Evaluation of Seedling Quality and Planting Tools for Successful Establishment of Tropical Hardwoods©

J.G. Mexal
Department of Agronomy and Horticulture, New Mexico State University, P.O. Box 3Q, Las Cruces, New Mexico 88003

P. Negreros-Castillo
Centro de Investigaciones Tropicales, Universidad Veracruzana, Sistemas Sostenibles de Produccion Forestal Ex-Hacienda, Lucas Martin Ave., Araucarias S/N Xalapa, Veracruz C.P. 91110 Mexico

R.A. Cuevas Rangel
CENID-COMEF, Instituto Nacional Investigaciones Forestales y Agropecuarias (INIFAP), Coyoacan C.P. 04110, D. F. Mexico

R. Moreno
Microseed Nursery, Ridgefield. Washington 98642

Tropical forests are endangered from overexploitation of valuable timber species, especially *Cedrela odorata* (Spanish cedar) and *Swietenia macrophylla* (mahogany). These species naturally regenerate poorly, and artificial regeneration often results in poor survival. The objectives of this study were to evaluate the effect of planting tools and stocktypes on survival and early growth of these valuable hardwoods in enrichment plantings in Quintana Roo, Mexico. Planting tools had no effect on seedling performance, although the local tool or "talacho" was preferred to the KB planting bar and flat, tree-dibble bar for making the planting hole. Seedling quality as measured by initial seedling diameter had a strong impact on both survival and growth at 28 months for both species. Stock type recommendations for enrichment plantings of mahogany and Spanish cedar are discussed and compared to recommendations for open field plantings.

INTRODUCTION

Swietenia macrophylla (mahogany) and *Cedrela odorata* (Spanish cedar) are valuable tropical hardwoods throughout. central Mexico and Latin America. However, annual harvest of both species is declining in Mexico due to overexploitation. Fifty years ago, over 30,000 m^3 per year were harvested in the state of Quintana Roo, Mexico (Cuevas, 1947), but only 10,000 m^3 were harvested in Quintana Roo in 1996 (Negreros, 1997). The decline in harvests has strained the economy of an economically depressed region. Fewer trees to harvest means harvesting costs are higher because trees are more difficult to find and travel distance between trees is greater.

The reduced occurrence of both mahogany and Spanish cedar is a function of both the rarity of these trees in the forests and the reproduction pattern of these species (Patifio, 1997). It is common for a forest to have fewer than seven trees of

both species per hectare (Snook, 2003). Furthermore, the natural regeneration of these species requires relatively large gaps in the forest for seedlings to establish. Generally, harvesting a few trees/ha may not create these gaps; precluding natural regeneration. Consequently, artificial regeneration is required.

The state of Quintana Roo plants about 4 million seedlings annually (Anon., 1997). However, survival has been low. Survival for enrichment plantings has been less than 20% for several communities (Negreros, 1997; Negreros and Mize, 2003), which is much lower than the national average of 50% (Anon., 1997) or the average for U.S.A. reforestation (Weaver et al., 1981).

Mahogany in this region traditionally has been produced in polybags, while Spanish cedar was produced as bareroot seedlings. Both species are rarely pruned, either the shoots (top-pruning or stripping of leaves) or the roots (stump planting), and seedlings are harvested and planted during the rainy season (May–September). Community members plant seedlings in logging roads or narrow clearings as enrichment plantings, using a sharpened stick and machete. Roots of the overstory trees are cut to make a planting hole in the rocky soil. The traditional planting technique uses a machete and large sharpened stick (5-7 mm in diameter). The stick can be used to plant about 10 seedlings before it has to be sharpened again. However, often the stick is dull, and the seedlings are planted too shallow.

The objective of this study was to evaluate planting tool use and stocktype on subsequent survival and early growth of mahogany and Spanish cedar in the state of Quintana Roo, Mexico. In addition, a subset of the planting tool evaluation compared containerized seedlings to the conventional stock type of each species.

MATERIALS AND METHODS

Quintana Roo is located at about 20 north latitude and 86-89° east longitude on the Yucatan peninsula of Mexico at an elevation less than 10 m. The state has nearly 350,000 ha of dry tropical forest and receives about 1,300 mm of precipitation per year primarily in July through September (Escobar, 1986). Over 80% of the inhabitants are indigenous Mayan, with most living in small communities (Negreros, 1997). This study was conducted in two of these communities ("ejidos").

Limones Ejido Cafetal. Spanish cedar and mahogany seedlings were grown in the San Felipe Bacalar nursery operated by Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP) (National Institute for Research in Forestry, Agriculture and Animal Husbandry). Spanish cedar seedlings were grown as bareroot seedlings with uncontrolled growing density. Mahogany seedlings were grown in gusseted polybags (10 cm in diameter [open] x 19 cm in height) filled with native soil. Containerized seedlings grown at New Mexico State University in 164-ml Ray Leach tubes at a growing density of 527 per m' were also used in the planting demonstration.

Three metal planting tools were evaluated: KB bar, traditional flat planting bar, and "talacho" or traditional agricultural planting tool. The talacho is a flat-bottomed, sharpened blade used for cutting roots.

The planting site consisted of planting 2-m wide lines cleared in the understory of a naturally regenerated forest. The site was a secondary forest about 15 years old and around 8 m tall that was considered by the local people as a "mahogany site." Three replications of each tool were planted. The first two replications consisted of ten seedlings each of bareroot. Spanish cedar and polybag mahogany seedlings. The

third replication of both species consisted of seven containerized seedlings of cedar and mahogany. Seedlings were planted 9 Oct. 1995 by community members. Following planting, seedling height and groundline diameter were measured. Seedling survival and growth were monitored over the next 28 mo.

Laguna Kanâ. Spanish cedar and mahogany seedlings were grown at the Laguna Karla nursery. Mahogany was grown in polybags (10 cm in diameter [when open] x 1.9 cm in height) filled with a 1 native black and red soils : 1 Spanish cedar (v/v) mixture as bareroot seedlings. Containerized seedlings grown at New Mexico State University were also used in the planting demonstration.

A planting design similar to the Limones Ejido Cafetal study was used. The site was an old mahogany plantation about 20 years old and 10 m tall. Three replications of each tool were planted. The first two replications consisted of 7 to 10 seedlings each of bareroot Spanish cedar and polybag mahogany seedlings. The third replications consisted of nine containerized seedlings of both Spanish cedar and mahogany. Seedlings were planted 6 Oct. 1995 by community members. Following planting, seedling height and groundline diameter were measured. Seedling survival and growth were monitored over the next 28 mo.

RESULTS

Planting Tool Evaluation. Workers preferred the talacho because it cut the roots of the overstory trees better than the tree planting tools or the traditional sharpened stick, which was not evaluated. Furthermore, the soil did not adhere as readily to the talacho as to the other tools. The talacho cut roots better than even a machete. The KB bar did not cut the roots and appeared to compact the soil. The foot peg on both forestry-planting tools (dibble bar and KB bar) often became entangled in the roots of overstory trees, reducing planter productivity. Furthermore, the foot peg was not usable because the workers wore thin sandals. Even with the metal tools, the planting hole appeared to be too small, occasionally resulting in shallow planting of all stock types. Beyond worker preference, planting tools had no obvi-

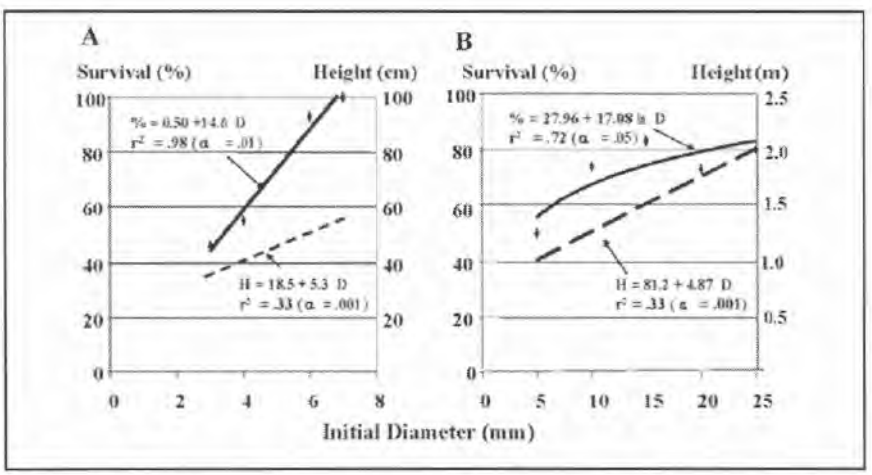

Figure 1. (A) Relationship between initial seedling diameter of *Cedrela odorata* and survival and growth after 28 month on the Limones site. (B) Relationship between initial seedling diameter of *Cedrela odorata* and survival and growth after 28 months on the Laguna Kaná site.

Table 1. Survival and growth by stocktypes of Spanish cedar and mahogany seedlings planted in Limones and Laguna Kaná. There are significant differences among means only where noted. Means followed by the same letter are not significantly different (a = 0.05).

Tool	Survival (%)	Height (cm)		Diameter (mm)		Tool	Survival (%)	Height (cm)		Diameter (mm)	
		Initial	Final	Initial	Final			Initial	Final	Initial	Final
		Limones – Spanish cedar						Limones – mahogany			
Bareroot	50 a	18 ns	32 a	3 a	7 ns	Polybag	90 a	46 a	119 a	5 ns	16 a
Container	95 b	21 ns	52 b	6 b	10 ns	Container	76 b	17 b	59 b	4 ns	9 b
		Laguna Kaná – Spanish cedar						Laguna Kaná – mahogany			
Bareroot L	70 ns	104 a	172a	17 a	25 a	Polybag	80 a	48 a	132 a	6 ns	17 ns
Bareroot S	56 ns	29 b	130b	6 b	17 ab	Container	26 b	14 b	108 b	3 ns	14 ns
Container	74 ns	18 b	95 c	6 b	12 b						

ous effect on survival or growth of either species at the two planting sites (data not shown).

Stocktype Evaluation.

Limones Ejido Cafetal, Spanish cedar-. Stock type had a strong effect on both survival and growth (Table 1). Containerized seedlings had higher survival (95%) and more importantly, no mortality beyond the establishment period. The bareroot Spanish cedar seedlings were out of the soil for several hours before planting and appeared somewhat wilted at. time of planting. Bareroot seedling survival was 82% after 8 months, but dropped to 50% over the next 20 months. The difference between stock types appears to be related to initial seedling size. The containerized seedlings were larger at time of planting. Larger seedlings had better survival and growth after 28 months (Fig. 1A). The best survival and growth was with seedlings that had a diameter of at least 6 mm.

***Limones** Ejido Ca fetal, mahogany.* Stock type had a strong effect on both survival and growth (Table 1). Polybag seedlings were larger initially and had better survival and growth than containerized seedlings. Neither stock type suffered significant mortality beyond the establishment period. Height at 28 months, but not survival, was weakly correlated with initial seedling diameter. However, the larger polybag seedlings resulted in seedlings that were twice the height of containerized seedlings after 28 months.

Laguna Kana, Spanish cedar. Seedling quality had a strong effect on both survival and growth, and stock type affected growth (Table 1). Containerized seedlings had higher survival the first year (100%) and 74% after the next 20 months. Bareroot seedling survival was 81% after 8 months and dropped to 63% over the next 20 months. However,

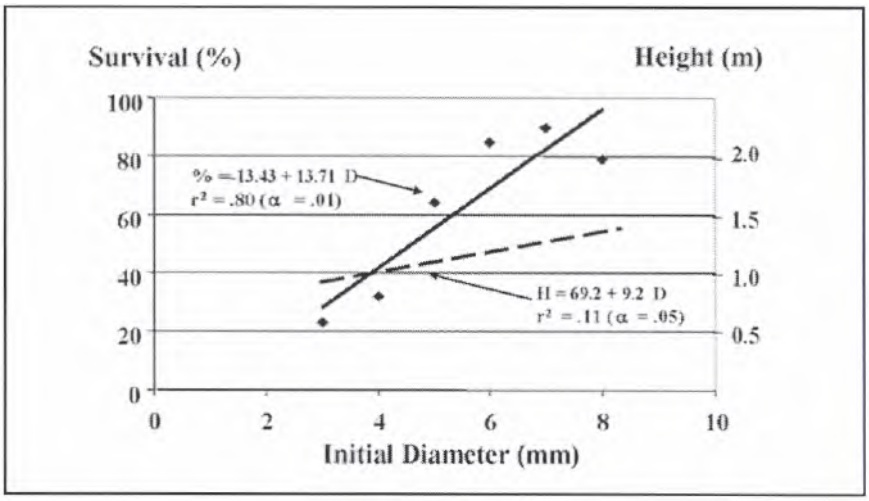

Figure 2. Relationship between initial seedling diameter of *Swietenia macrophylla* and survival and growth after 28 months on the Laguna Kand site.

there was a strong interaction between survival and seedling size. Replication 1, which averaged 104 cm in height and 17 mm in diameter, had 70% survival after 28 months, while Replication 2, which averaged 29 cm in height and 6 mm in diameter, had only 56% survival after 28 months. Containerized seedlings (Replication 3) were small (18 cm height and 6 mm diameter), but survived well (75%). Both survival and growth were correlated with initial seedling diameter (Fig. 1B). Larger seedlings had high survival and were nearly 2 m tall after 28 months. Growth was only weakly correlated as diameter explained only 33% of the variation in height.

Laguna Kana mahogany stock type had a strong effect on both survival and growth (Fig. 2). Containerized seedlings had poor first-year survival. Survival of containerized was 29% in May 1996 and 26% after the next 20 months. Polybag seedling survival was 88% after 8 months, but dropped only to 80% over the next 20 months. There was a strong correlation between survival and seedling size and a weak correlation between size and height growth (Figure 2).

DISCUSSION

Planting Tool Evaluation. Enrichment planting under native forests requires a tool to cut through overstory tree roots. Traditionally, the roots are cut with a machete and a hole dug with a planting stick. Conventional tree planting tools were not as effective in cutting roots as the talacho. Furthermore, this tool is readily available, inexpensive, and can be attached to wooden handles cut from saplings in the forest. This tool should be more effective than a simple wooden stake. Regardless of the tool selected, close inspection to ensure the seedlings are planted to the proper depth is critical (Randall and Johnson, 1998).

Seedling Quality. Seedling size more than stock type was a better predictor of performance with these tropical hardwoods. Polybag-grown mahogany seedlings, with

the larger leaf area and intact rootball, outperformed container-grown seedlings on both sites. The results were mixed with the bareroot Spanish cedar seedlings. The larger bareroot seedling had better growth than containerized seedlings on the Laguna Rand site. However, the containerized Spanish cedar seedlings were larger than the bareroot on the Limones site, and subsequent performance was better for containerized *seedlings*.

Combining the data from both the Limones and Laguna Rand sites illustrates the importance of seedling size in determining seedling survival. There was a strong correlation between initial seedling diameter and seedling survival. The equations were:

Mahogany % = 27.83 + 8.49 (Di) r^2 = .76

Cedar % = 9.76 + 10.29 (Di) r^2 = .82

For both species, the best survival was obtained when the seedlings had an initial diameter of at least 6 mm. This size is larger than that reported by Mexal et al. (2002), who reported seedlings should be at least 4 mm. However, that study was in an abandoned field with less initial overstory competition. Enrichment plantings such as this, where overstory trees compete for light and water, require larger seedlings. In general, seedling survival was 48% with a diameter less than 5 mm, while it was over 80% with a diameter over 6 mm.

Napier (1985) proposed a target seedling diameter of 5-10 mm for tropical hardwoods in Central America. This recommendation would seem to hold for Mexico as well. However, few studies appear to follow this target guideline. Macario and Sanchez (2000) reported survival of enrichment plantings after two years of 40% for mahogany and 31% for cedar. These seedlings were small (<30 cm in initial height) and grew poorly (15 cm) following outplanting. Wightman (2000) had better survival, but the largest seedlings were only 7 mm for Spanish cedar (42% survival) and 5 mm for mahogany (50% survival).

Growth following outplanting was also related to seedling size, but was confounded by species and site. The Laguna Rand site was better than the Limones site. Growth of both species was better on the Laguna Rand site. Furthermore, growth of the containerized seedlings, which were similar in initial morphology, was about 80% greater on the Laguna Rand site. Regardless, larger seedlings will likely result in long-term growth differences (Dierauf and Garner, 1996; South et al., 1988).

There appeared to be no advantage to using a containerized system to produce either species. Container seedlings were more expensive to produce and often smaller than either bareroot or polybag-grown seedlings. The polybag-grown seedlings grown at two nearby nurseries were similar in size. They were grown in similar soils under natural precipitation without fertilization.

Patino (1994) reported mahogany seedlings planted after a hurricane in 1971. had 86% survival and were 5.4 in after 9 years 55 cm/year), whereas Spanish cedar was only 3.3 in 33 cm/year) with only 25% survival. In this study growth of mahogany after only two growing seasons was comparable to the growth reported by Patino (1994), while Spanish cedar survival and growth were substantially better in this study. Furthermore, Mexal et al. (2002) reported much better growth of mahogany on sites with better site preparation. Thus, site preparation, proper planting, coupled with high seedling quality can result in enrichment plantings with excellent growth potential.

LITERATURE CITED

Anon. 1997. National reforestation program. Mexico. Dept. of Social Development, Mexico. ISBN: 968-838-397-X.

Cuevas Lopez, A. 1947. Explotación de tre[y] especies forestales y propagación artificial de mahogany en Quintana Roo. B.S. Thesis Escuela Nac. de Agricultura, Chapingo, Mexico.

Dierauf, T.A. and J.W Garner. 1996. Effect of initial root collar diameter on survival and growth of yellow-poplar seedlings over 17 years. Tree Planters' Notes 47:30-33.

Escobar Nava, A. 1986. Geografia General del Estado de Quintana Roo. 2nd ed. Quintana Roo State Govt.

Macario Mendoza, P.A. and L.C. Sanchez Perez. 2000. Enriquecimiento de acahuales mediante la reforestación de mahogany y cedro. en el ejido X-Hazil y anexos, Felipe Carrillo Puerto, Quintana Roo. In: Proc. Congr. Nacional de Reforestación, Texcoco, Mexico. Nov. 8-10,2000.

Mexal, J.G., R.A. Cuevas Rangel, P. Negreros-Castillo, and C. Parraguirre Lezarna. 2002. Nursery production practices affect survival and growth of tropical hardwoods in Quintana Roo, Mexico. Forest Ecology and Management. 168(1-3):125-133.

Napier, I. 1985. Técnicas de viveros forestales con referencia especial a Centroamésica. ESNACIFOR, Siguatepeque, Honduras, CA. Nota Técnica No. **5.**

Negreros Castillo, P. 1997. Evaluación de la sustentabilidad del sistema de manejo forestal de la organización de ejidos productores forestales de la Zona Maya de Quintana Roo. Report submitted to the Rockefeller Foundation, Mexico City.

Negreros Castillo, P and C. Mize. 1993. Effects of partial overstory removal on the natural regeneration of a tropical forest in Quintana Roo, Mexico. Forest Ecology and Management 58:259-272.

1994. Algunas experiencias de investigación y desarrollo de tecnologias para plantaciones forestales, p. 233-269. In: Plantaciones: Producir para Conservar. Proc. IV Reunion Nacional de Plantaciones Forestales. INIFAP, Mexico.

Patiño Valera, F. 1997. Genetic resources of *Swietenia macrophylla* and *Cedrela odorata* in the neotropics for coordinated action. FAO For. Gen. Res. No. 25: 20-31.

Randall, W and G.R. Johnson. 1998. The impact of environment and nursery on survival and early growth of Douglas-fir, noble fir, and white pine—A case study. Western Journal of Applied Forestry 13(4):137-143.

Snook, L.K. 2003. Regeneration, growth and sustainability of mahogany in Mexico's Yucaton forests, p. 169-192. In: A. E. Lugo, J. C. Figueroa Colon, M. Alayon (eds.) Bigleaf mahogany: Genetics, ecology and management, Ecological Studies, Vol. 159, Springer-Verlag, New York.

South, D.B. J.G. Mexal, and J.P. van Buijtenen. 1988. The relationship between seedling diameter at planting and long-term growth of loblolly pine in east Texas, p. 192-199. In: Proc. 10th North Amer. Forest Biol. Workshop, Vancouver, B.C. Canada.

Weaver, G.H., B. Izla, F.S. Broerman, and K. Xydias. 1981. Preliminary report on the 1979 American Pulpwood Association pine plantation survival and nursery practices survey, p. 24-30. In: Proc. 1980 South. Nursery Conf., Lake Barkley KY Sept. 2-4, 1980. USDA Forest Service-State and Private Forestry Tech. Pub. SA-TP17.

Wightman, K. 2000. Técnicas para mejorar la calidad de planta en vivero: ejemplos con cedro *(Cedrela odorata)* y mahogany *(Swietenia macrophylla).* Proc. Congr. Nacional de ReforestaciOn, Texcoco, Mexico. Nov. 8-10,2000.