil and water loss by transpiration (Vázquez-Yanes and Orozco-Segovia 1990). The inability to store seeds means that, for most rain forest trees, the remaining patches of forest are the only available sources of seeds for planting and nurseries.

Most forest seed suppliers in the tropics market mainly exotic species and some rain forest plants that produce storable seeds (orthodox type: Roberts 1973) like ceiba *(Ceiba* spp.), balsa *(Ochroma* spp.), tropical-cedar *(Cedrela* spp.), teak *(Tectona grandis* L.), limba *(Terminalia* spp.) and few others. Most rain forest species having valuable or potentially valuable timber and fruit or medicinal trees are not available in any seed storage bank (Chin and Roberts 1980, FAO 1975, Willan 1985).

Native tree seedling nurseries for reforestation are poorly developed in most tropical rain forest areas. Because of the lack of seed handling techniques and seed reforestation methods, combined with the economical and methodological exploitation difficulties produced by the diversity and complexity of the rain forest.

Conclusions

Although there has been an increasing interest in developing basic research on rain forest structure and dynamics in the American tropics by U.S. and Latin American scientists, there is still a considerable lack of information on conservationist methods of management, reforestation with native species, and seed handling.

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El Bosque Lluvioso en América Tropical: Dinámica Forestal, Reforestación, Manipulación de las Semillas y Problemas de Manejo

Carlos Vázquez-Yanes and Alma Orozco-Segovia

Centro de Ecología, Universidad Nacional Autónoma de México, México, D. F.

En la época actual los bosques altos perennifolios lluviosos de América tropical están siendo destruídos a una velocidad alarmante. Hay aún una considerable carencia de conocimientos básicos acerca de la dinámica forestal y de métodos adecuados para manejar este tipo tan complejo de comunidad vegetal. El entendimiento de los procesos de regeneración vegetal que tienen lugar después de la formación espontánea de claros en el bosque maduro está aclarando algunos aspectos de esta dinámica. El papel que juegan los árboles de corta vida y rápido crecimiento llamados pioneros, que colonizan los claros de luz y su efecto en el restablecimiento del ambiente forestal pueden ser decisivos en el desarrollo de métodos de manejo y reforestación con especies nativas. El almacenamiento y manejo de las semillas presenta dificultades para la mayoría de las especies maderables y frutales valiosas, debido a su alto contenido de humedad y tasa metabólica. Esto genera deficiencias en la disponibilidad de semillas de especies nativas para la reforestación y en la creación y mantenimiento de viveros de las especies más valiosas. Se necesita aún mucha investigación cientifica para resolver estos problemas. Tree Planters' Notes 43(4):119-124; 1992.

El bosque alto perennifolio tropical lluvioso es una comunidad vegetal fantásticamente diversa de los trópicos del mundo. Cubre una parte importante del Continente Americano tropical. La mayor superficie se extiende por millones de kilómetros cuadrados sobre la cuenca del río más caudaloso del mundo, el Amazonas. Hay otros parches más pequeños de bosque tropical lluvioso en América, la mayoría de ellos fuertemente alterados y reducidos por la actividad humana. Uno de ellos, de gran importancia por la gran cantidad de investigación básica efectuada en él, comienza en la costa pacífica de Ecuador y Colombia, cubre el Darién situado en la unión entre Sudamérica y América Central en la República de Panamá y continúa a lo largo de la costa atlántica desde Panamá hasta Guatemala, entrando en Norteamérica a través del sureste de México. En este país cubría una franja a lo largo de la costa del Golfo de México hasta el estado de San Luis, Potosí cruzando el Trópico de Cancer, a alrededor de 400 km de la frontera de los Estados Unidos. En Centro América y México gran parte de este bosque ha desaparecido durante este siglo y sólo quedan parches importantes aislados en Panamá, Costa Rica, a ambos lados de la frontera entre México y Guatemala y en el estado mexicano de Oaxaca. En México sólo el 10% del bosque original aún existe, el resto está transformado en pastizales y cultivos como caña de azucar, maíz y café. El estado de San Luis Potosí ha perdido todo su bosque tropical en sólo 20 años (Dirzo y Miranda 1991).

Una parte del conocimiento básico acerca del bosque tropical lluvioso viene de investigaciones hechas en tres instalaciones de investigación situadas a lo largo de la franja antes mencionada. Hacia el sur la Isla de Barro Colorado, Zona del Canal de Panamá (Smithsonian Tropical Research Institute) (Leigh et al. 1982); en "La Selva" en la parte norte de Costa Rica (Organization for Tropical Studies) (Clark et al. 1987) y en México en el macizo montañoso de "Los Tuxtlas" en el estado de Veracruz (Universidad Nacional Autónoma de México) (Gómez-Pompa y Del Amo 1985).

La principal diferencia entre el bosque tropical lluvioso con la mayoría de los bosques templados es la asombrosa abundancia de diferentes clases de árboles. La mayoría de los bosques tropicales están compuestos de una mezcla de especies con escasa o nula dominancia de ninguna de ellas. Una hectárea cuadrada del bosque amazónico puede tener hasta más de 200 especies diferentes de árboles, en el bosque costarricense 150 y en el mexicano algo menos de 100 (Bongers et al. 1988).

La diferencia en riqueza entre los bosques del sur y del norte se puede deber a la edad del bosque. El bosque actual de México y el norte de Centro América parece tener un orígen relativamente reciente porque durante la última glaciación hace aproximadamente 10 000 años el clima era más seco en esta región de lo que es ahora, por lo que es posible que el bosque lluvioso no existía en esa época o era mucho menos extenso. La expansión del bosque hacia el norte comenzó después de la última glaciación (Toledo 1982).

La estructura del bosque lluvioso es muy compleja. Un perfil diagramático del bosque muestra un complejo arreglo de plantas que simulan diferentes estratos. El estrato inferior está formado por plántulas y arbolitos pequeños, palmas, plantas herbáceas. Sobre éste hay una capa de arbustos, pequeños árboles y palmas. Arriba árboles medianos y en algunos lugares más palmas. Sobre estratos se encuentra el dosel de árboles grandes que tiene entre 25 y 40 metros de altura dependiendo del lugar. Sobre el dosel hay aisladamente gigantéscos árboles emergentes que pueden llegar a medir hasta 70 metros en las partes más exuberantes de la selva, creciendo sobre toda la diversidad de tamaños de árboles hay una asombrosa abundancia de plantas criptógamas, trepadoras, epífitas y árboles estranguladores que contribuyen a la complejidad estructural de la comunidad (figura 1) (Richards 1952).

Figura 1—*Las ramas de los árboles están densamente cubiertas de plantas epífitas que incrementan su peso y ayudan a hacerlas vulnerables a las tormentas y al viento.*

El principal factor limitante para las plantas pequeñas en este sistema es el escaso nivel de energía radiante gue llega a los estratos bajos dentro de la selva. La luz disponible para la fotosíntesis se reduce a un mínimo y muchas plantas no pueden crecer en esta luz. Solamente las plantas situadas bajo la influencia de ocasionales flecos o rayos de luz pueden recibir suficiente energía para el crecimiento; sin embargo, para la mayoría de las plantas leñosas la única posibilidad de establecerse exitosamente y crecer hacia el dosel se da cuando se abre un claro en el dosel que puede permitir que más energía alcance los niveles bajos dentro de la comunidad (Chazdon 1988).

Dinámica del Bosque Lluvioso

Los claros en el dosel del bosque son disturbios naturales que ocurren al azar. La aparición de claros y el proceso de llenado de estas aperturas permiten explicar muchos aspectos de la estructura del bosque, sus mecanismos de regeneración y las características del crecimiento de los árboles que se presentan en los bosques lluviosos de América Central y México donde se han estudiado bastante bien (Brokaw 1985).

Los claros aparecen con frecuencia. Se calcula que cerca del 1% del dosel se transforma en un claro cada año (Poema et al. 1988). Las ramas o los árboles del bosque lluvioso no mueren de vejez, las raíces superficiales de los árboles, el peso de su carga de epífitas y trepadoras y el del agua durante las fuertes lluvias aunado al daño producido por termitas, hongos y otros parásitos los hace vulnerables a los vientos fuertes por lo que generalmente terminan su vida cayendo violentamente al suelo durante una tormenta, creando en esta forma una apertura en el dosel. Muchos árboles se desenraizan dejando un agujero de suelo expuesto que contribuye a la heterogeneidad del ambiente del claro (figura 2).

La súbita llegada de más energía luminosa a los niveles bajos del bosque tiene consecuencias para todas las plantas ubicadas bajo su alcance: pueden crecer nuevas ramas hacia la apertura, plántulas y arbolitos pueden desarrollarse más rápidamente, semillas fotosensibles pueden germinar e incluso algunas plantas de los estratos bajos pueden disponer finalmente de suficiente energía para producir flores y frutos (figura 3). Los claros generan nuevas oportunidades de crecimiento para muchas plantas permitiendo la renovación del dosel y ayudando en el mantenimiento de la diversidad de especies del bosque (Bazzaz 1984).

Figura 2—*La mayoría de los árboles caen al suelo mucho antes de que sean lo suficientemente viejos para morir en forma natural, creando un hueco en el dosel.*

Los claros grandes del bosque lluvioso se caracterizan por la aparición de una clase especial de árboles que no están presentes en los parches de selva madura. Estos árboles pioneros también llamados a veces "árboles maleza" por su rápido crecimiento y corta vida se tipifican por la formación de leño de muy bajo peso, una copa en forma de sombrilla formada por hojas heliófilas (requieren luz solar directa) y por una producción masiva de pequeñas semillas (figura 4). Sobreviven en claros medianos a grandes por 20 a 30 años hasta que árboles de más lento crecimiento de la fase madura del bosque acaban sombreándolos. El árbol pionero mejor conocido de américa tropical es el palo de balsa que produce una madera ligera muy útil para maquetas (Gómez-Pompa y Vázquez-Yanes 1981).

Los árboles pioneros también son comunes en sucesiones secundarias producidas en áreas alteradas por la actividad humana, pero solamente cuando el suelo no está demasiado dañado y hay aún árboles semilleros cercanos. También crecen a lo largo de los caminos y carreteras construídos através de bosques maduros y en algunos lugares son abundantes a lo largo de las riveras.

Figura 3—*Los pioneros como estas delgadas y altas cecropias son colonizadores de claros grandes que juegan un papel importante en el proceso de cicatrización del bosque.*

Algunos autores consideran a los árboles pioneros una forma de vegetación cicatrizante (Gómez-Pompa y Vázquez-Yanes 1981). De hecho estos árboles ayudan a restaurar las condiciones microclimáticas y la materia orgánica del suelo en las grandes aperturas del bosque y, debido a las características de su copa, no producen una sombra muy profunda. Bajo su protección las plántulas de árboles del bosque maduro podrían crecer mientras que sin ellos posiblemente no podrían sobrevivir. P pesar de que ha habido poca investigación acerca de este asunto, es obvio que los árboles pioneros van a jugar un papel importante en el manejo y reforestación de las especies nativas. Pueden tener importancia en la recuperación de la fertilidad del suelo y del microclima, lo que ayudaría al desarrollo de árboles del bosque maduro en áreas que están ahora desprovistas de su vegetación original (Gómez-Pompa et al. 1990).

Prácticas de Reforestación

La comprensión del proceso natural de regeneración del bosque lluvioso va a proveer de la información básica requerida para el manejo apropiado

Figura 4—*El piso del bosque está cubierto de plántulas de crecimiento interrumpido o lento de muchas especies de árboles que esperan una oportunidad (un claro de luz) para crecer hacia el dosel.*

de este tipo de bosque que hasta ahora ha sido explotado en una forma muy destructiva en todo el trópico americano. Los recursos maderables del bosque, en forma parecida a los minerales valiosos de una mina, se explotan hasta el agotamiento y si continuamos haciendo esto en el futuro, la desaparición del bosque en la mayor parte de los trópicos sólo requerirá de pocos años (Wilson 1988).

La actividad de los leñadores aún es vista por muchos conservacionistas como el principio del fin del bosque lluvioso. Estos extraen la madera valiosa construyendo caminos que son después la vía de entrada al bosque para los agricultores de roza, tumba y quema. Debido a la falta de técnicas de manejo apropiadas el bosque lluvioso puede aún ser considerado como un recurso natural no renovable (Gomez-Pompa et al. 1972).

La explotación de madera valiosa como la caoba en los bosques lluviosos de los trópicos americanos ha sido muy dañina para la especie que ahora está en peligro de extinción en parte de su área de distribución. Se han hecho algunos intentos de desarrollar viveros para producir plántulas de caoba con el fin de reemplazar los árboles derribados en el bosque, una práctica común en bosques templados, pero los resultados con caoba han sido muy decepcionantes en plantaciones porque los insectos parásitos terminan destruyendo todas las plántulas. Este es un buen ejemplo de como la extrema complejidad de las interacciones bióticas del bosque lluvioso requiere de mucho más investigación antes de que seamos capaces de desarrollar técnicas de manejo adecuado para muchas especies.

En los trópicos americanos la reforestación con especies nativas del bosque lluvioso se intenta rara vez. Con mayor frecuencia se usan especies exóticas como eucaliptos, gmelina, pinos tropicales del Caribe y Asia, con el objeto de crear bosques monoespecíficos de rápido crecimiento para la producción de madera y celulosa. Estos bosques manejados desplazan totalmente a las plantas y animales nativos y con frecuencia son notablemente pobres en otros seres vivos aparte de los árboles plantados.

Problemas con Semillas Tropicales

Las semillas de las diferentes especies de plantas son liberadas al ambiente con un amplio rango de niveles de humedad, tasas metabólicas y variedad de mecanismos de latencia que tienen influencia en su longevidad en el suelo y en almacenamiento artificial (Priestley 1986). Estos atributos de las semillas están cercanamente relacionados con las características del ambiente donde las plantas viven.

La disponibilidad de semillas para la reforestación en el bosque lluvioso es uno de los principales problemas que tienen que ser resueltos para desarrollar técnicas de manejo de especies nativas. La mayoría de los árboles del bosque lluvioso producen grandes semillas carnosas que germinan rápidamente originando plántulas con extensa superficie de raíces y hojas. Estas características están relacionadas con las condiciones casi continuamente favorables para la germinación que caracterizan al bosque lluvioso, la intensa competencia por luz que existe el nivel del suelo y las altas tasas depredación de semillas y parasitismo que operan favorecidas por la continua alta temperatura y humedad del ambiente (Foster 1986).

La mayoría de las especies del bosque maduro se caracterizan por la falta de un periodo de latencia, un contenido alto de humedad y alta tasa metabólica (Garwood y Leighton 1990). Esta combinación de características se ajustan al tipo de semilla llamado recalcitrante tropical descrito por Roberts (1973) y redefinido por Bonner y Vozzo (1987). Por definición son difíciles o imposibles de almacenar por largos periodos de tiempo. Su sobrevivencia en el campo sobre la superficie del suelo, donde la mayoría de ellas germinan, es frecuentemente impredecible porque depende del balance entre ganancia de agua del suelo y la cantidad de esta perdida por transpiración, de acuerdo con los niveles de humedad atmosférica y calor (Vázquez-Yanes y Orozco-Segovia 1990). Para la mayoría de los árboles tropicales las únicas fuentes proveedoras de semillas para la reforestación y los viveros son los restantes parches de bosque maduro.

Los proveedores comerciales de semillas en los trópicos manejan principalmente especies exóticas como las ya mencionadas y algunas species tropicales que producen semillas almacenables (ortodoxas; Roberts 1973) como ceiba, balsa, cedro tropical, teca de Asia, terminalia y algunas otras. La mayoría de las especies frutales o maderables valiosas del bosque lluvioso no pueden ser obtenidas en ningún banco de almacenamiento de semillas (Chip y Roberts 1980, FAO 1975, Willan 1985).

Como consecuencia de la falta de técnicas apropiadas de manejo de semillas y de métodos de reforetación combinado con las dificultades de explotación producidas por la diversidad y complejidad del bosque tropical lluvioso, los viveros de plántulas de especies nativas con fines de reforestación están pobremente desarrollados en la mayor parte del trópico húmedo. Pueden encontrarse algunas en instalaciones de investigación pero muy pocas de ellas están ligadas a la explotación comercial.

Conclusiones

A pesar de que ha habido un interés creciente en desarrollar investigación básica sobre la estructura y dinámica del bosque lluvioso en America por parte de científicos estadounidenses y latinoamericanos, hay aún una considerable falta de información que ligue el conocimiento que ya tenemos con el desarrollo de métodos conservacionistas de manejo, reforestación con especies nativas y manejo de semillas.

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Plantation Establishment Techniques in Tropical America

William E. Ladrach

Forest consultant, Zobel Forestry Associates, Raleigh, NC
and adjunct assistant professor, North Carolina State University, Raleigh, NC

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.

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**).

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.

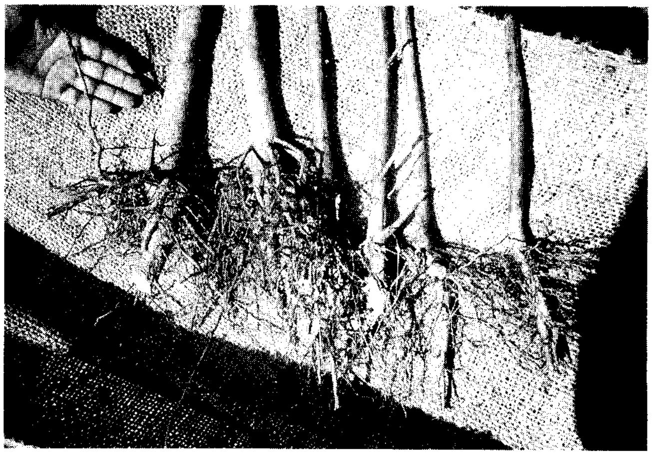

Figure 2—*Stump seedlings, or "pseudoestacas," of* Gmelina arborea *prepared for planting. Their roots are dipped in clay slurry.*

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 *(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).

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

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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Técnicas Para el Establecimiento de Plantaciones Forestales en la América Tropical

William E. Ladrach

Asesor forestal, Zobel Forestry Associates, Inc., Raleigh, Carolina del Norte, EE. UU. y Profesor adjunto, Universidad Estatal de Carolina del Norte

El manejo de las plantaciones tropicales no es muy diferente de su contraparte en las zonas templadas. Los principios de manejo son los mismos, aunque las aplicaciones pueden modificarse algo, dependiendo de la especie, el sitio y el producto final que se desea obtener. Debido a que no hay una estación fría latente, la plantación en los trópicos tiene que hacerse durante el comienzo de la estación de lluvia. Aunque es común plantar árboles con cespedón, en el oriente de Venezuela se están plantando pinos a raíz desnuda a gran escala. En varios países se están plantando estacas enraizadas de algunas especies latifoliadas con plántulas con diámetros grandes.

La investigación aplicada y los ensayos con plantaciones piloto son una absoluta necesidad para desarrollar árboles localmente adaptados, así como para mejorar la productividad de la plantación a través del mejoramiento genético. La preparación intensiva de sitio y la fertilización son prácticas corrientes y generalmente requeridas para el establecimiento exitoso y el crecimiento de plantaciones operacionales en el trópico. La diferencia más significativa entre las prácticas de plantación en Norte América y el trópico radica en la necesidad de un control de malezas y pastos en el trópico, después de la plantación. Muchas plantaciones tropicales se hacen con especies exóticas, las cuales, inicialmente, están libres de plagas. Eventualmente, aparecen los problemas causados por las plagas, pero con una buena investigación y con la ayuda de expertos en el tema, se minimiza la amenaza causada por las plagas o, en algunos casos, se elimina. Tree Planters' Notes 43(4):133-141; 1992.

Introduction

Un buen número de ingenieros forestales norteamericanos, que ha tenido la oportunidad de trabajar en los trópicos, ha creado ciertos mitos acerca de las plantaciones tropicales. Seguramente sin mala intención, muchos conferencistas muestran diapositivas con ejemplos de los árboles tropicales de más rápido crecimiento y mejor formados, con el objeto de impresionar a sus colegas norteamericanos. Semejante crecimiento rápido sí existe y se puede lograr, pero hay que colocar todas las cosas en perspectiva, presentando un cuadro real con todas las variables respectivas, con el fin de poder mejorar los conceptos generales sobre el manejo en plantaciones forestales tropicales.

No hay una diferencia abrupta y radical entre el manejo forestal en las zonas templadas y las tropicales; en realidad se trata de modificaciones y ajustes para adaptarse a las necesidades y retos que se afrontan en el trópico. Los conceptos que un ingeniero forestal ha aprendido en la región templada son aplicables en los trópicos, aunque hay diferencias en cuanto al énfasis y a la intensidad del manejo.

Suelos y Preparación de Sitio

Los suelos tropicales varían mucho de sitio a sitio al igual que en los suelos en las zonas templadas y los principios de manejo de suelos se pueden aplicar a ambos. El generalizar con respecto a los suelos tropicales nos ha llevado a establecer malos entendidos (Sánchez y Buol 1975). En algunos casos, las publicaciones y programas populares aseveran que los suelos tropicales son extremadamente frágiles y pobres en nutrientes y esta creencia se acepta a menudo. Hay suelos pobres, pero otros son excelentes y fértiles. Por ejemplo, se dice que los suelos de laterita vuelven como concreto una vez que la cobertura forestal ha sido retirada. De hecho, solamente el 2 porciento de los suelos en América tropical son lateritas (Sánchez y Buol 1975). Mis experiencias en el sudeste de los Estados Unidos y en los trópicos, no han mostrado diferencias demasiado marcadas entre los suelos del trópico y aquellos del sudeste de los Estados Unidos.

El fósforo es uno de los nutrientes que a menudo falta en los suelos tropicales y en los suelos de zonas templadas como los del sudeste de los Estados Unidos. Otro de los elementos que frecuentemente falta en el trópico es el boro, especialmente en suelos volcánicos y en suelos de origen de diabasa. A menudo es necesario hacer aplicaciones de fósforo y boro en el momento de la plantación con el fin de obtener un crecimiento aceptable. La respuesta a los fertilizantes puede ser dramática en suelos que tienen deficiencias en el trópico (Ladrach 1980).

La mayor parte de las plantaciones de árboles forestales en la América tropical son establecidas en tierras marginales, con rastrojo, pastizales, o en tierras agrícolas abandonadas, debido a la facilidad relativa de reforestar estos terrenos. Es ventajoso reforestar terrenos cercanos a las plantas manufactureras y a los molinos, donde hay la disponibilidad de mano de obra en los centros poblados, mas la abundancia de tierras marginales que se pueden convertir a plantaciones a costos razonables. El concepto contrario de que se están reemplazando los bosques naturales a gran escala con especies exóticas de plantación es incorrecto (Zobel y otros 1987).

La reforestación requiere una buena preparación del terreno antes de hacer la plantación, cuyo objetivo es el control de la vegetación competitativa y el aflojamiento del suelo, con el fin de mejorar su estructura y aumentar el espacio en macro-poros. Esto facilita el movimiento de agua y/o la retención de agua.

La preparación de sitio para el establecimiento de plantaciones tropicales es generalmente mucho más intensiva que la preparación de sitio que se hace en las plantaciones en Norte América. Cuando se están plantendo especies tropicales de rápido crecimiento, especialmente las especies latifoliadas, la diferencia entre el éxito y el fracaso de una plantación radica en hacer una preparación de sitio bien hecha y o una mediocre. Sin el control adecuado de la competencia, el potencial total del crecimiento de los árboles no se realiza.

El fuego es un factor históricamente integral de la ecología de los climas monzónicos y se utiliza frecuentemente para eliminar las malezas, el rastrojo y el pasto como un primer paso en la preparación sitio. En los suelos arenosos en la parte central del Brasil así como en las arenas del norte de la Florida, la desmalezada mediante el paso con el rolo argentino y la quema son una mejor alternativa ecológicamente hablando, ya que con esta alternativa se dejan la ceniza y el material orgánico en su lugar, y se suministran nutrientes, en cambio con el apilado del material superficial en trincheras o fajas para facilitar el arado, la superficie del suelo se verá negativamente afectada .

En los suelos planos, bien drenados y con texturas pesadas, la preparación de sitio a menudo se hace utilizando tractores con arados y rastras. En los sitios bajos y húmedos se necesita hacer drenajes y camellones para quitar el exceso de agua y aumentar el volumen de suelo drenado disponible para que las raíces tengan un buen crecimiento. Aun en los sitios que no son inundables se ha visto que los camellones son muy efectivos para incitar el crecimiento temprano de los árboles (figura 1). El subsolado también es muy efectivo para incrementar el crecimiento en los sitios en que los suelos han estado sujetos durante años a la compactación causada por la ganadería o que tienen una capa de suelo duro, esta práctica se está generalizando.

Aunque se ha comprobado que no es la mejor práctica en los terrenos pendientes, la preparación de sitio a menudo consiste en el plateo manual con azadón o escardilla antes de hacer la plantación (Ladrach 1983, Lambeth 1986). La maleza y el pasto que quedan entre los platos, se controlan con machete o con azadón.

Se ha comprobado que los herbicidas como glifosato son efectivos para la preparación de sitios muy enmalezados, con pasto y/o arbustos. A menudo se encuentran pastos comerciales muy agresivos en terrenos que habían sido utilizados en la ganadería que, si no son controlados, suprimen el crecimiento o destruyen las plantaciones de árboles. La respuesta que se ha obtenido con los herbicidas ha sido muy significativa. Una práctica generalizada es la de aplicar el herbicida a los pastos solamente alrededor del hoyo o plato, en un diámetro de 1,0 a 1,5 m, antes de plantar. Luego, se hace la plantación en el pasto seco para evitar erosión. Cuando se plantan eucaliptos, pinos y cipreses en suelos de ceniza volcánica en la cordillera de los Andes, en donde la compactación del suelo no es problema, el solo use de los herbicidas es un medio efectivo de preparación de sitio en terrenos previamente utilizados en los que hubo pastos importados (Ladrach 1983). En los sitios en que la competencia por malezas y pasto es alta hay que controlarla primero mecánicamente, manualmente o por medio de la quema antes de aplicar los herbicidas.

Figura 1—*Una plantacion de* Eucalyptus grandis *de un mes de edad en al estado de Cojedes, Venezuela. Este potrero no inundable fue arado y rastrillado antes de la plantación. El crecimiento de los árboles es modesto, pero la competencia por pastos y malezas es abundante.* **B**—*Esta parcela adyacente a la anterior, fue encamellonada después de ser rastrillada. Los árboles, de un mes de edad, tienen mas del doble de la altura de los de la figura 2A y la competencia por malezas es significativamente menor.*

Métodos de Plantación

Debido a que no hay una estación fría en los trópicos, la mayor parte de las plántulas arboreas forestales no tienen una verdadera etapa de latencia que es la mejor época para plantarlas en los climas fríos. La mayor parte de las plantaciones a gran escala en los trópicos se establecen en el clima de monzón, o sea, húmedo/seco, a diferencia del clima húmedo en donde no hay una estación de sequía o esta es muy corta. El error que más comúnmente se comete es el de demorar la plantación hasta casi el comienzo de la época de sequía. La clave es hacer la plantación al comienzo de las lluvias continuas, con el fin de que tengan tiempo de desarrollar su sistema radicular antes de que comience la época de sequía. A1 final del primer año, las especies latifoliadas que se plantan al comienzo de las lluvias, tienen el doble de la altura, que aquellas que fueron plantadas a mitad de estación o justo antes de la sequía, y tienen una tasa de supervivencia mucho mas alta al final de la primera estación de sequía.

En los sitios en donde hay una estación de sequia muy coma o inexistente, como en el caso de las costas de Centro América en el Caribe y en algunas de las islas, a veces se hace la platación durante todo el año. No obstante, es mas común que la plantación se haga solamente en un período de unos pocos meses al comienzo de la época de lluvias, durante el cual se puede contar con lluvias subsecuentes, las cuales ocurren, a menudo, después de una estación de fuerte sequía prolonganda. Cerca del Ecuador puede haber dos estaciones de lluvia y dos estaciones de sequía durante el año. En las regiones sub-tropicales generalmente hay solamente una estación de lluvia por año.

Las especies caducifolias tales como la teca *(Tectona grandis),* el cedro *(Cedrela odorata) y la Gmelina arborea* se defolian durante la sequía para sobrevivir los largos períodos secos. El pino Caribe *(Pinus caribaea* var. *hondurensis)* se ha adaptado para poder sobrevivir largos períodos de sequía y crecer en suelos con bajo nivel de nutrientes. Las leguminosas tales como el trupillo o cují *(Prosopis juliflora), Leucaena leucocephala, y algunas* especies de *Acacia* pueden crecer en sitios secos y alcalinos. Se ha encontrado que muchas especies de eucaliptos crecen rápidamente bajo una diversa cantidad de condiciones ecológicas y se prefieren para la producción de pulpa en los casos en que se necesita una máxima producción de biomasa. Algunas especies, como *Eucalyptus camaldulensis,* son muy resistentes a la sequía.

Algunas especies de eucalipto se plantan durante las últimas semanas de la estación de sequía y se riegan para mantenerlas vivas hasta que comiencen las lluvias, con el fin de obtener un crecimiento adicional. Cada plántula se riega con aproximadamente tres litros de agua al momento de la plantación, empleando un tractor con tanque de agua. El agua se aplica manualmente con mangueras alimentadas por gravedad desde el tanque. Se hacen riegos cada una a dos semanas hasta tanto que las lluvias se inicien. Se ha demostrado en Minas Germs, Brasil, que este procedimento aumenta el crecimiento de los árboles mas del 50% al final de la primera estación de crecimiento, comprando con los procedimientos de plantación normales hechos al comienzo de la estación de lluvia (Rodrigues 1991).

Casi toda la plantación de árboles en los trópicos se hace a mano. Solo unas pocas organizaciones plantan mecánicamente. Hay varias razones para la plantación manual:

1. A menudo las plántulas son producidas en los viveros en envases y no se adaptan fácilmente a las plantadoras mecánicas.
2. Muchos de los sitios de plantación no pueden ser atravesados por tractores, especialmente aquellos que se encuentran en terrenos montañosos o quebrados.
3. La maquinaria para hacer plantaciones, en su mayor parte, es importada y costosa. A menudo es mucho mas económico plantar a mano.
4. Muchas empresas mantienen una política de utilización de la mano de obra local en cuanto sea posible, como medio de colaboración social y beneficio adicional de la reforestación, ya que el desempleo es alto en la mayor parte de las áreas de tierras marginales en donde se lleva a cabo la reforestación.

Invariablemente se manejan los eucaliptos como plántulas en envases. Las bolsas plásticas de 12 x 15 cm cuando están planas se utilizan frecuentemente, al igual que los tubos ribeteados de 3-4 cm de diámetro x 15 cm de longitud. En los viveros los tubos se colocan en marcos plásticos o metálicos colocados sobre bases para facilitar la poda aérea de las raíces. Hay que coordinar la plantación de suerte que cuando las plántulas estén listas en el vivero se puedan transportar hasta el cameo inmediatamente. El crecimiento de las plántulas de eucalipto debe mantenerse constante entre el vivero y el cameo para obtener mejores resultados. Por tanto, otra de las razones para hacer el riego inicial de las plántulas de eucaliptos es la de asegurar su supervivencia una vez plantadas en el cameo; hay que plantar el material del vivero tan pronto esté listo, sin importar si las lluvias se han demorado.

En la mayor parte de los programas de plantación se levantan los pinos como plántulas envasadas o en contenedores. Pero en un programa gubernamental en el este de Venezuela se plantan 30.000 ha de plántulas a raíz desnuda anualmente (Ladrach 1991). En esta región de suelos arenosos muy drenados, en la cual hay una prolongada estación de sequía de mas de cuatro mews por año, es necesario tener un excelente manejo de viveros y un cuidadoso control de la logística de plantación, con el fin de obtener buenos resultados en la plantación a raíz desnuda. Se levantan las plántulas del vivero, se califican, y se sumergen sus raíces en una solución de arcilla y se plantan mecánicamente el mismo día. En estos viveros de plántulas a raíz desnuda el diámetro mínimo aceptable del cuello de las raíces es de 4,5 mm, ya que árboles de buen tamaño tiepen un mejor crecimiento y supervivencia inicial. En el vivero se rechazan las plántulas más pequeñas.

Las especies frondosas que producen plántulas de diámetros mayores, frecuentemente son plantadas a raíz desnuda en forma de pseudoestacas (stumps), así como también en envases. Unas de las especies mas importantes son la *Gmelina arborea, Tectona grandis* (teca), *Bombacopsis quinata,* y *Tabebuia* sp. Las semillas se siembran bien espaciadas con 30 a 40 plántulas por m z con el fin de obtener plántulas de con un diámetro mayor. Se ha encontrado que las plántulas con cuello de raíz de 1,5 cm de diámetro tiepen la mejor tasa de supervivencia en la plantación en el cameo (Urueña 1991). Se levantan las plántulas en el vivero y se podan antes de plantarlas en el camp. En algunos viveros se levantan las plántulas al anochecer, se clasifican, se polo la pane superior de la plántula a 20 cm y la raíz a 15 cm, se sumerge la raíz en una solución de arcilla y se colocan las pseudoestacas en guacales para ser transportados al cameo (figura 2) . Se plantan las pseudoestacas en la mañana siguiente.

Bombacopsis, un caso especial. *Bombacopsis quinata* es una especie latifoliada nativa del none de Sur América y pane de América Central. Time varios nombres comunes según el país: saqui-saqui (Venezuela), ceiba tolúa, ceiba roja (Colombia), cedro espino (Panamá), pochote (Costa Rica) y es una de las especies más rams que se están plantando comercialmente. Los árboles de *Bombacopsis* tiepen espinas gruesas y agudas que crecen a to largo de todo su fuste y ramas, desde que son plántulas hasta su vida adulta. Las plántulas jóvenes en las plantaciones tiepen un fuste recto y

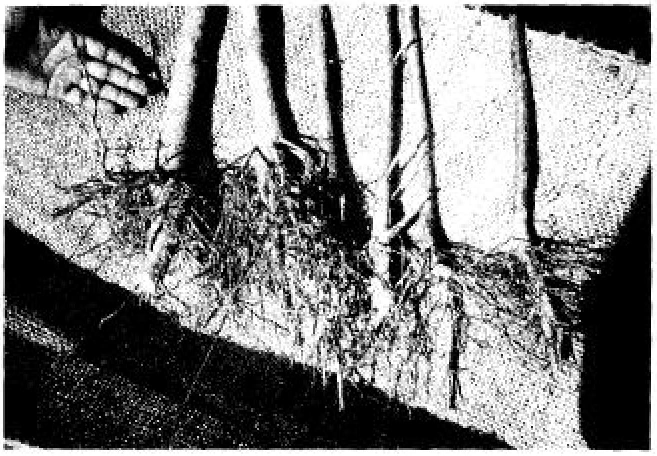

Figura 2—*Pseudoestacas de* Gmelina arborea *preparadas para la plantación, sus raíces fueron sumergidas en un lodo de arcilla.*

un crecimiento moderado to cual la hace una especie promisoria para la producción de enchapados y madera aserrada. Esta especie no se autopoda, por tanto, es necesario hacerle podas para obtener madera Lisa. Los árboles viejos en bosques naturales pueden llegar a tener diámetros a altura de pecho, superiores a un metro.

Las plántulas que se levantan a raíz desnuda en el vivero, pierden sus hojas durante la estación seca y se dejan sin riego durante este período. Se pueden levantar las plántulas del vivero durante la estación seca y plantarlas a tamaño completo 0 como pseudoestacas. Los ensayos de plantación que se han hecho, han mostrado que el mejor crecimiento y una buena supervivencia se logran cuando las pseudoestacas se plantan a raíz desnuda durante la estación de sequía, sin riego, un mes antes de las lluvias, en vez de plantarlas al comienzo de las lluvias (Kane 1989). Esta capacidad de sobrevivir y de crecer cuando han sido plantadas en suelos absolutamente sews es única entre las especies de árboles forestales comerciales.

La especie *Bombacopsis* retoña bien y cuando se inserta una rama gruesa en el suelo húmedo, esta se enraiza. Gracias a que la *Bombacopsis* se enraiza fácilmente es apta para ser plantada en forma de estacas enraizadas, una vez que se haya mejorado genéticamente la cepa y ésta haya sido seleccionada y probada. En Centro América esta especie se considera como de los altiplanos secos, pero también puede crecer en tierras bajas, en las terrazas de los ríos, y en suelos húmedos durante la estación de lluvia y luego, soportar la sequía extrema de la estación seca en las plantaciones de la Costa none de Colombia (figura 3).

Figura 3—*Esta plantación de* Bombacopsis quinata *de ocho años de edad de Pizano, S.A., acabando de hacersele una entresaca. Los árboles en pie serán destinadas a la producción de láminas contrachapadas.*

Aunque *Bombacopsis* es una especie relativamente desconocida fuera de su distribución nativa, está siendo plantada comercialmente en Colombia, Costa Rica y Venezuela. Sus taws de crecimiento no son altas si las comparamos con las de muchos eucaliptos, o con las de la *Gmelina,* pero la calidad de la madera y la facilidad de su manejo en plantaciones la hace una especie altamente deseable para la producción de productos de madera sólida con turnos de 20 años ó menos. Algunos han llegado a predecir que la *Bombacopsis* va a convertirse en una especie comercial muy importante dentro de los próximos años, como una fuente para producir enchapados y madera para aserrrío a medida que vayan desapareciendo las fuentes de bosques naturales.

Control de Malezas y Pasto Después de la Plantación

Una diferencia mayor entre el manejo de plantaciones en la América tropical y la América del Norte es el control de malezas después de la plantación. Con el fin de obtener buenas plantaciones en casi todos los sitios tropicales es indispensable hacer el control de los agresivos pastos y malezas. Las plantas trepadoras tales como la batatilla *(Ipomoea* sp.) y las campanitas *(Thevetia* sp.) pueden deformar los árboles jóvenes y aún jalarlos al suelo. En los lugares en donde se encuentran hay que cortarlos varias veces al año durante los primeros años de la plantación.

Muchos de los potreros viejos están cubiertos con pastos comerciales exóticos. El pasto kikuyu *(Pen-*

nisetum clandestinum) del Africa fué introducido en la Cordillera de los Andes hace más de un siglo y ha colonizado muy eficientemente casi todas las altiplanicies abiertas a mas de 2000 m de altura y se ha convertido en una verdadera plaga. Este pasto time raíces grandes y compite ferozmente por la humedad del suelo y sus nutrientes; también es alelopático, produciendo en sus raíces sustancias que inhiben el crecimiento de otros tipos de vegetación. Si no se controla totalmente este pasto alrededor de los árboles jóvenes, su crecimiento se verá severamente afectado.

Se ha encontrado que los herbicidas son mas efectivos en el control de pastos comerciales que el control manual, debido a que los herbicidas matan las raíces alelopáticas además de la parte superior. En un ensayo con *Eucalyptus globulus* en Colombia, se aplicó Roundup (glifosato) al pasto kikuyu a un metro de diámetro alrededor del Plato en el momento de la plantación, y se hizo una aplicación posterior a los siete meses. A los dos años se encontró que el volumen de to árboles tratados con herbicida fue 250% mayor que el de las parcelas que habían sido limpiadas a mano con azadón (Lambeth 1986) (figura 4).

El pasto yaraguá melao *(Melinus minutiflora)* es otro de los pastos exóticos encontrados en los altiplanos de los Andes que es altamente alelopático y que time que ser controlado en las plantaciones jóvenes de árboles. En un ensayo con paraquat aplicado al yaraguá en el Plato en el momento de la plantación y los dos años, se encontró que el crecimiento del *Eucalyptus grandis* al finalizar cinco años había aumentado en un 70%, de 158 m3/ha a 269 m3/ha (Osorio 1988). El control del pasto yaraguá en una plantación de ciprés *(Cupressus lusitanica)* de tres años de edad dió como resultado un aumento del 50% en el diámetro promedio de los árboles en un año, comparado con los lotes en que se hizo un buen control de la maleza con azadón (Cannon 1981).

Los pastos altos de las tierras bajas también compiten fuertemente con las plántulas. En Venezuela, en una plantación de *Gmelina arborea* de dos años de edad que fué establecida en un terreno con pasto guinea *(Panicum maxiumum),* la cual fué cortada dos veces después de la plantación, se obtuvo una altura promedio de aproximadamente 2,5 m, con una Bran variabilidad en el crecimiento y baja sobrevivencia, mientras que, en una prueba vecina, en que se hizo un control manual continuo de la competencia, la altura fué de 7 m en promedio y hubo una buena sobrevivencia (observación personal). Esto fué observado personalmente en la reserva forestal de Ticoporo en el Estado de Barinas, Venezuela. También, se observaron respuestas similares al control del pasto guinea en plantaciones de teca en la misma área.

Los pastos *Brachiaria* son sumamente nocivos para el crecimiento de los árboles y son, quizás, los más alelopáticos de los pastos que hay en la América tropical. Se han observado significativas reducciones en el crecimiento del *Eucalyptus urophylla* y el *E. camaldulensis* en el Estado de Minas Germs, Brasil, en donde la *Brachiaria* ha invadido plantaciones de árboles jóvenes al salirse de los pastizales vecinos (observación personal).

A

Figura 4A—*Un ensayo de* Eucalyptus globulus *hecho por Smurfit Cartón de Colombia, S.A. Estos árboles fueron plantados en platos de 1 × 1 m, hechos con azadón en un potreto viejo con pasto kikuyu, su altura promedio es de 3,4 m al finalizar sus dos años.* **B**—*En una parcela adyacente a la anterior, en el mismo ensayo, se aplicó el herbicida glifosato (Roundup) al pasto antes de hacer la platación y de nuevo a los siete mese de edad. La altura promedio de los árboles de bluegum eucalyptus es de 7,1 m al cumplir dos años.*

B

Los pinos tropicales también has mostrado una buena respuesta al control completo de la maleza en el momento de la plantación y durante sus años jóvenes. En Venezuela y Brasil los pastos indígenas de la sabana tal como el *Trachypogon* sp., no son una competencia tan severa como los pastos exóticos, pero si no se eliminan, pueden absorber la humedad del suelo rápidamente durante la estación de sequía, y pueden reducir significativamente la supervivencia de las plántulas durante el primer año.

Mejoramiento Genético

La mayor pane de las plantaciones en la América tropical has sido establecidas con especies exóticas, e.j., especies que se encuentran fuera de su distribución natural. Esto crea un factor de riesgo bastante grande ya que a menudo hay pocos o ningunos conocimientos sobre el comportamiento de la especie exótica en un medio ambiente nuevo, especialmente durante varios años o varios turnos. Es necesario hacer ensayos de especies y procedencias con el propósito de determinar cuales son las mejores especies y procedencias para ser plantadas en un sitio determinado. Se pueden obtener grandes respuestas en cuanto a crecimiento mediante la selección de la procedencia o procedencias correctas para un sitio determinado (Ladrach en imprenta, Zobel y otros 1987). Es posible duplicar el rendimiento de los eucaliptos en algunas áreas seleccionando la procedencia apropiada (Ojo & Jackson 1973).

Una vez establecidas las plantaciones operacionales, se puede lograr un crecimiento adicional mediante la selección de los mejores árboles en las mejores plantaciones locales para utilizarlos como árboles semilleros para las futuras plantaciones. A estos árboles que se has adaptado a un nuevo sitio se les da el sombre de cepas criollas (Zobel y otros 1987).

En los programas forestales de mayor éxito, se inician investigaciones para hacer selecciones de los mejores árboles y los establecen en huertos semilleros, con la evaluación de su potencial genético en ensayos de progenie. Se has establecido huertos semilleros clonales para varias especies en un número de países. Aunque muchas de las plantaciones que se hacen en la América Latina son establecidas con semilla no mejorada, en la actualidad, una buena pane de la reforestación se está haciendo a partir de semilla genéticamente mejorada o material clonal genéticamente mejorado. Se has obtenido importantes logros en el mejoramiento genético de árboles forestales en los trópicos y, gracias al rapido crecimiento y corto turno, se espera que la investigación forestal tropical avance mas rápidamente que la investigación en las zonas templadas.

La plantación de clones con estacas enraizadas de árboles superiores se está generalizando, particularmente con los eucaliptos. La plantación con clones time grandes ventajas ya que captura y duplica con exactitud los rasgos deseables no-aditivos, así como los rasgos aditivos genéticos de los árboles mejorados y se logra una uniformidad en el producto (Zobel 1992). En el Brasil se has más que doblado las taws de crecimiento a través del mejoramiento genético y la plantación clonal del *Eucalyptus grandis* (Brandao 1984). La uniformidad del tamaño de los árboles es otro logro importante con el mejoramiento genético y la plantación por clón. En Colombia y en Venezuela se espera que los esfuerzos que se están realizando en este mismo sentido produzcan incrementos de un nivel del 60% (Lambeth & López 1988, Jurado-Blanco & Lambeth 1991). Los costos de producción de estacas enraizadas en el vivero se has reducido hasta llegar a un nivel competitivo con la producción de plántulas obtenidas a partir de semilla (Campinhos 1984).

Problemas Causados por Plagas y Enfermedades

Las plantaciones exóticas en un comienzo tienen la ventaja de no tener plagas o pestes, pero a la larga las plagas locales se adaptan a los árboles introducidos o Megan pestes que se introduces en el nuevo ambiente y atacan las plantaciones (Zobel y otros 1987). A la larga, es obvio que se presentarán algunas plagas en las plantaciones exóticas y que hay que buscar soluciones. A continuación se presentan algunos ejemplos de plagas que se has encontrado en los trópicos y los controles que se has empleado en cada caso.

Las hormigas arrieras o bachaco *(Atta sexdans, Atta laevigata, Acromyrmex landolti)* son plagas sumamente graves tanto para los pinos como para las especies latifoliadas; su control es un procedimiento estándar en algunos lugares de los trópicos (Jaffe y otros 1982). Este control es particularmente importante para la plantación de pino Caribe en los suelos arenosos de las sabanas de Venezuela y para los eucaliptos en el noreste y el centro del Brash. El arado inicial reduce las poblaciones de la hormiga arriera, pero hay que hacer el seguimiento con aplicaciones de insecticidas para ejercer un mejor control.

Los insectos defoliadores de los bosques nativos se pueden adaptar a las plantaciones de especies exóticas y se pueden convertir en plagas bastante serias. Las larvas de las Lepidopteras son defoliadores comunes que pueden alcanzar proporciones epidémicas en las plantaciones exóticas. En Colombia, algunas plantaciones de *Cupressus lusitanica y Pinus patula* han sido completamente defoliadas por ataques de *Glena bisulca y Oxydia trychiara* con pérdidas sustanciales (Lara 1985). *Glena* sp., *Thyrinteina ernobia, Sarcina violascens y Eupseudosama* sp. se ban convertido en pestes defoliadores del *Eucalyptus urophylla* en el Brasil (Anjos y otros 1987, Zanúncio 1989).

El control natural de estos defoliadores ha sido efectivo. A1 dejar áreas de bosque nativo dentro de algunas plantaciones, como por ejemplo en las cuencas de los arroyos o en bosques de galería donde se conservan las poblaciones de parásitos y depredadores y estas controlan las poblaciones de defoliadores para que no se vuelvan epidemias. Manteniendo un espaciamiento adecuado y aumentando el espaciamiento mediante las entresacas de los rodales muy poblados se disminuye la posibilidad del ataque de los insectos defoliadores. En el Estado de Minas Germs, Brasil, una plantación de *Eucalyptus urophylla* plantada a 2 x 3 m de espaciamiento (1660 árboles/ha) fue atacada por lepidópteras durante una prolongada estación de sequía, pero las plantaciones adyacentes plantadas a 3 X 3 m (1110 árboles/ha) no fueron atacadas (Joáo Flavio da Silva, comunicación personal). En las plantaciones de otras compañías reforestadoras vecinas, en las cuales se habían dejado franjas de 50 m de bosque nativo a intervalos regulares en toda la plantación, no bubo ataque de los defoliadores en las plantaciones aún con espaciamientos reducidos. Se ban observado resultados similares en plantaciones de coníferas en Colombia en donde los espaciamientos amplios y una política de dejar bosques nativos a to largo de los arroyos y protección de los totes de bosques nativos dentro de las áreas de plantación ha eliminado virtualmente toda amenaza de ataque de las polillas defoliadoras.

En el Brasil, bubo una chancrosis de fuste bastante severa en plantaciones de *Eucalyptus grandis* a principios de 1970. Aunque generalmente este tipo de chancrosis no es mortal, excepto en árboles muy jóvenes en el cual si to es, causó deformidades en los árboles con crecimiento de la corteza hacia adentro y un aumento de los depósitos de resina, haciendo que la madera fuese indeseable para la fabricación de pulpa blanqueada. Cientos de miles de hectareas se vieron afectadas por esta chancrosis, *Cryphonectria cubensis,* y se pensó que *E. grandis* no sería utilizable para la producción comercial de pulpa. Durante el estudio del bongo, se encontró que algunas progenies de eucalipto eran completamente resistentes a la chancrosis. Como resultado de to cual, se llevaron a cabo selecciones de las familias resistentes y boy en día, la mayor parte de las compañias están plantado material clonal de las familial resistentes y virtualmente ban eliminado la chancrosis del *Eucalyptus* en sus plantaciones (Hodges y otros 1976, Hodges & McFadden 1987).

Los animales de pastoreo pueden también convertirse en pestes en las plantaciones de árboles. En los proyectos agroforestales a menudo se ponen animales de pastoreo y árboles en el mismo lote y se utiliza la sombra de los árboles para beneficiar a los animales, esta práctica es muy aceptable cuando la cosecha principal es el animal, no el árbol. En el caso de árboles y animales como una cosecha conjunta, hay una reducción mutua en cuanto a productividad y solamente es justificable cuando se hace con árboles de muy alto valor para madera de aserrío, en buenas tierras para pastoreo (Clinton & Mead 1990, Knowles y otros 1991). En los rodales de *Gmelina arborea* en donde se ha permitido el pastoreo en los primeros años de crecimiento, no solamente se rebaja el crecimiento sino que también la forma del árbol es invariablemente peon

Conclusiones

Las plantaciones en América tropical están concentradas en los terrenos agrícolas marginales y en sabanas, mas bien que en áreas boscosas explotadas. Para la plantación exitosa, se requiere una preparación intensiva del suelo y, en muchos casos, la fertilización. El use de herbicidal es práctica común para el control de pastos y malezas antes y después de la plantación. La mayoría de las plantaciones son establecidas con plántulas envasadas, pero algunas especies son plantadas a ráiz desnuda o como pseudoestacas. La plantación manual es típica en toda la América tropical.

La mayoría de las plantaciones se establecen con especies exóticas y la selección de semilla por procedencia es importante para maximizar el crecimiento de los árboles. El meyoramiento genético de los árboles es una Ease integral de la investigación en los programas exitosos de reforestación; se han establecido huertos semilleros clonales para muchas especies.

Aunque las plantaciones con especies exóticas tienen, a menudo, la ventaja de estar libres de pester al principio de la reforestación en un área nueva, existen ataques de plagas o enfermedades en algunas de las reforestaciones y su control se considera como trabajo rutinario en el manejo forestal.

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Seed Technology: A Challenge for Tropical Forestry

F. T. Bonner

Project leader, USDA Forest Service
Southern Forest Experiment Station, Starkville, Mississippi

About one million hectares (2.47 million acres) in the Tropics are planted in tree seedlings each year, but only a small portion of these seedlings are indigenous species. A common barrier to the use of indigenous species is the unavailability of high-quality seeds arising from the lack of seed technology information. Seed problems of tropical forest trees that need more study include phenology of flowering and fruiting, collection, cleaning, storage, and pretreatment for germination. A number of capable research centers around the world are working to find the answers. Tree Planters' Notes 43(4):142-145; 1992.

Deforestation of tropical regions is a well-documented problem that has raised international concerns from many quarters. Almost daily we are bombarded by print and visual media presentations on the many benefits of tropical forests and how we must arrest and reverse their destruction. While environmental problems (global warming, flooding, biological diversity, etc.) are often foremost in the public eye, there is also widespread concern for the 1.5 to 2 billion people who depend on trees for livestock fodder, fruits, local construction, and cooking and heating fuel. A simple, yet effective, solution for these problems is to plant more trees. To plant more trees, reliable sources of high-quality seeds are needed. Some might say that we have an abundance of tree seeds, but are these seeds from the proper species for the Tropics?

Tropical forestry plantations have been estimated to total about 6.9 million ha in 1975, 11.5 million in 1980, and 17.0 million in 1985 (Willan 1985). If this rate of planting (slightly more than 1 million ha, or 2.47 million acres, per year) has been maintained, then there should be about 25 million ha of plantations in 1992. On the basis of surveys made in the 1980's (Greathouse 1982, Keipi 1987, Turnbull and Doran 1992), one must conclude that approximately 90% of this total is in industrial plantations of fast-growing species *(Eucalyptus, Pinus, Gmelina,* etc.). Very little planting has been done with indigenous species.

In the latter half of the last decade, however, interest shifted somewhat from large industrial plantations, especially exotics, to smaller plantings of indigenous multipurpose species. This change in interest has been accelerated by the awareness of germplasm conservation needs, as many multipurpose trees are on lists of endangered species-41 fuelwood species in Africa alone (Palmberg 1981). Many donor agencies now favor social forestry/ agroforestry projects over industrial plantations. These conditions have created a larger demand for seeds of indigenous species, a demand that is difficult to meet because of the lack of basic seed information on these species. For example, the International Council for Research in Agroforestry (ICRAF) published a directory of multipurpose trees that totaled 1400 species (Von Carlowitz 1980). Only 196 of these species are listed in the current Rules for Testing Seeds (International Seed Testing Association 1985), and that number includes 169 species that are listed generically under *Acacia* and *Eucalyptus.* There are many gaps in our understanding of tropical seeds, and seed testing is only one of them.

Deforestation will continue in the Tropics, for economics is a strong driving force. Environmental and social impacts can be ameliorated, of course, by replanting these areas. Exotics may dominate planting programs for a while yet, but the best indigenous species should emerge to be important components of sustainable forestry systems. One step in this direction should be the development of strong national seed programs. The objectives of such programs should include choosing the best species, determining the best seed sources, and developing appropriate seed and nursery technology.

A good example of this approach is currently underway in Costa Rica under the auspices of the Organization of Tropical Studies. Originally funded by a grant from the MacArthur Foundation, this study is evaluating indigenous species for their ability to survive and grow in abandoned pastures that are being replanted to trees. In the early stages, several native species are outperforming the more common exotics. This program could pay big dividends to forestry in Costa Rica and serve as a model for other tropical countries. Numerous problems in seed technology exist, however, and must be solved before optimum utilization of these species can proceed.

Major Seed Problems

One major seed problem in the Tropics is the lack of definitive information on the phenology of flowering and maturation of fruits and seeds. In moist tropical forests in particular, extensive phenological observations of many species have been recorded in recent years, yet predictive models for flowering are lacking (Bawa et al. 1990). Flowering and fruiting of some species seem related to wet season-dry season cycles (Whitmore 1983, Wright and Cornejo 1990), and these patterns are not difficult to predict. Even where good data exist, all is not easy. Unlike most temperate zone species, many tropical trees flower over a period of many months, so that multiple stages of seed maturity may be present at any one time on the same tree. This condition complicates seed collection, for there is no single definable period of seed maturation within a species or even among trees of the same species.

Other collection problems are presented by the spatial distribution or size of trees in natural stands. Low distribution frequencies of species in tropical forests are common (Gentry 1988). If only a few fruits are available from individual trees, then collection costs soar quickly. Plantations and/ or seed orchards would solve this dilemma, but they are almost nonexistent for these species. In moist tropical forests, fruit-bearing limbs of desirable trees may be as much as 35 meters above the forest floor. Unless seeds can be collected from the ground after natural seedfall, climbing is the only practical option.

Predators present another major problem in the Tropics. Birds, monkeys, and bats eat fruits and seeds before natural seedfall (Howe 1990). Animals are natural seed dispersal mechanisms in tropical ecosystems, but they complicate things for human seed collectors. And when seeds are dispersed on the ground, numerous birds, rodents, and insects are there to eat them. Timely collections are needed to avoid these losses, but incomplete knowledge about fruiting phenology and wide spatial distribution of trees combine to make this difficult.

Extraction and cleaning are areas of seed technology that have not been emphasized for tropical species. As long as collections are limited and seed lots are small, hand labor is sufficient for most jobs. If collections grow in size for reforestation efforts (as surely they will), then mechanized extraction and cleaning will be needed. Is the seed extraction and cleaning equipment that is currently used for temperate species suitable for tropical tree seeds? Until the equipment has been tested, no one can say for sure. This subject has good potential for applied research; modest efforts could produce significant gains.

In contrast to the common image of rapid germination in tropical forests, there are many species that exhibit seed dormancy. While many species germinate promptly when dispersed, others exhibit long delays in germination. Seed dormancy is most common among leguminous species and species of dry tropical forests. Numerous species (including non-legumes) have seed coats hard enough to survive in the litter in moist forests for at least 3 years (Whitmore 1983). Seed coat dormancy, the most common cause, is easily overcome with scarification, but other, more complex dormancies may be encountered. On the forest floor, for example, spectral quality of light is often the key to timely germination (Vázquez-Yanes and Orozco-Segovia 1990).

The most challenging problem for seed science in the Tropics is storage of **recalcitrant seeds.** Seeds are described as recalcitrant if they are killed by desiccation below moisture contents of 20 to 30% (Chin and Roberts 1980). If seeds can be dried to 10% moisture, they can be stored at subfreezing temperatures. Such seeds are described as orthodox, and their number includes most important temperate zone timber species. The recalcitrant group can be divided further into temperate recalcitrants, seeds that tolerate temperatures down to freezing, and tropical recalcitrants, seeds that are killed by temperatures below 15 to 20 °C. (Bonner 1990).

The intolerance of tropical recalcitrant seeds to both low moisture content and low temperature prevents the use of these conditions for storage. Temperate recalcitrant seeds fare better in storage because low temperatures can be used, but both groups have short storage lives (table 1). Solution of the storage problem for one of the recalcitrant

Table 1—*Storage test results for some recalcitrant tree seeds*

	Test conditions		Test results	
Species	Temp. (°C)	Seed moisture (%)	Time (month)	Viability loss (%)
Temperate recalcitrant				
Acer saccharinum	−3	50	18	8
Quercus falcata var. *pagodaefolia*	3	35	30	6
Q. robur	−1	40–45	29	31–61
Q. rubra	−1 to −3	38–45	17	18–46
Q. virginiana	2	—	12	35
Tropical recalcitrant				
Araucaria hunsteinii	2	30	12	82
A. hunsteinii	19	25–30	2	±30
Azadirachta indica	26	10–18	2	65
Hopea helferi	15	47	1	2
Shorea robusta	13.5	40–50	1	60
S. roxburghii	16	40	9	±30

Source: Adapted from Bonner (1990).

seed groups should benefit the other group as well.

Current Efforts

There are plenty of challenges in seed technology of tropical species, and much can be done without massive expenditures for laboratories and equipment. Most of the research suggested in this article must be done on-site in the Tropics, not in the comfort of well-equipped temperate-zone laboratories. There are many competent seed researchers and institutions in tropical regions around the world (table 2). This is not a complete list, by any means, and new programs seem to be continually coming on line. While seed research is not the primary focus of some of these institutions, they all have the capability to solve their respective problems.

Some of these research centers, such as the ASEAN Tree Seed Center of Thailand; CONIF of Columbia, and the University of Campeche of Mexico, publish their own series of seed research bulletins. Silvical characteristics of tropical species, including seed data, are highlighted in leaflets published by the USDA Forest Service's International Institute of Tropical Forestry in Puerto Rico, CATIE in Costa Rica, and the North American Forestry Commission's Tropical Silviculture Study Group.

Table 2—*Some forestry research centers with expertise in tropical tree seed technology and/or physiology*

Region	Institution and location
Africa	Kenya Forest Research Institute (Nairobi, Kenya)
	Centre National de Semences Forestieres (Ouagadougou, Burkina Faso)
Asia	ASEAN-Canada Forest Tree Seed Center (Mauk-lek, Saraburi, Thailand)
	Kerala Agricultural University (Trichur, India)
	Australian Tree Seed Centre, CSIRO Division of Forestry & Forest Products (Canberra, ACT, Australia)
Latin America	Instituto Nacional de Pesquisas da Amazonia (Manaus, Brazil)
	Corporacion Nacional de Investigacion y Fomento Forestal (CONIF) (Bogota, Colombia)
	Centro de Investigaciones en Bosque Tropicales, Universidad Autonoma de Campeche (Campeche, Mexico)
	Centro de Ecologia, Universidad Nacional Autonoma de Mexico (Los Tuxtlas, Mexico)
Europe	Royal Botanic Gardens (Kew, Sussex, UK)
United States	Forestry Sciences Laboratory, USDA Forest Service, & Mississippi State University (Starkville, Mississippi)

Research papers on tropical tree seeds appear now in scientific journals at an ever increasing rate, which is evidence of two trends. One is that many more researchers from the temperate zone are working on tropical seed problems these days, and the second is that the capabilities of research staffs and institutions in tropical countries are increasing. In the long run, it will be the scientists from the tropical countries who contribute the most to meeting the challenges of tree seed technology in tropical forestry.

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The ISSA System for Production of Container Tree Seedlings

Emilio Amorini and Gianfranco Fabbio

Researchers, Istituto Sperimentale per la Selvicoltura, Arezzo, Italy

A new system for producing container seedlings has been developed specifically to produce planting material suitable for degraded soils in semi-arid regions, like most of the afforestation areas in Mediterranean countries. The ISSA system (named for the Istituto Sperimentale per la Selvicoltura, Arezzo) consists of a large-capacity pot (1 liter) and a multipot unit holding 12 pieces. The system was designed to improve the standard quality of nursery stock and to avoid problems of root spiralling typical of seedlings grown in the "phytosack," the most common container in Italian nurseries. Seedlings produced with the ISSA system showed a well-balanced growth ratio (root to aboveground biomass), as well as good structural development of their root systems. The operative use of the ISSA system pointed out the possibilities to improve the mechanization level of present nursery practice. The first results of plantations showed the good development of planted seedlings also in difficult reforestation sites in southern Italy. Tree Planters' Notes 43(4):146-149; 1992.

The production of container-grown seedlings has been continuously increasing since many years (Balmer 1979, Tinus 1983) both in temperate-cold and in hot-arid countries. Improvement and standardization of the nursery stock, extension of the planting season, and mechanization of nursery practices and planting techniques are the general reasons that supported this trend.

In arid regions with a minimum rainfall during the growing season, the use of container-grown seedlings ensures also the reduction of planting failures. In these areas, which include the countries of the Mediterranean Basin, very degraded soils, water stress, and drying of the soil surface are often joint adverse conditions. Container planting creates a microhabitat around the root system, minimizes the external limiting factors, and assists in the establishment of the plant.

Production of container-grown seedlings began in Italy (Magini 1979) for reforestation with pine and oak species (typical tap-rooted trees) in difficult sites where bareroot planting and broadcast seeding had given a bad field performance. This practice was then extended to other species and sites.

The container most commonly used in Mediterranean countries has been, and still is, the "phytosack" a round, nondegradable, polyethylene sack, 50-µm thick, provided with a variable number of small holes on its walls and bottom. Its capacity is variable, but usually about 1 liter (61.02 cubic inches). As a rule, the seedling is pulled out of the sack before planting.

Because this container is cheap and easy to use, it is still largely utilized in nursery practice. However, the phytosack has limited the possibilities of nursery mechanization. Most importantly, the root systems of tap-rooted species spiral and develop a characteristic deformation that becomes irreversible with the lignification of plant tissues (figure 1).

Figure 1—*Irreversible root strangling in a stone pine plant grown in a phytosack, several years after outplanting.*

Negative results of root system deformation appear a few years after planting, when the plant reduces its growth rate and shows stability problems (Ben Salem 1971, Franclet 1978, Owston and Seidel 1978, Riedacker 1976).

This question, common to all container seedlings, has been discussed for a long time and different solutions have been suggested. A wide series of containers different in shape, capacity, and materials, from containers with rigid walls and punched bottoms, to those degradable or bottomless, to containers without walls nor bottom or container-growth mediums, were developed.

Most of them were, however, from North America or northern Europe, which made it difficult to use them under different environmental conditions, such as those found in Mediterranean countries and in hot-arid regions in general. The small capacity of the proposed containers, and the complexity of the nursery techniques were the main elements of the poor adaptability to our requirements and to our current organization.

The purpose of our research project was to develop a containerized system able to

??Replace the phytosack and improve seedlings quality, that is, root structure and development.
??Maintain the operational simplicity of the previous system.
??Increase the nurseries' mechanization level compatible with afforestation projects divided on quite small areas in prevailing mountain sites.

Materials and Methods

Our research was developed according to the following steps:

??Review of the different container systems already in use to identify the optimal technical features according to our purpose.
??Planning and manufacturing of a prototype pot.
??Experimental nursery trials and choice of the final version.
??Manufacturing of a multipot unit.

Technical features. *Capacity.* Survival and growth of seedlings on semi-arid afforestation sites requires seedlings of an adequate size and with a good ratio of root to above ground biomass (Cousin and Lanier 1976). Seedlings need to be capable of growing rapidly above competing natural grasses and shrubs. These features directed our choice towards a container of 1-liter capacity. This was also the size of the long-used phytosack in Mediterranean countries.

Shape. Among the possible different combinations of cross (circular and polyhedric) and longitudinal (cylindrical and conical) section, the circular truncated-conical one, with a high diameter to height ratio, was chosen (Marien and Drouin 1977, Riedacker 1978). The sloping walls make easy the descent of root tips towards the bottom of the container, reducing lateral spiraling. Ribs on the inner walls prevent root spiraling. The tray system holds multiple pots and enables efficient stacking.

Bottom. The large capacity and the need for simple growth media requires that the container have a bottom. The bottom is provided with guides and openings so that the root tips are guided outside. Air pruning then causes the roots to stop growth and stimulates the proliferation of secondary roots inside the container.

Manufacturing material. The container was manufactured in polypropylene. It has rigid walls and can be reused for several nursery cycles.

Testing the prototype. A prototype manufactured in accordance with these characteristics was tested during 4 nursery cycles with the following species: stone pine *(Pinus pinea* L.), European turkey oak *(Quercus cerris* L.), evergreen oak *(Quercus ilex* L.), and cork oak *(Quercus suber* L.). A standard growth medium (50% leaf mould, 30% peat, 20% inert material + Osmocote 8/9-4/5 months as a chemical fertilizer), was used. A morphometric description of seedlings and a detailed classification of deformations still existing at different branching levels in the root system at the end of each yearly cultivation cycle were made.

A series of modifications was carried out during the experimental stage. On the whole, 4 different versions of the pot were manufactured; the bottom was the most-modified detail. The achievement of root systems of the required quality (absence of lateral and lower spiraling and good structure) and development of root biomass well-balanced with the aerial part of the seedling concluded the experimental tests (figure 2).

The final version-named ISSA-pot (figure 3)has a circular-conical section; ribs 2 mm thick (.079 in.) are inserted along the inner side for the overall length of the walls. The convex, conical bottom is provided with V-shaped wedges leading to the rectangular drainage holes along the perimeter of the bottom. The open area is about 9% of the whole bottom area.

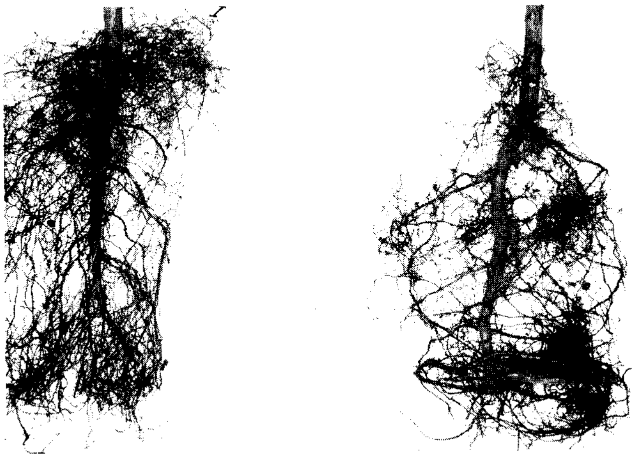

Figure 2—*Comparison of root systems of 1-year-old seedlings grown in an ISSA pot* **(left)** *and phytosack* **(right).**

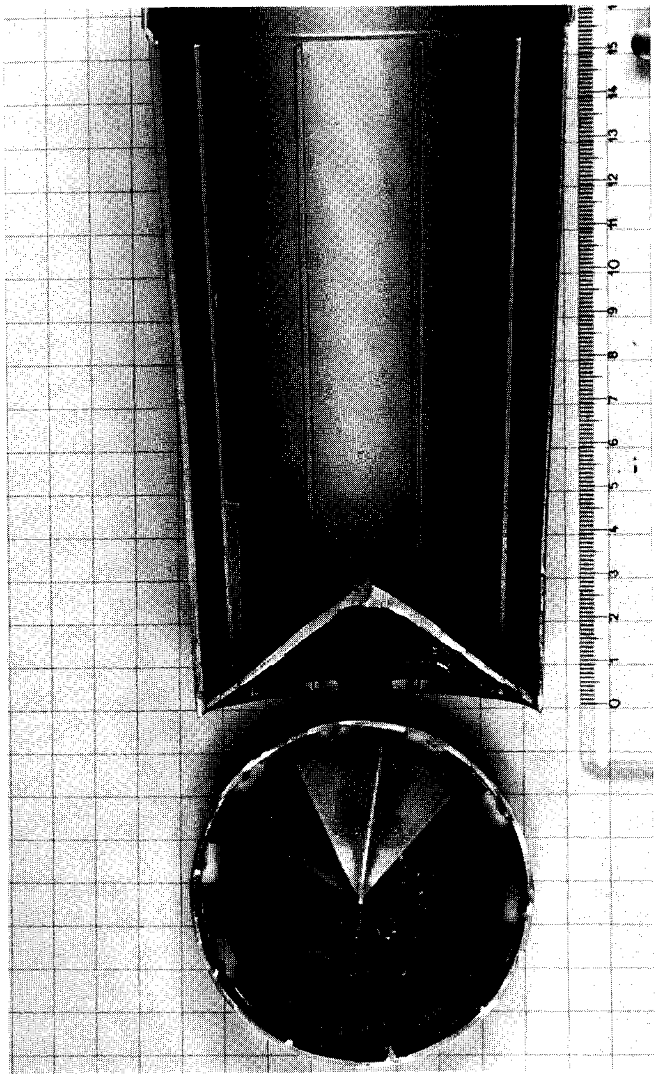

Figure 3—*Inside view of the ISSA pot showing walls and bottom.*

The pot has the following specifications: capacity, 930 cm^3 (56.75 cubic inches); weight, 67 g (2.36 ounces avoir.); height, 17 cm (6.69 inches); and diameter at the top, 9.7 cm (3.82 inches).

The multipot. The last stage of the project consisted of producing a multipot unit that enables nurseries to achieve a higher level of mechanization in filling up, sowing, and handling all the way to the planting site. The multipot unit had several requirements:

?? to hold a number of pots but still be an overall size and total weight that can be handled easily at planting, even on mountain sites.
?? to allow the overlapping of empty and full units.
?? to hold the bottom of the pots a few centimeters raised above the ground level to get the air pruning effect.

The box, named ISSA-box, is manufactured in Moplen, and measures 430 x 330 X 165 mm (16.9 x 13 x 6.5 inches). Its total weight is 720 g (25.39 ounces avoir.) and it holds 12 pots.

The modular structure of the multipot unit (figure 4) was achieved by manufacturing it in two elements, the tray and the frame. The two parts are connectable by pressure and become integral to assure solidity and resistance. The insertion of a frame allows full boxes to be stacked on top of each other.

Preliminary outplantings of seedlings grown in the ISSA container are very promising and will be the subject of a subsequent paper.

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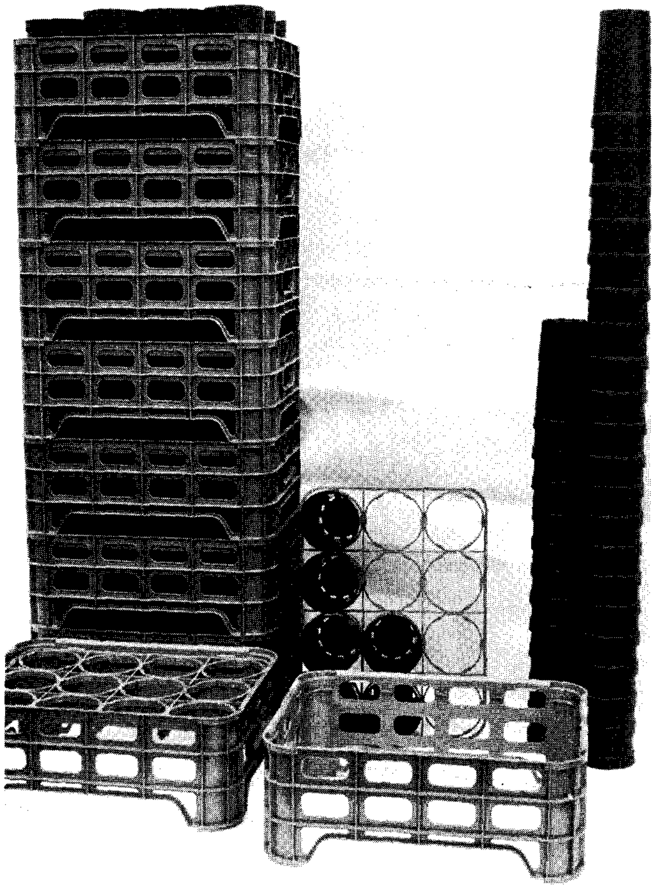

Figure 4—*The ISSA system.*

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Scarification of Limba Seeds With Hot Water, Bleach, and Acid

P. D. Khasa

Graduate student, Faculté de Foresterie et de Géomatique, Université Laval, Quebec, Canada

*Soaking seeds of limba (*Terminalia superba *Engler & Diels) in hot or boiling water resulted in seed death. Soaking seeds in concentrated sulfuric acid 95 to 98% (V/V) or sodium hypochlorite 5.25% (V/V) for 15 min and then rinsing them for 15 min with tap water resulted in the highest germination. This technique is appropriate for large-scale plantations or for research purposes. Investigations of low-technology techniques to improve germination in nurseries for social forestry should be undertaken.* Tree Planters' Notes 43(4):150-152; 1992.

Limba *(Terminalia superba* Engler & Diels) is a member of the family Combretaceae indigenous to Zaire and one of that country's most commercially important tree species, being used for veneer and timber (anonymous 1988). Its natural distribution according to Aubreville (1959) is given in figure 1. It thrives best in secondary semi-deciduous tropical forests on wet valley soils. In optimum edaphoclimatic conditions, it tends to form monospecific stands. Early work on reproductive biology and population genetics of this species was done by Vigneron (1984). The botanical description is given by Aubreville (1959) and by Vivien and Faure (1985). The fruit is a two-winged samara with a hard pericarp.

From 1953 to 1958, about 1,520,000 m^3 of logs were exported by Congo, Zaïre, and Cabinda. In 1958, 7,500 ha of limba were already planted, particularly in agroforestry systems in the Mayombe region of Zaïre, and initial provenance trials were established in 1968. Some of these agroforestry systems included the intercropping of limba with banana, coffee, cacao, or taro. Since 1985, afforestation programs with this species have been funded by the Fonds de Reconstitution du Capital Forestier.

Seeds of the tropical genus *Terminalia* are recognized as short-lived and recalcitrant. Both chemical and physical seedcoat dormancy has been recognized as well (Schaeffer 1990, Willan 1985). Although considerable information exists about most exotic tree species in the Tropics, information for handling, storage, and germination pretreatment for seeds of many indigenous species is scarce (Shehaghilo 1990). Therefore, basic information such as the time required for seeds to germinate, and pretreatments to ensure rapid and uniform germination in nursery are very important. To achieve good germination, seed dormancy must be broken. Dormancy may result from chemical, mechanical, physical or physiological factors. Chemical dormancy apparently occurs in *T. ivorensis* (Willan 1985). By using alternating temperature (34 °C/ 24 °C), 93%, germination was obtained in 41 days compared to 27% germination at a constant temperature of 30 °C, both under continuous light (see Willan 1985). For *T. superba,* germination problems occur in nurseries, but no information is available about the requirements for breaking seed dormancy.

This study was conducted to test the effect of hot water, bleach, and acid scarification as presowing treatments with potential to accelerate germination of *T. superba* seeds.

Materials and Methods

Seeds of *Terminalia* were collected from 4 stands with 5 parent trees each in June 1990 at Luki Biosphere Reserve (lat. 5° 37' S, long, 13° 06' E, alt. 350 m) in Zaïre. They were then air dried and sealed in polyethylene containers and stored at 4 °C until used in this experiment in November 1990. Nine presowing treatments were applied to 900 seeds of the bulked seed collections (table 1). The 900 seeds were divided into 9 subsamples of 100 seeds. Each subsample of 100 seeds was further divided into 4 replications of 25 seeds.

The pretreated seeds were sown on Kimpak K-22 media in clear germination boxes. Germination took place in Conviron G30 germinators in conditions as previously described (Khasa 1993). Germination counts were made weekly for a 5-week period. Seeds were considered to be successfully germinated when their radicles had reached the same length as the seed. At the end of the germination experiment, a cutting test was used to determine

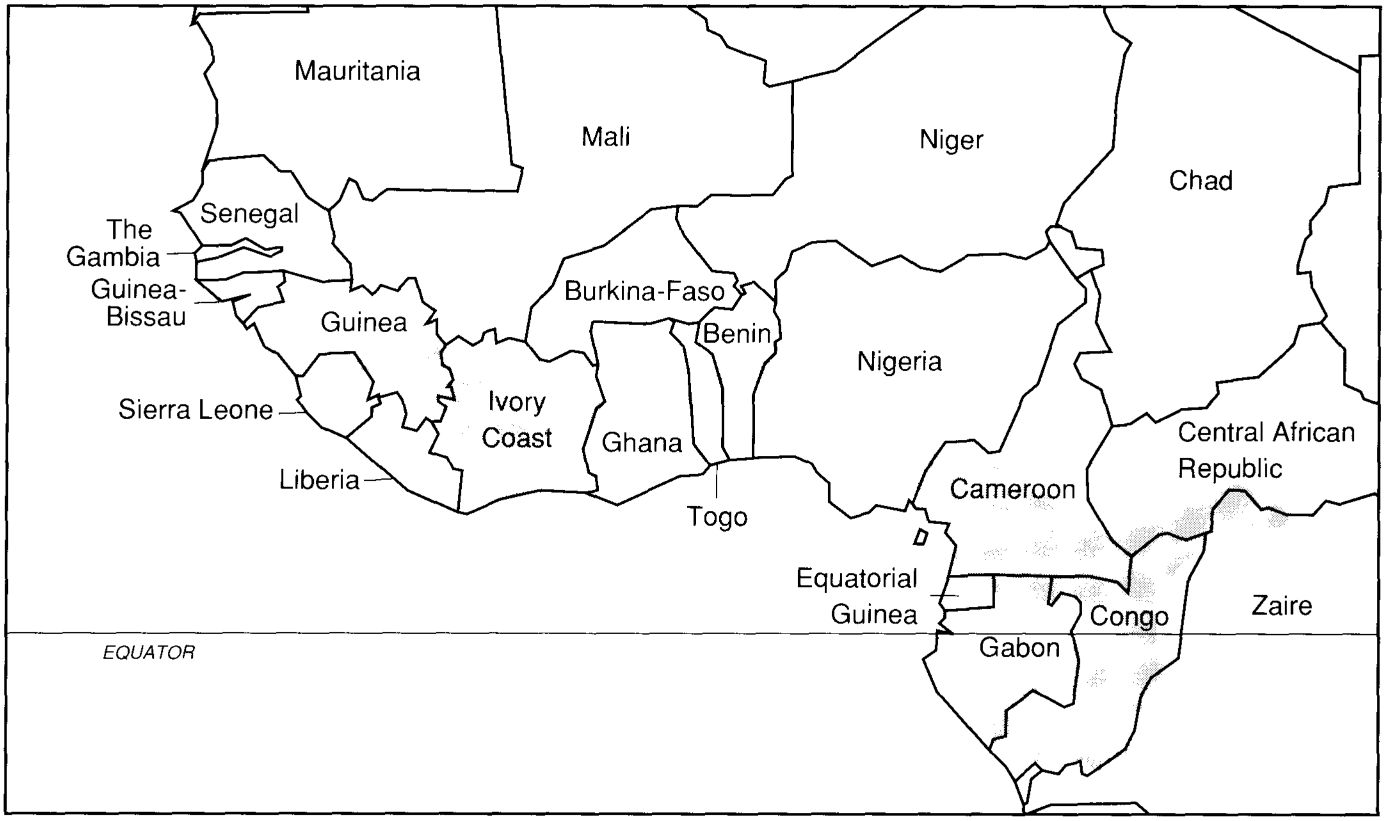

Figure 1—*Natural distribution of limba* (Terminalia superba) *(Aubreville 1959).*

Table 1—*Pretreatments used in this study*

Pretreatment	Description
0	Control (no pretreatment)
1	Pour 1 volume of seeds into 10 volumes of boiling water from which the heat source has been removed and soak until cool (12 to 24 h)
2	Immerse for 1 min in boiling water
3	As for 2, with immersion for 3 min
4	Immerse for 15 min in sodium hypochlorite 5.25% (V/V) and rinse under tap water for 15 min
5	Immerse in concentrated sulfuric acid 95 to 98% (V/V) at room temperature for a period of 15 min, then rinse under running tap water for 15 min
6	Same as 5, with immersion for 30 min
7	Same as 5, with immersion for 45 min
8	Same as 5, with immersion for 60 min

the apparent viability of ungerminated seeds (Willan 1985). Cumulative germination percentages (CG) were calculated.

Analyses of variance were performed using the General Linear Model Procedure of SAS® (SAS 1990) on transformed arcsin square root of percentages of CG, to fill the basic assumptions for use of Duncan's multiple range test for comparison of the means among treatments (Kirk 1982).

Results and Discussion

Hot water scarification has been reported as an economical method for breaking seed dormancy, especially for hard-coated seeds used in social forestry (Khasa 1993). In contrast, based on germination and cutting test data, all the *T. superba* seeds treated with hot or boiling water in this experiment were dead (table 2). This lethal effect demonstrates that this species is very sensitive to hot water, which passes through the slits in the pericarp during immersion. This was not the case with sulfuric acid, its high viscosity presumably limiting flow through the slits in the pericarp.

All the seeds scarified with concentrated sulfuric acid, 95 to 98%> (V/V), or treated with sodium hypochlorite 5.25% (V/V) germinated well (table 2), but these methods could be used only for large-scale plantations or for research purposes because

Table 2—*Cumulative germination percentages of limba* (Terminalia superba) *during a 5-week period*

	Cumulative germination %				
Pretreatment	1 wk	2 wk	3 wk	4 wk	5 wk
0	0.0 b	30.3 b	53.3 b	56.5 c	—
1	0.0 b	0.0 c	0.0 c	0.0 d	0.0 c
2	0.0 b	0.0 c	0.0 c	0.0 d	0.0 c
3	0.0 b	0.0 c	0.0 c	0.0 d	0.0 c
4	30.4 a	59.3 a	63.9 ab	66.0 abc	70.0 b
5	40.5 a	59.9 a	69.4 ab	73.9 ab	79.9 ab
6	31.9 a	50.0 a	59.6 ab	64.0 ab	67.0 b
7	0.0 b	56.6 a	62.5 ab	78.3 ab	82.5 a
8	0.0 b	54.9 a	74.0 a	82.2 a	86.2 a

Means with the same letter within each column are not significantly different at $\alpha = 0.05$ by Duncan's multiple range test.

of the high cost (Khasa 1991). Both sulfuric acid and sodium hypochlorite softened the seed pericarp, causing uniform inflow of water and unrestricted expansion of the embryo. Seeds soaked in sulfuric acid exhibited more fungal contamination than those from water treatments, whereas seeds soaked in sodium hypochlorite showed no fungal development. The acid treatment may have enhanced the leakage of metabolites from the seed, thus providing a nutritious medium for germination of fungal spores.

Sulfuric acid scarification may give erratic results; treatments 7 and 8 were among the worst at the first week but among the best during the following weeks. Similarly, treatment 6 gave unexpected results. Treatment 5 (immersion in concentrated sulfuric acid, 95 to 98% (V/V), at room temperature for a period of 15 min, followed by rinsing under running tap water for 15 min and then sowing immediately, was the most stable and therefore recommendable in nurseries for large-scale plantations or in laboratories for research purposes. According to the cutting test data, the percentage of seed that had the potential to germinate, but did not, was 18%. We noticed that some seeds had been damaged by insects. The potential germinability may be calculated from the total of cumulative germination and sound ungerminated seeds.

Mechanical scarification of the pericarp may enhance germination of limba as observed for other species (Schaeffer 1990). Future investigations of simpler methods suitable for use in small village nurseries for social forestry activities should be undertaken. Some of these methods are soaking in room temperature water for 24 or 48 hours, and mechanical scarification of the pericarp with subsequent overnight soaking in room temperature water.

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Tree Planter's Notes Volume 43, No. 4 (1992)

Nursery Morphology and Preliminary Comparison of 3-Year Field Performance of 1+0 and 2+0 Bareroot Ponderosa Pine Seedlings

Robin Rose, Mary Atkinson, John Gleason, and Diane Haase

Assistant professor of forest science, Nursery Technology Cooperative, Oregon State University, Corvallis; forestry extension agent, Yamhill County Extension Service, McMinnville; and research assistants, Nursery Technology Cooperative, Oregon State University, Corvallis, Oregon

*The preplanting morphology and subsequent field performance of a relatively new stocktype, 1+0 bareroot ponderosa pine (*Pinus ponderosa *Dougl. ex Laws.), was evaluated on 5 different field sites over a 3-year period. Regression analyses indicate that 1+0 field performance was directly related to initial seedling root volume and total fresh weight. Compared to 2+0 seedlings planted at the same time for comparison purposes, the 1+0 seedlings were initially smaller in absolute total height and, in most cases, remained significantly smaller than 2+0 seedlings after the third season in the field. Although preplanting needle morphology (high percentage of seedlings with only primary needles) and bud phenology (lack of a firm, well-developed bud) of 1+0 seedlings differed from that of the typical 2+0 seedling, the 1+0 seedlings had annual height growth increments (in both absolute and relative terms) after the first year that were equal to, and sometimes better than, 2+0 seedlings.* Tree Planters' Notes 43(4):153-158; 1992.

Traditionally, 2+0 bareroot ponderosa pine *(Pinus ponderosa* Dougl. ex Laws.) have been outplanted throughout eastern and southern Oregon. With this stocktype, 2 years are required to produce a seedling of adequate size for outplanting. Advances in nursery culture in the Pacific Northwest have resulted in larger 1-year-old seedlings than had been thought possible in the past, sparking interest in the 1+0 stocktype as an alternative to the 2+0 stocktype.

Benefits may include greater flexibility and accuracy in planning for seedling needs, reduced cost of production, and increased nursery growing capacity (Hobbs 1984, Owston 1990). The planning horizon and response time can be reduced by 1 year, which is beneficial when nursery bed space is limited, when seedling demand is increased due to natural disasters or changes in harvest levels, or when sites are not ready for planting because of delays in site preparation or harvest. In these situations, seeds can be sown and seedlings ready in 1 year or seedlings can be left in the nursery beds and/or transplanted for outplanting the following year as 2+0 or 1+1 seedlings. In addition, 1+0 seedlings may possess attributes that make them perform as well as or better than larger stock-for example, less outplanting shock.

Over the years, numerous studies have examined the influence of stocktype on field performance (Arnott 1975, Mullin 1980, Hobbs and Wearstler 1983, Burdett et al. 1984, Helgerson et al. 1989, Paterson and Hutchison 1989, Racey et al. 1989, Pendl and D'Anjou 1991), but no clear consensus has been reached on which stocktypes perform best, especially on harsh, dry sites. In the past, 1+0 seedlings have been rarely used in the Pacific Northwest because foresters believed these seedlings were too small to cope with field conditions. A few studies, however, have shown that using 1+0 stock is an acceptable option (Jenkinson and Nelson 1982, Hobbs 1984).

The objectives of this study were to 1) examine the morphological characteristics of 1+0 ponderosa pine, 2) compare field performance of 1+0 bareroot ponderosa pine with 2+0 seedlings that are used operationally, and 3) assess field performance across a wide range of harsh outplanting sites. It was not our intent to determine the best stocktype but to test our belief that 1+0 seedlings are an acceptable alternative to more traditionally planted stocktypes.

Methods

One-year-old (1+0) seedlings from five Oregon seed lots (Left Short, Power, Rox, Sumpter, and Zinc Fink) were grown at the USDA Forest Service's J. Herbert Stone Nursery, Central Point, Oregon, using nursery cultural practices developed for this stocktype-that is, lower density. Seedlings were operationally lifted, graded, and placed in cold storage at 1 to 2 °C. Lift dates ranged from January 29 until February 6, 1988, depending on the seed lot. After the 1+0 seedlings were washed free of dirt and dried of excess water, they were measured on February 23-24, 1988, for total height (centimeters) from root collar to top of terminal bud, stem diameter (millimeters) at the root collar, total fresh weight (grams), root volume (cubic centimeters) according to the displacement method (Burdett 1979), type of terminal (firm versus rosette), and the percent of seedlings with secondary needle development.

The 2+0 seedlings used for a general comparison of outplanting performance were grown according to the standard cultural regimes at the USDA Forest Service's Bend Pine Nursery, Bend, Oregon, (Power, Rox, and Left Short seed lots) and J. Herbert Stone Nursery (Zinc Fink and Sumpter lots). These 2+0 seedlings planted at each site were not measured for pre-planting morphological characteristics and, in all but one instance, were from a seed lot different from that of the 1+0 seedlings (table 1). However, at each planting location the 2+0 seed lots were, in most cases, from the same seed zone and/or breeding block and from the same, or nearby, elevational band as the 1+0 lots. The seed used to grow the 1+0 seedlings planted at Left Short came from a seed zone adjacent to the zone from which the seed for the 2+0, Left Short seedlings originated. Although stocktype comparisons were made, the interpretation of any differences must be limited due to the confounding effects of different nurseries of origin and different seed lots.

The outplanting sites used in this study were located on the Fremont and Umpqua National Forests in southern and south central Oregon (table 2). The Power site was clearcut in 1986 and machine-piled in 1987. The Rox unit was clearcut in 1983 and slashed and machine-piled in 1987. Left Short was clearcut in 1985 and slashed and machine-piled in 1987. Zinc Fink was partially harvested and machine-piled in 1979 followed by a final harvest in 1987 with hand-piling of slash. The Sumpter unit was clearcut in 1985, the slash hand-piled and burned in 1986, and originally replanted in 1986; this planting showed poor survival. All sites experience hot, dry conditions during the summer and have undergone 7 years of continuous drought conditions.

The 1+0 and 2+0 seedlings were operationally planted at a 1.5 x 1.5 m spacing in alternating rows on February 26, February 26, April 9, April 20, and May 17, on the Sumpter, Zinc Fink, Power, Left Short, and Rox sites, respectively. Each site contained 6 blocks, 2 stocktypes per block, and

Table 1—*Seed lot codes for each location and stocktype*

Location & stocktype	Seed lot code	Seed zone†	Elevation of source (m)
Power			
1+0	122-02051-400-78-SB	Bald Mtn. Breeding Block	1,524–2,134
2+0	122-02051-400-78-SB*	Bald Mtn. Breeding Block	1,524–2,134
Left Short			
1+0	122-702-03-000-65-68-SIB	702	1,981
2+0	122-02032-500-85-SIB*	Gearhart Breeding Block	1,829–2,134
Rox			
1+0	122-712-03-000-70-68-SIB	712	2,134
2+0	122-02032-500-85-SIB*	Gearhart Breeding Block	1,829–2,134
Sumpter			
1+0	122-15-492-02000-25-81	492	762
2+0	122-15-492-02000-15-78	492	457
Zinc Fink			
1+0	122-15-492-02000-35-78	492	1,067
2+0	122-15-492-02000-30-78	492	914

*Seedlings grown at Bend Pine Nursery, Bend, OR; all others grown at J. Herbert Stone Nursery, Centerville, OR.

†State of Oregon Tree Seed Zone Map (Western Forest Tree Seed Council); Bald Mtn. Breeding Block includes seed zone 703, Gearhart Breeding Block includes seed zone 712.

Table 2—*Outplanting sites description*

National Forest	Location	Size (ha)	Elevation (m)	Aspect	Surface soil texture
Fremont	Power	2	1,622	NE	Sandy loam
	Left Short	11	1,823	NE	Loamy sand
	Rox	7	2,063	W	Sandy loam
Umpqua	Zinc Fink	10	1,036	NW	Loam
	Sumpter	7	579	NW	Fine sandy loam

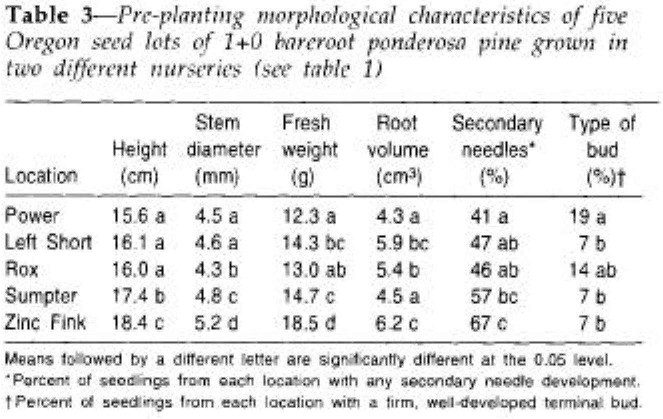

Table 3—*Pre-planting morphological characteristics of five Oregon seed lots of 1+0 bareroot ponderosa pine grown in two different nurseries (see table 1)*

Location	Height (cm)	Stem diameter (mm)	Fresh weight (g)	Root volume (cm³)	Secondary needles* (%)	Type of bud (%)†
Power	15.6 a	4.5 a	12.3 a	4.3 a	41 a	19 a
Left Short	16.1 a	4.6 a	14.3 bc	5.9 bc	47 ab	7 b
Rox	16.0 a	4.3 b	13.0 ab	5.4 b	46 ab	14 ab
Sumpter	17.4 b	4.8 c	14.7 c	4.5 a	57 bc	7 b
Zinc Fink	18.4 c	5.2 d	18.5 d	6.2 c	67 c	7 b

Means followed by a different letter are significantly different at the 0.05 level.

*Percent of seedlings from each location with any secondary needle development.

†Percent of seedlings from each location with a firm, well-developed terminal bud.

25 seedlings/ stocktype/block. Each row contained 5 seedlings resulting in 5 rows of each stocktype per block. Seedlings were protected from animal browsing with rigid mesh tubes. One month after outplanting, initial field height was measured on both 1+0 and 2+0 seedlings. At the end of the first, second, and third growing seasons all seedlings were measured for height and survival. Annual absolute height growth was determined by subtracting the previous year's absolute total height from the current year's absolute total height-for example, first-year height growth = first-year total height minus initial height at planting. Relative growth, or total height growth as a percentage of initial height, was determined by dividing total height growth after 3 years by initial height at planting.

The experimental design in the field was a 2 (stocktype) x 5 (location) factorial with blocking within location. Data were analyzed using analysis of variance, and, when appropriate (i.e., significant stocktype and/or location effect), Fisher's protected least significance difference test was used to separate means at the 0.05 significance level. Regression analyses were done in order to examine the relationship between pre-planting morphological features and subsequent height growth of 1+0 seedlings after outplanting.

Results

Pre-planting 1+0 nursery morphological characteristics varied by seed lot (table 3). The Sumpter and Zinc Fink seed lots had larger seedling heights, stem diameters, and fresh weights. Power seedlings were generally smaller for most morphological parameters measured. The seedlings planted on the Power site were inadvertently root pruned to 18 cm for nursery transplanting instead of the standard root pruning length of 25 cm for outplanting, which resulted in small root volumes. A high percentage of the 1+0 seedlings at all locations had terminal buds that typically were small and rosette-like instead of the firm, well-developed terminals normally found on 2+0 seedlings. Only 41 to 67% of the 1+0 seedlings had begun to produce any secondary needles, depending upon the seed lot.

Seedling survival remained high through the first 3 years (table 4). There were no stocktype by location interactions so main effect means were examined. The 1+0 seedlings survived significantly better than 2+0 seedlings after the first two seasons. By the end of the third year, 1+0 and 2+0 survival was identical. Survival among locations was similar except for the Rox unit, which had lower survival all 3 years.

Table 4—*First-, second-, and third-year seedling survival by stocktype and location*

	Survival (%)		
	1st yr.	2nd yr.	3rd yr.
Stocktype			
1+0	98 a	90 a	87 a
2+0	95 b	87 b	87 a
Location			
Power	99 a	97 a	95 a
Left Short	99 a	95 a	95 a
Rox	91 b	69 b	60 b
Sumpter	96 a	85 a	83 a
Zinc Fink	99 a	97 a	97 a

Means within a stocktype or location followed by a different letter are significantly different at the 5% level.

The stocktype x location interaction was significant for all height parameters measured so the analysis was done by location (table 5). The 2+0 seedlings maintained their greater total height after the first 3 years compared with 1+0 seedlings at the Power, Sumpter, and Zinc Fink sites. The Left

Table 5—*First-, second-, and third-year mean total height and height growth of 1+0 and 2+0 bareroot ponderosa pine seedlings outplanted on five sites in southern and southwestern Oregon*

	Total seedling height (cm)								Height growth increment									
	Initial height at planting		1st-yr. total height		2nd-yr. total height		3rd-yr. total height		1st-yr. height growth (cm)		2nd-yr. height growth (cm)		3rd-yr. height growth (cm)		Total height growth (cm)		Total height growth (% initial height)	
Location	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0	1+0	2+0
Power	13.9*	19.5	17.5*	24.8	25.2*	31.4	38.2*	45.2	3.6*	5.3	7.7*	6.7	12.9	13.8	24.2	25.6	174*	131
Left Short	13.1*	9.4	14.8*	11.1	25.3*	18.4	38.6*	28.2	1.7	1.8	10.8*	7.3	13.3*	10.0	25.6*	18.7	204	213
Rox	10.5*	7.0	12.5*	8.7	13.9	11.2	—	—	2.0	1.8	2.2	2.0	—	—	—	—	—	—
Sumpter	19.9*	33.0	25.0*	41.7	33.2*	50.5	44.8*	55.1	5.1*	8.7	8.2	8.6	13.5	11.0	24.8	24.9	118*	73
Zinc Fink	19.5*	32.1	26.6*	41.7	37.0*	49.8	57.3*	70.2	7.1*	9.6	10.4*	7.8	20.6	20.4	37.8	37.8	198*	118

Height growth increments were calculated as follows (note that all means shown in the table have been adjusted for missing values):
1st-year height growth = 1st-year total height − initial height at planting.
2nd-year height growth = 2nd-year total height − 1st-year total height.
3rd-year height growth = 3rd-year total height − 2nd-year total height.
Total height growth = 3rd-year total height − initial height at planting.
Total height growth (as percentage of initial height) = (total height growth/initial height at planting) × 100.
*Mean for these 1+0 seedlings differ significantly from mean for their matched 2+0 seedlings at the 5% level.

Short and Rox 2+0 seedlings, however, were significantly shorter than the 1+0 seedlings after planting because on the Forest Service district on which those two sites are located, seedlings are operationally planted deeply, that is, up to the first green needles. The 1+0 seedlings, in contrast to 2+0 seedlings, retained their juvenile needles along the lower portion of the stem and, thus, were not planted as deeply as the 2+0 seedlings. During the first growing season, 2+0 seedlings had significantly greater absolute annual height growth increment than 1+0 seedlings at all locations except at the Left Short and Rox sites where absolute height growth increment of both stocktypes was poor and not significantly different from one another. Rox is a harsh site and was planted late (in the later part of May). The Rox site was dropped from the experiment after 2 years because of severe frost, livestock, and browsing damage on a majority of seedlings in the study.

During the second and third growing seasons, the 1+0 seedlings had absolute annual height growth increments that were greater than, or not significantly different from 2+0 seedlings. The 1+0 seedlings on one site, Left Short, had significantly more absolute total height growth after 3 years than 2+0 trees. The 1+0 seedlings' total height growth increment after 3 years was not significantly different from the 2+0 seedlings at the other locations. When total height growth increment after 3 years is expressed as a percent of initial height (total relative growth), 1+0 seedlings exceeded the 2+0 seedlings on 3 of 4 sites.

The coefficients of determination (r^2) for the regression analyses for the morphological variables and height growth are low, 0.32 or less, but, in most cases, significant (tables 6 and 7) indicating these variables explain a statistically significant amount of the variation in height growth.

The coefficients of determination for fresh weight are larger than those for root volume which means that fresh weight explains more of the variation in height growth than does root volume (tables 6 and 7). Coefficients of determination for root volume and fresh weight decreased for second- and third-year height growth but remained statistically significant in most cases (table 6). The positive correlations indicate 1+0 seedlings with larger root volumes and fresh weights at time of planting tend to grow more in height during the first growing season after outplanting.

Coefficients of determination for initial stem diameter and height growth are similar although slightly smaller than those for root volume while those for initial height and height growth are mostly nonsignificant and small (r^2 < or =.10, tables 6 and 7).

Discussion

Based on the regression analyses (table 5), the growth of the 1+0 seedlings appears directly related to their initial fresh weights and root volumes, whereas initial height was very poorly correlated with subsequent absolute height growth increment in the field. This indicates that although overall seedling size is important in the success of the 1+0, it is a poor predictor of third-year growth.

Two-year-old ponderosa pine generally have a firm, well-developed terminal bud with foliage

Table 6—*Coefficients of determination for pre-planting 1+0 morphological characteristics and subsequent absolute annual height growth increments*

	Root volume			Total fresh weight			Stem diameter			Initial height		
Location	1st-yr.	2nd-yr.	3rd-yr.	1st-yr.	2nd-yr.	3rd-yr.	1st-yr.	2nd-yr.	3rd-yr.	1st-yr.	2nd-yr.	3rd-yr.
Power	.03*	.06**	.02	.12**	.12**	.05**	.04*	.07**	.04*	.03*	<.01	.03*
Left Short	.20**	.18**	.10**	.21**	.26**	.11**	.19**	.13**	.09**	<.01	<.01	.02
Rox	.06**	<.01	—	.08**	.01	—	.09**	<.01	—	<.01	.01	—
Sumpter	.12**	.06**	.08**	.18**	.12**	.08**	.04*	.06**	.04*	<.01	<.01	.10**
Zinc Fink	.26**	.03*	.01	.32**	.04*	.03*	.18**	.01	.02	.08**	<.01	.02

*Significant at the 5% level.
**Significant at the 1% level.

Table 7—*Coefficients of determination for pre-planting 1+0 morphological characteristics and total absolute height growth increment (final 3rd-year height minus initial height at planting) after three growing seasons*

Location	Root volume	Fresh weight	Stem diameter	Initial height
Power	.05**	.11**	.07**	.03
Left Short	.22**	.28**	.17**	<.01
Sumpter	.15**	.19**	.07**	.07**
Zinc Fink	.07**	.11**	.05**	.02

*Significant at the 5% level.
**Significant at the 1% level.

comprised mainly of fascicles of secondary needles. At the time of nursery lifting, most of the 1+0 seedlings in this study possessed an underdeveloped, rosette-like terminal bud, and many seedlings had not yet produced any secondary needles by the time of outplanting. These needle morphology and bud phenology characteristics, however, did not appear to have any negative effect upon the subsequent field performance of the 1+0 stock.

The preliminary results of this study indicate that 1+0 seedlings are an excellent alternative to the more traditionally planted 2+0 stocktype. This study will continue to be measured in order to determine if the stocktypes maintain their total height differences or if one outgrows the other in the future. Although caution is necessary in comparing the performance of the two stocktypes due to several confounding factors mentioned earlier, the 1+0 trees, although initially smaller in absolute total height, survived and had annual height growth increments as large as 2+0 seedlings, a finding that agrees with those of other studies (Jenkinson and Nelson 1982, Hobbs 1984).

However, other studies also suggest that the smaller 1+0 stocktype, compared to larger stocktypes, may be at a disadvantage on sites with severe animal or vegetative competition (Racey et al. 1989, Tanaka et al. 1988). The 1+0 seedling appears to be a stocktype that provides increased management flexibility in a more cost-efficient manner while maintaining necessary field performance characteristics.

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Root Dipping of Seedlings With Water-Absorbent Gel Improves Survival on Surface Mine Sites in West Virginia

Ray R. Hicks, Jr.

Professor of Forestry, West Virginia University, Morgantown, WV

*Eight tree species were planted at two surface mine sites in north-central West Virginia. In 1990, seedlings were planted on a reclaimed bench at Maidsville and in 1991 on an unreclaimed spoil near Masontown. At both sites, half the seedlings of each species were treated by root dipping with a water-absorbent gel (Supersorb-F). For 11 of 18 comparisons, seedlings with the root dip treatment had higher survival than untreated seedlings. The benefit was small except for black locust (*Robinia pseudoacacia *L.) on the Maidsville site. Root dipping is an inexpensive option for bareroot planting on surface mines and will probably produce the most consistent benefit on harsher sites.* Tree Planters' Notes 43(4):159-162; 1992.

There are several obstacles to successful tree planting on surface mine sites. Minesoils frequently possess chemical or physical limitations, including particle size distribution, which adversely affect water relations (Vogel 1981). Coarse fragments often constitute a high proportion of minesoil volume, particularly in the case of unreclaimed sites. On such sites, moisture retention is low and root desiccation can be a major problem for newly planted seedlings.

In this study I tested the effectiveness of Supersorb-F®, a copolymer acrylamide acrylate gel, as a root dip pre-planting treatment on bareroot seedlings. Such root dip treatments are sometimes recommended for bareroot planting to draw and retain water in close proximity to the roots due to the gel material's hydrophylic properties. The material was tested during two separate growing seasons (one wet, the other dry) on a reclaimed site and an unreclaimed site. Reclamation consisted of leveling, topsoil replacement, and seeding to a grass and legume cover.

Methods

The first planting site, planted in April 1990, was on a reclaimed surface mine near Maidsville, WV. The site was a level bench that was densely vegetated with grass/legume cover (figure 1). The second site, planted in April 1991 near Masontown, WV, was on an unreclaimed area of a surface mine (figure 2). The elevation at Maidsville was 850 feet (259 m) and that at Masontown, about 2,000 feet (609 m). For both plantings a 5-strand barbed wire deer exclosure 180 X 120 feet (55 X 36.5 m) was constructed.

Figure 1—*The Maidsville, West Virginia, planting site.*

Figure 2—*The Masontown, West Virginia, planting site.*

Eight different species were planted: black locust *(Robina pseudoacacia* L.), northern red oak *(Quercus ruba* L), sweetgum *(Liquidambar styraciflua* L)., silver maple *(Aver saccharinum* L.), Virginia pine *(Pinus virginiana* Mill.), pitch X loblolly pine hybrid *(Pinus rigida* X *taeda).* Scotch pine *(Pinus sylvestris* L.) and eastern white pine *(Pinus strobus* L.). Black locust, northern red oak, Virginia pine, and eastern white pine were planted at both sites, but the hybrid pine and silver maple were planted only at Maidsville and sweetgum and Scotch pine only at Masontown. Thus a total of 6 species were represented at each site, 4 of which were common to both sites.

Seedlings were planted in 25-tree row plots with a treated and untreated pair for a given species being randomly replicated 3 times. A 4 X 4 foot (1.2 X 1.2 m) spacing was used and all planting stock were 1+0 nursery-grown seedlings. Thus 150 seedlings of each species were planted on each site with half treated with Supersorb-F® as directed on the label and half being controls. A standard tree planting bar was used for planting. At the Maidsville site, a 2-foot-wide (.6-m) strip corresponding to the planting row was treated with glyphosate herbicide just before planting. A 2-foot (.6-m) circle around each seedling was spot sprayed with glyphosate in June 1990 because the initial treatment did not kill all the competing vegetation. The vegetation at the Masontown site was very sparse and did not need herbicide treatment (figure 2). Because of the paucity of vegetation at the Masontown site, the possibility of soil problems was suspected. A bulk soil sample was taken from the upper 10 inches at 6 locations and tested in the West Virginia University soil testing laboratory.

In October 1990, the survival and total and seasonal height growths were tabulated for each seedling at the Maidsville planting. Similar data were collected for the Masontown site in August 1991. At the same time, second-year growth and survival data were collected for trees growing at the Maidsville site. Data were summarized by species and treatment to allow for comparisons.

Results

Survival of treated seedlings was higher than that of controls in 11 of the 18 comparisons, lower in 4, and equal in 3 (table 1). Treated seedlings showed (on the average) 83.3% survival and control seedlings 79.6% (table 1). The second-year survival of treated black locust at Maidsville was twice that of untreated seedlings (21.3% and 42.7%).

Incremental height growth of seedlings treated with acrylate gel was slightly greater than untreated seedlings in 13 of 16 comparisons (table 1).

There were obvious species effects in all cases studied. At the Maidsville site, the best survival (98% in 1990 and 60% in 1991) was achieved by pitch X loblolly pine hybrids (table 1). The poorest survival at Maidsville occurred for Virginia pine (2% in 1990 and 0% in 1991). Black locust produced the greatest incremental height growth at Maidsville in 1990 (table 1). Its growth of 34.76 cm was 3 times greater than the next highest species (northern red oak). Interestingly, eastern white pine had the greatest incremental height growth at Masontown in 1991 (9.00 cm) which was almost twice that of black locust at that site.

Discussion

The results of our study indicate that root dipping before bareroot planting appeared to slightly improve survival of several species. The benefits were greater for some species. This is consistent with the results of Alm and Stanton (1990), who found that a polymer root dip aided in survival of red and jack pines but not white spruce. They also found that survival was not improved on 7 of 9 planting sites but was improved on the remaining 2 sites. In our study, our 2 sites were considerably different and to add to the difference, the sites were planted in 2 different years, with different rainfalls (table 2).

Although both sites are coal surface mines, the reclaimed site at Maidsville was much less harsh: Topsoil had been replaced and the area had been limed, fertilized, and planted to a grass/legume cover. It was a nearly level bench site upon which water would frequently stand after rain. Any treatment designed to prevent desiccation, such as the root dipping, would probably not be as beneficial as on a drier site. The Masontown site was a hilltop and the soil consisted of gravel to stone spoil material. It has not been reclaimed and was essentially devoid of vegetation. The West Virginia University Soils Laboratory analyzed a bulked sample representing the upper layer of material at the site. They found that the minesoil was low in nutrient element content and, probably more significantly, that the pH averaged 3.6.

Add to the site differences the fact that 1990, the year the Maidsville site was planted, had a normal

Table 1—*Summary statistics for the acrylate gel-treated and control seedlings at the two planting sites*

	% Survival			Avg. height (cm)			Avg. height growth (cm)		
Species & treatment	MDV 90	MDV 91	MST 91	MDV 90	MDV 91	MST 91	MDV 90	MDV 91	MST 91
Pitch × loblolly pine									
Root dip	97.3	60.00	—	25.14	28.43	—	1.11	3.28	—
Control	96.0	52.00	—	24.30	27.49	—	1.35	2.99	—
Virginia pine									
Root dip	1.3	0.00	93.3	31.00	—	21.86	0.00	—	0.73
Control	2.5	0.00	88.0	29.50	—	19.12	0.00	—	0.53
Black locust									
Root dip	93.3	42.67	80.0	44.66	53.47	45.27	36.76	4.00	5.68
Control	88.0	21.33	76.0	37.67	44.00	44.19	32.76	6.00	5.17
Northern red oak									
Root dip	78.7	1.33	66.7	29.55	15.00	56.72	12.42	-8.33	3.82
Control	80.0	4.00	60.0	26.20	19.33	47.91	7.85	-7.00	2.49
Eastern white pine									
Root dip	12.0	0.00	89.3	16.83	—	21.10	1.50	—	9.15
Control	9.3	0.00	85.3	15.79	—	21.56	0.14	—	8.86
Silver maple									
Root dip	88.0	29.33	—	24.63	28.27	—	4.99	1.32	—
Control	81.3	29.33	—	25.05	27.14	—	5.20	-0.53	—
Scotch pine									
Root dip	—	—	73.3	—	—	31.00	—	—	6.95
Control	—	—	69.3	—	—	28.42	—	—	6.27
Sweetgum									
Root dip	—	—	97.3	—	—	21.89	—	—	5.44
Control	—	—	98.7	—	—	20.77	—	—	6.51

MDV = Maidsville, MTS = Masontown.

Table 2—*Precipitation for 1990 and 1991 growing seasons in the vicinity of Morgantown, West Virginia*

		Measured monthly precipitation (in.)†	
Month	Normal precip. (in.)*	1990	1991
April	3.33	2.52	2.95
May	3.63	5.73	2.05
June	4.22	4.53	1.46
July	4.05	3.68	3.40
August	4.11	3.70	—
September	2.83	5.05	—

*Data taken from Weedfall and Dickerson (1965).
†Data measured at Coopers Rock State Forest, West Virginia.

to wet growing season whereas 1991, when the Masontown site was planted, was drier than normal. The high rate of mortality in 1991 at the Maidsville site was unrelated to treatment and probably relates to the fact that a wet year was followed by a dry one. The saturated soil that occurred at the Maidsville site in 1990 may have resulted in root dieback, and trees that survived the saturated conditions would be ill equipped to cope with the extremely dry conditions that occurred in June and July of 1991.

Conclusion and Practical Recommendations

It appears that root dipping with acrylate gels may benefit survival of some tree species on some sites, and although this study does not allow for statistical validation, it also seems likely that the benefits may be greater in certain years than in others. The benefit in survival was small (averaging approximately 4%). However the cost of applying a root dip is very small when compared to the other costs of site preparation, seedlings and planting. Thus a small improvement in survival and growth could easily justify the use of a root dip. Based on these findings, the following recommendations are made:

1. Root dipping seems justified for use in bareroot planting of forest tree seedlings.
2. Root dips should provide the most consistent benefit when seedlings are planted on very harsh and dry sites.
3. During very dry years, root dips will probably provide the maximum benefits.
4. Most species seem to benefit from root dipping, however in this study, sweetgum did not show increased survival.

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