Root immersion in water; a promising method for successful bare-root planting of Honduras pine*[1/]

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C O M P E N D I O

En una serie de experimentos en Puerto Rico, plántulas de Pinus caribaea *var. hondurensis sobrevivieron bien el transplante a raiz desnuda cuando fueron almacenadas en agua después de la extracción y transportadas en agua al sitio del transplante. Cuando se plantaron en suelo razonablemente húmedo, las plántulas almacenadas en agua tuvieron un por ciento de supervivencia de más de 80 por ciento. Las plántulas testigo (aquellas extraídas con la bola de suelo intacta) tuvieron una supervivencia de 90 por ciento o más. El almacenamiento de las plántulas de raiz desnuda en musgo esfagnaceo, o en este musgo más un antitranspirante foliar dio como resultado una pobre supervivencia (menos de 80 por ciento).*

Introduction

MOST subtropical pine seedlings are grown and outplanted in containers because bae-root planting, the procedue typically used in temperate climates, is not successful in climates where pines do not exhibit dormancy. Containerized planting is expensive, however; and researchers have been looking for a bare-root technique that would permit the economic establishment of large plantations of *Pinus caribaea* Morelet, and in particular of *P. caribaea* var. *hondurensis* (Honduras pine), in subtropical lowlands.

In a Puerto Rican trial, survival was only 18 per cent for *P. caribaea* seedlings planted with bare roots after being packed in sphagnum moss (2). Wood (5) reported 47.5 per cent survival of bare-root Honduras pine seedlings in Tanzania. Survival after exposing roots of young Honduras pine seedlings grown in hydroponic beds to full sunlight for up to 18 minutes was about 95 per cent (1) or after lifting potted seedlings at the planting site (3). These two studies showed that pine seedlings can survive brief periods of root exposure. In 1969, Monteith and Ybarra (4) tried to increase bare-root survival by pruning new flushes, by removing all needles, and by combining both these treatments. However, their highest survival rate was only 52 percent.

This paper reports a series of three experiments in which we tested several bare-root techniques for planting *P. caribaea* var *hondurensis* in Puerto Rico. The most promising, storing and transporting bare-root seedlings to the field in water, proved to be simple, inexpensive, and reliable enough to assure an 80 percent survival rate under normal planting conditions.

Materials and Methods

Experiment I: The planting site at Catalina is in a subtropical wet life zone having a mean temperature of 25°C and a mean annual rainfall of 2900 mm. Rainfall for September, October, and November of 1970 was abnormally high with 450, 770, and 410 mm, respectively. The site is about 500 meters above sea level and slopes to the south; so it receives full sunlight. Although the site is protected on three sides, moisture-laden winds pass over the area as they rise up the mountainside from the nearby Atlantic Ocean. The soil is a deep, red, acid clay of the Humata series with medium drainage. The site was cleared by machete, and the stubble was cleaned by undercutting with an adze to leave the area completely free of vegetation.

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Half the seedlings for the test were grown in soil-filled polyethylene bags (10 × 23 cm); and half, in elevated nursery beds. Seedlings in the nursery beds were root-pruned by undercutting with a machete; 6 weeks later they were lifted by undercutting them with a shovel, pulling them out, and shaking the soil from their roots. Bagged seedlings were removed from their containers on the day of planting, and the roots were freed after gently squeezing the soil loose. Seedlings were 6 to 7 months old and 20 to 30 cm high when they were lifted and randomly assigned to the following 11 treatments:

A_0 - Roots were packed in moist sphagnum moss and wrapped in burlap; the pack was then dipped in water for 2 minutes to insure complete saturation. Seedlings were planted the same day they were lifted.

A_3 and A_6 - Treatment was identical to A_0 except that the bundles were left in a shaded, moist area at the planting site for 3 days (A_3) or for 6 days (A_6) before planting. Root packs were dipped in water once daily for 2 minutes.

B_0 - Treatment was identical to A_0 except that the foliage of the bundled seedlings was dipped in the anti-transpirant Key-kote for 2 minutes.

B_3 and B_6 - Treatment was identical to B_0 except that the bundles were left in a moist, shaded area at the planting site for 3 days (B_3) or for 6 days before planting. Root packs were dipped in water once daily for 2 minutes.

C_0 - Seedlings were lifted from their bags upon arrival at the planting site, immediately placed in a pail with enough water to cover their roots, and planted within 30 minutes after lifting.

D_0 - Seedlings were lifted from their bags at the nursery, immediately placed in a pail with enough water to cover their roots, and planted within 6 hours after lifting.

E_0 - Control seedlings were grown in polyethylene bags (10 × 23 cm) and outplanted with the soil ball intact.

E_3 and E_6 - Control seedlings in soil-filled polyethylene bags were stored near treatments A_3, A_6, B_3, and B_6 for 3 days (E_3) or of 6 days (E_6) before planting.

Seedlings were outplanted on October 6, 9, and 12, 1970, by two teams of two men each. One man dug a hole with a pick-ax, and the other man planted the seedling at root-collar depth so that the roots were completely covered with loose soil. The planting design was four randomized complete blocks, each containing a row of 20 seedlings in each treatment. Spacing was 1 meter between seedlings and 1.5 meters between rows. Survival was determined 10 weeks after the final planting date.

The techniques for site preparation, lifting seedlings, planting, and spacing described for Experiment 1 were also used in all subsequent tests unless otherwise noted.

Experiment II. The high survival of seedlings in treatment D_6 warranted testing this method on a drier site.

The planting site, an abandoned pangola pasture, in the central mountain range near Orocovis, corresponds to a subtropical moist life-zone with a mean annual temperature of 24°C and a mean annual rainfall of 2600 mm. Rainfall during February, March, and April of 1971 was 195, 65, and 68 mm, respectively. The site is a flat knoll completely exposed to wind and sun from all directions. Elevation is about 600 meters above sea level. The soil is a deep, red, acid clay of the Humata series with good drainage.

All seedlings were grown in soil-filled polyethylene bags (10 × 23 cm). They were 8 to 9 months old and 25 to 35 cm high when they were lifted and assigned to treatment D_0, E_0 (control seedlings described in Experiment 1), or D_2, a treatment identical to D_0 except that seedlings were kept in water for 45 to 48 hours before planting.

The seedlings were outplanted on February 4, 11, and 18, 1971. The planting design was three randomized complete blocks, each containing a row of 10 seedlings in each treatment. Survival was determined 10 weeks after the last planting.

Experiment III. This experiment, a further refinement and expansion of the previous two trials, tested survival of bare-root seedlings planted in sandy soils. Two widely separated sites with sandy soils were selected for comparison.

One site, Las Piedras, is located in the center of a good pinegrowing region in southeastern Puerto Rico and corresponds to a subtropical moist forest life zone with a well drained sandy, clay loam soil. Mean annual temperature is about 27°C, and mean annual precipitation is 2500 mm. Rainfall for the months of May, June, July and August of 1971 was 384, 180, 150, and 550 mm, respectively. The site is about 80 meters above sea level and is exposed on all sides. Formerly an improved pasture for cattle, the site was abandoned three years before this experiment.

The other site, Monterrey, corresponds to a subtropical moist forest life zone with a well-drained, very fine, sandy loam soil. Mean annual temperature is about 28°C. Mean annual precipitation is 1800 mm. Rainfall during May, June, July, and August of 1971 was 160, 88, 90, and 100 mm, respectively. The site is about 20 meters above sea level and is completely

exposed. It is located at the Commonwealth of Puerto Rico Agriculture Nursery; and because this area has been extensively cultivated, the soil is quite loose. The site had been lying fallow under a sparse weed cover. The weeds were removed with a hoe.

Seedlings were grown in nursery beds. Their roots were pruned by undercutting with a machete, and one month later they were lifted and randomly assigned to treatment D_0 or D_2. Seedlings were 8 months old and ranged from 25 to 35 cm high at time of planting. Three randomized complete blocks with single row plots of 20 seedlings in each treatment were planted at each site on May 28, June 24, and July 19, 1971. Survival was determined 38 days after the last planting.

Table 1: Survival of Experiment I seedlings 10 weeks after last planting date at Catalina.

Treatment	Seedlings planted	Percent survival
A_0 Seedlings were transported in a moss pack, and planted on the day of lifting	80	35
A_3 Seedlings were transported in a moss pack, and planted 3 days after lifting	80	66
A_6 Seedlings were transported in a moss pack, and planted 6 days after lifting	80	79
B_0 Seedlings were dipped in an anti-transpirant, transported in a moss pack, and planted on the day of lifting	80	44
B_3 Seedlings were dipped in an anti-transpirant, transported in a moss pack, and planted 3 days after lifting	80	29
B_6 Seedlings were dipped in an anti-transpirant, transported in a moss pack, and planted 6 days after lifting	80	21
C_0 Seedlings were lifted at the planting site, stored in water, and planted within 30 minutes	20	98
D_0 Seedlings were transported in water and planted on the day of lifting	20	99
E_0 Potted seedlings (control)	80	99
E_3 Potted seedlings (control) stored 3 days	80	100
E_6 Potted seedlings (control) stored 6 days	80	98

Results

Experiment I. Ten weeks after the last planting date, survival of seedlings stored in spagnum moss root-packs (A treatments) ranged from 35 per cent for those planted on the day they were lifted to 79 per cent for those stored 6 days (Table 1). Seedlings stored in sphagnum moss root-packs and treated with foliar anti-transpirant (B treatments) also survived poorly; survival rates ranged from 21 per cent for seedlings stored 6 days to 44 per cent for those planted on the day of lifting. However, the survival rate of seedlings stored and transported to the planting site in water from either the roadside or the nursery was 98 percent for treatment C_0 and 99 per cent for treatment D_0. The survival rate of these bare-root seedlings was about the same as that of the control seedlings (Table 1).

Experiment II. The survival rate of the bare-root seedlings was slightly less than that of the bagged seedlings. Ten weeks after the last day of planting, mean survival for the three planting dates was 91 per cent for seedlings stored in water and planted the same day they were lifted, 90 per cent for seedlings stored 2 days in water, and 96 per cent for the bagged seedlings (Table 2).

Experiment III. Thirty-eight days after the last planting date, the survival rate of bare-root seedlings at Las Piedras was 97 per cent for those stored in water and planted on the same day and 95 per cent for those stored 2 days in water (Table 3). At Monterrey, the survival rate was 67 per cent for seedlings lifted, stored in water, and planted on the same day but only 51 per cent for those stored 2 days in water.

Discussion

Storing bare-root seedlings in water enhances survival and seems to be a viable alternative to planting balled seedlings. Survival of the balled control seedlings ranged from 90 to 100 per cent for the 21 plots studied. Survival of water-stored seedlings was somewhat lower but still acceptable.

In the combined study a total of 62 row plots were planted with bare-root seedlings stored in water for 30 minutes to 48 hours after lifting. Fifty five plots had 80 per cent survival; one had 70 per cent survival; and the six plots planted on June 24 at Monterrey had 0 per cent survival, apparently because of lack of soil moisture. There was no rain for ten days before planting and for eight days after planting; thus, the very fine sandy loam soil at Monterrey was extremely dry.

Survival was low (less than 80 per cent) for seedlings stored in sphagnum moss, with or without the anti-transpirant treatment. Earlier studies have also shown poor success with sphagnum moss treatments (1, 2, 3, 4, 5,). This low survival has generally been attributed to degeneration of roots and root-hairs

Table 2: Survival of Experiment II seedlings 10 weeks after last planting date at Orocovis.

Treatment	Seedlings planted	Mean survival for three blocks			
		Feb 4	Feb 11	Feb 19	x
D_0 Bare-root, planted on day of lifting	90	87	87	100	91.3
D_2 Bare-root, planted after 2 days storage in water	90	90	80	100	90
E_0 Bagget stock control seedlings	90	97	90	100	96

Table 3: Survival of Experiment III seedlings 38 days after last planting date at Las Piedras and Monterrey.

Treatment and Site	Seedlings planted	Mean survival for three blocks			
		May 28	June 21	July 19	x
D_0 Bare-root planted on day of lifting					
Las Piedras	180	100	97	93	97
Monterrey	180	100	0	100	67
D_2 Bare-root planted after 2 days storage in water					
Las Piedras	180	90	97	97	95
Monterrey	180	70	0	83	51

during storage. But we examined the roots at time of planting and found that the moss pack had maintained surface moisture on the roots during storage and there was no visible physical deterioration. Thus, while we agree that root degeneration may figure in mortality, we also feel studies of physiological changes in roots stored in a moss pack are needed to clarify this point.

A major determining factor in survival may be the seedlings' capacity to rapidly establish root-hairs and to utilize "available soil moisture". In these trials all planting sites were completely cleared of vegetation and thus were exposed to the sun until new weed growth provided cover. Although this exposure resulted in extensive drying and cracking in the upper few centimeters of the soil profile (particularly at the Orocovis site in Experiment II), the low "apparent soil moisture" did not affect survival of water-store seedlings. The seedlings apparently can rapidly establish contact between their roots and the soil and can provide water for their immediate needs better than seedlings stored in moist sphagnum moss. We cannot explain this phenomenon but can only speculate that roots stored in water retain much more surface water than those stored in sphagnum moss and perhaps this excess water acts to cohere the roots to the soil for more immediate contact.

Although water storage apparently solves the problem of low survival in bare-root planting, another questions remains: Do bare-root seedlings grow as well as containerized seedlings? Both Wood (5) and Barres (1) reported that growth rates of bare-root seedlings were less than those of containerized seedlings. Marrero (3) found the opposite. Additional tests are need to determine how water storage affects seedling growth.

Conclusion

Honduras pine plantations can be established in Puerto Rico with bare-root planting stock if the seedlings are stored and transported in water and if the soil is reasonably moist and is adequately packed around the seedlings' roots at planting time. This technique should result in considerable savings in

nursery and outplanting costs since pine seedlings can be grown in conventional nursery beds and transported in water pails much more cheaply than in individual containers.

Summary

In a series of experiments in Puerto Rico, *Pinus caribaea* var. *hondurensis* seedlings survived bare-root planting well if they were stored in water after lifting and transported to the planting site in water. When planted in reasonably moist soil, water-stored seedlings usually had better than 80 per cent survival. Control seedlings (those outplanted with the soil ball intact) had 90 per cent survival or better. Storing bare-root seedlings in sphagnum moss or in sphagnum moss plus a leaf antitranspirant resulted in poor survival (less than 80 percent).

Literature cited

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Reseña de Libros

DE RENZO, DOROTHY J. Energy from bioconversion of waste materials. Park Ridge, N. J., Noyes Data Corporation, 1977. 223 p. (Energy Technology Review 11 and Pollution Technology Review 33). US$ 32 net.

El libro de Miss De Renzo está basado en 16 informes y 1 patente sobre estudios de la conversión y reutilización de desechos urbanos, animales y vegetales, por vía microbiológica para la producción de metano y otros gases en plantas piloto de los Estados Unidos.

La importancia del libro se comprende al saber que en Estados Unidos se producen anualmente 881×10^{10} kg de desechos que pueden ser tratados para la producción de metano. Los residuos urbanos (California 3,5 kg/capita al día) son de relativo fácil tratamiento; el libro presenta algunos ejemplos de Pennsylvania e Illinois en los cuales también se tratan los procesos biogeoquímicos de la producción del metano.

Los desechos de animales (en USA 110 millones de reses, 22 millones de carneros, 54 millones de cerdos, 825 millones de pollos) sobrepasan notablemente la producción de desechos urbanos; en el libro se presentan ejemplos de plantas en California y Oregón.

Los restos vegetales y de las industrias del papel se presentan con base en los resultados obtenidos en plantas en California, Pennsylvania aunque ellos representen un monto pequeño en comparación a las otras fuentes de desperdicios.

Los artículos hacen hincapie en el aspecto de la producción del metano para cubrir las necesidades de energía crecientes en USA. El punto de vista del tratamiento biológico presenta sin embargo una serie de problemas especialmente en relación con el mal olor, producción de fangos de desperdicios, mayores costos del tratamientos que aun no están resueltos y que serán decisivos en las posibilidades futuras.

El libro presenta en forma clara y detallada los resultados, una literatura amplia y las referencias a los informes parciales de las investigaciones.

La descomposición anaeróbica para producir metano puede hacer útil cosechar recursos naturales indeseables, tales como algas, jacinto de agua *(Eichhornia crassipes)*, y otras plantas acuáticas como "cosechas energéticas" no convencionales.

La obra encontrará acogida en un grupo pequeño de especialistas que trabajan sobre aspectos de la producción de desperdicios en áreas tropicales.

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Reseña de Libros

BOGDAN, A. V. Tropical pasture and fodder plants (grasses and legumes) London, Longman, 1977 475 p. (Tropical Agriculture Series).

Un libro de A. V. Bogdan sobre pastos tropicales, debe reflejar la larga y distinguida carrera del autor. Esto se cumple a cabalidad en este volumen, en que Mr. Bogdan, ya retirado, analiza su experiencia en Africa Oriental, y la relaciona con las investigaciones desarrolladas en otras regiones.

El libro se divide en dos secciones. La primera trata de Gramíneas en sus aspectos generales: clasificación, factores ambientales en relación a la fisiología, estructura, cultivo, valor nutritivo, reproducción y mejoramiento, y luego trata en detalle las especies más importantes por orden alfabético.

La segunda, sobre Leguminosas: clasificación, estructura, fijación de nitrógeno, mezclas con gramíneas, cultivo, enfermedades y plagas, rendimiento y usos, valor nutritivo, aceptabilidad y toxicidad, reproducción y mejoramiento genético. Como en la anterior, se discuten luego las especies principales. En ambas partes el tratamiento individual de las especies puede variar desde una nota general hasta la discusión detallada cubriendo aspectos botánicos, ambientales y culturales; en ciertos casos se discuten también el rendimiento y cualidades nutritivas.

Como ejemplo del tratamiento detallado de una especie, puede tomarse *Pennisetum purpureum*. Se inicia con los nombres corrientes en varios idiomas, seguido por la descripción de la planta, subespecies, en que corrige varios conceptos; condiciones ambientales en que crece en estado natural; factores climáticos y edáficos que determinan producción óptima; siembra, que se discute en detalle lo mismo que manejo, fertilización y ensilaje; enfermedades y plagas, en que no hay mucha información; rendimiento en forraje fresco; asociación con leguminosas; composición química y valor nutritivo; producción de forraje; floración y reproducción; cultivares comerciales. Entre estos últimos, se incluyen los dos más importantes que provienen de los cruces hechos por G. Burton, sin mencionar propiamente su origen. En total 9 páginas y un diseño.

Los tratamientos breves, como por ejemplo el de *Entolasia imbricata*, incluyen el nombre corriente y una descripción compendiada de la planta, seguida de su distribución geográfica, cultivares y manejo. Tanto en las descripciones largas como cortas, hay numerosas referencias bibliográficas por autor y fecha.

Son estos tratamientos individuales de las gramíneas y leguminosas forrajeras lo que constituye la parte medular del libro.

Este aspecto está bien balanceado en el sentido de que el autor aporta no solo su experiencia personal, sino que discute los resultados de otros investigadores. En lo que se refiere a América Tropical, la inclusión de resultados es satisfactoria, posiblemente tomada del Herbage Abstracts y no de las fuentes originales. Las investigaciones publicadas en francés están cubiertas con menor intensidad.

Para las personas interesadas en pastos tropicales el libro es de gran utilidad. Si bien es cierto que no hay un tratamiento detallado de los trabajos recientes en Australia, tiene el gran mérito de poner en forma clara y ordenada, la información fundamental de distintas procedencias. Informa sobre las identificaciones correctas, por ejemplo, el "pasto estrella" o "estrella africana", al que se asigna corrientemente el nombre de *Cynodon plectostachyus*, es un clon de *C. aethiopicus*. Clara también la posición del "pasto pará", que asigna al género *(Brachiaria, B. mutica)* en lugar de la posición común en América Latina de colocarlo en *Panicum (P. purpurascens, P. barbinode)*. En cambio, es muy dudoso que el "jaragua" *Hyparrhenia rufa*, sea americano, como lo sugiere una cita.

Los métodos de mejoramiento son mencionados brevemente; en cambio son de mucho valor las referencias a cultivares comerciales en la mayoría de las especies, aunque en *Panicum maximum* estas referencias son escasas.

En leguminosas, es de notar la poca información sobre los trabajos recientes en Hawaii en *Leucaena*.

Aparte de estos detalles, el libro de Mr. Bodgan es de gran valor para América Latina en primer lugar por la forma compacta, clara y balanceada de presentar la información en cada especie. Luego, porque contiene muchas novedades para los latinoamericanos, sobre especies usadas en Africa que son desconocidas en América Latina. Finalmente, una lista muy completa de referencias. El libro termina con índice de nombres botánicos y comunes. Contiene numerosas ilustraciones, lineales y esquemáticas. Pertenece a Tropical Agricultural Series, y como los otros volúmenes, está nítidamente impreso.

America Tropical ha dependido tradicionalmente de Africa para sus gramíneas forrajeras, y como lo muestra este libro, aún hay campo para introducciones prometedoras. En cambio, es la fuente principal de leguminosas forrajeras, que han "domesticado" en Australia. Ojalá que un libro como el de Mr. Bogdan despierte en los investigadores latinoamericanos el interés por aprovechar mejor los pastos foráneos y autóctonos, y dirigir sus esfuerzos hacia el conocimiento de su mejoramiento genético, condiciones fisiológicas y manejo cultural.

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