"Jellyrolling" May Reduce Media Use and Transportation Costs of Polybag-Grown Seedlings

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Growing medium and transportation are major costs for polybag nursery systems. Both could be reduced if the medium could be removed for reuse, and the seedlings stored as bareroot seedlings before planting. The objective of this study was to evaluate the effect of the "jellyroll" system on root growth potential (RGP), water status, and survival of Pinus pseudostrobus *Lindl. and* P. ayacahuite *var.* veitchii *Shaw, conifers native to central Mexico. Seedling root systems, grown in polybags, were removed from the media, soaked in hydrophilic polymer, and planted in a greenhouse study and field trial. Seedling survival decreased linearly with storage. Storage temperature had little effect on survival or RGP, and RGP was not correlated with survival or seedling water status. Needle pressure potential was highly correlated with survival. Jellyrolling also reduced the survival of seedlings outplanted in Mexico. Implications for polybag nurseries are discussed.* Tree Planters' Notes 47(3):105-109; 1996.

Pinus pseudostrobus Lindl. and *P. ayacahuitc* var. *veitchii* Shaw are important timber species growing in the highlands of central Mexico between 1,600 and 3,200 m (~5,250 to 10,500 ft). Trees often reach heights of 30 to 40 m (~98 to 131 ft), with diameters exceeding 1 m (~3.3 ft) (Perry 1991). Although both are important timber species, little research has been conducted on the nursery production and outplanting performance of these and other pine species in Mexico (Patino V. and Marin C. 1993). This paper is one of a series of studies conducted to gain more information on nursery production to aid in reforestation efforts.

Nurseries in Mexico and many other countries grow seedlings for reforestation in polybag nurseries. Seedlings are grown in plastic bags filled usually with forest soil. This container system is heavy and often expensive. One nursery in Mexico City uses 35,000 m^3 (45,500 yd^3) of forest soil every year at a cost of over $13 /$m^3$ ($10/$yd^3$). Not only is the resource expensive, but also limited. Each harvest of forest soil for this nursery alone destroys about 1 ha (2.47 ac) of forest land. There are 137 federal nurseries and more than 1,800 forest nurseries in Mexico using this type of production system (Sanchez V. 1995). Developing alternatives would conserve a valuable resource and possibly reduce the production costs for nurseries.

One possible alternative is to reuse the container medium. This would entail removing the medium at time of harvest, treating the root systems to minimize desiccation and transporting the seedlings as bareroot seedlings. One technique of protection is the "jellyroll" system consisting of dipping the roots in a hydrophilic slurry and then wrapping the roots in burlap or toweling (Lopushinsky 1986). This technique has been used primarily for bareroot seedlings (Dahlgreen 1976), but it does show promise for container seedlings (Fidelibus and Bainbridge 1994).

In addition to the reduction of forest soil used, this technique would facilitate transport of seedlings to the planting site. Virtually all of the weight and much of the volume is associated with the medium. Eliminating the medium would greatly reduce transportation costs, and reduce storage requirements. In some cases, it may also increase the productivity of planters who must wait for seedlings to be transported to remote sites.

The objectives of this study are to examine the effect of jellyrolling on the survival and root growth potential of polybag-grown *Pinus pseudostrobus,* and evaluate the potential of using the jellyroll system in an operational trial in Mexico with *P. ayacahuite* var. *veitchii* seedlings.

Root growth potential (RGP) has been used as an indicator of seedling survival potential for many species (Ritchie and Dunlap 1980). However, much of the work has focused on the RGP of seedlings during dormancy. Little work has examined RGP during the growing season, or with species with little or no dormancy (Donald 1988). Typically, RGP is low in late summer, increases to a mid-winter peak, and drops again in spring as growth begins (Johnsen and others 1988). This may be a problem with warm temperate and tropical pines, as they lack a true temperature-induced dormancy (Johnsen and others 1988), which may affect the RGP. Furthermore, some regions, such as Mexico, have planting seasons coinciding with the late summer to early fall rainy season, when RGP of conifers is generally low.

Materials and Methods

Greenhouse trial. On February 21, 1995, *Pinus pseudostrobus* seeds were planted in double-thickness black polybags— 10 cm (~4 in) wide (15 cm (~ 6 in) deep–- containing 2 parts composted bark, 1 part scoria (lava rock), and 1 part sand. These bags have a surface area of about 32 cm^2 (5.0 in^2), and an effective growing density of about 300/m^2 (28/ft^2). Seedlings were grown under greenhouse conditions of 15 to 27 /C (59 to 81 /F), and "fertigated" daily with a 1:100 injector applying 100 mg N/L of irrigation water. In September, 120 seedlings were graded by height and diameter into 15 groups of 8 similarly sized seedlings, with 1 from each group dedicated to each treatment. The study was a 2 × 4 factorial with 2 storage temperatures (6 and 22 /C; that is, 42 and 72 /F) and 4 storage times (0, 1, 4, and 7 days) with 15 seedlings/ temperature × storage combination.

At 7 days before planting (September 5, 1995), the first treatment (7-day storage) was lifted. Shoot length and root collar diameter were measured on 30 seedlings. The roots were then rinsed carefully of growing medium, dipped in a TerraSorb® slurry (3.7 g/L water), and wrapped in a moist cotton cloth (figure 1). The cloth was rolled to accommodate the entire treatment group of 15 trees, and then dipped in the slurry once again. The cloth rolls were placed in plastic bags and 1 bag was stored at 6 /C and the other at 22 /C (room temperature). This was repeated for each of the subsequent storage periods (4 and 1 day). The 0-day treatment (control) was lifted, measured, dipped, and planted immediately.

All treatments were planted the same day in 3-L (2.7gal) pots filled with sand in a randomized block along a greenhouse bench. The greenhouse temperature during the 28 days was 23/C (73.4 /F) (figure 2). Predawn xylem pressure potential (R) of needle fascicles was measured at 1, 3, 7, 14, and 21 days after planting for each treatment to assess seedling water stress following transplanting. Plants were watered as needed for 28 days. At the end of the study, live plants were measured for shoot growth (length and root collar diameter) and the number of white root tips greater than 0.5 cm (0.2 in). The length of new white roots greater than 0.5 cm was measured on a subset of live seedlings.

Operational field trial. On July 25, 1995, seedlings of *Pinus ayacahuite* were outplanted on a reforestation site near Mexico City, Mexico. The seedlings were removed from the polybags and carefully shaken to remove the growing medium (forest soil). The roots were dipped in Terra-Sorb® slurry (2.7 g/L water), wrapped in cotton toweling and transported to the planting site by horseback (figure 3). Seedlings were planted the same day by 5 community tree planters.

Figure 1—*Wrapping roots of* Pinus pseudostrobus *seedlings in a moist cotton cloth.*

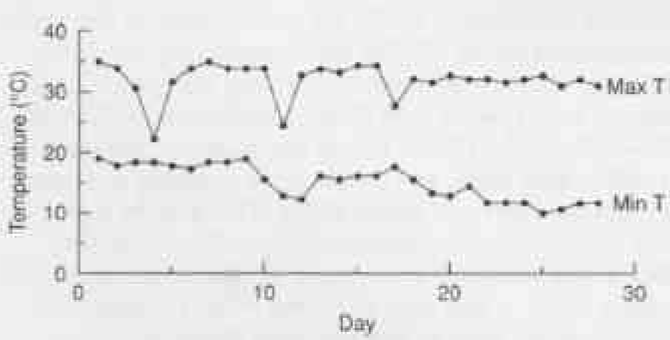

Figure 2—*Minimum and maximum temperatures in the greenhouse during the "outplanting" phase of the RGP test.*

Figure 3—*Seedlings awaiting transport to a planting site in central Mexico.*

Each planter planted 5 jellyroll seedlings adjacent to 5 polybag seedlings for 5 replications. Initial seedling size and planting quality was determined. The seedlings were reevaluated on May 3, 1996.

Results

Greenhouse trial. *Pinus pseudostrobus* responded poorly to the combination of jellyrolling and short-term storage in late summer (table 1). Survival ranged from 97% for nonstored seedlings to 0% for seedlings stored 7 days at 22 /C (figure 4). The decline in survival was linear with no significant difference in slope for the 2 storage temperatures. The roots of seedlings given the 4-day/6 /C treatment appeared to be drier than those of seedlings given the other treatments at the end of the storage period. This may have contributed to the poorer survival of these seedlings compared to those given the 4-day/22 /C treatment.

Root growth potential as measured by number of new roots was highly correlated with total length of new roots (figure 5). Thus, this quick assessment of RGP was a reasonable assessment of overall root growth over the test period. RGP was highest for the control treatment, and tended to be higher for the 6 /C storage temperature for all storage durations (table 1).

However, only the control was different from the 22 /C storage temperature. Length of storage had no significant effect on RGP of surviving trees. If a seedling survived, the root growth was comparable among treatments. The only difference was survival varied among treatments. Neither storage length nor temperature had a significant effect on seedling growth over the 28 days. However, height growth ranking was control > 6 /C > 22 /C (table 1). Although there appeared to be a poor relationship between RGP and seedling response to the treatments, water stress as measured by xylem R (MPa) was more closely related to treatments. Storage temperature had no significant effect on seedling water stress over the test period. However, time in storage and time after planting affected seedling water status (figure 6). Seedling R tended to decline from day 1 to day 14, and increase from day 14 to day 21 as the seedlings recovered from transplant shock. The control treatment had the highest R throughout the study. Seedlings stored for 7 days had the lowest R. Beginning 1

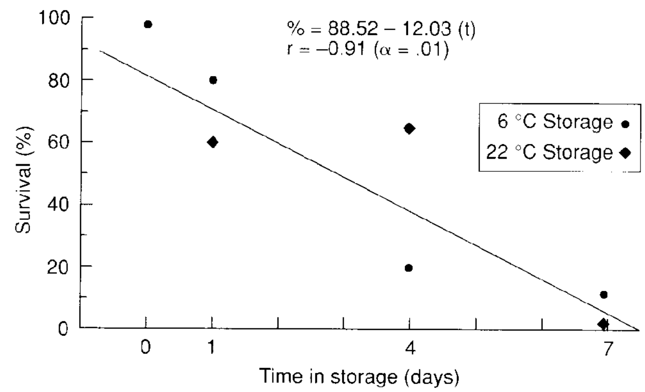

Figure 4— *Effect of time in storage at 6 and 22 °C (42 and 72 °F) on survival of* Pinus pseudostrobus.

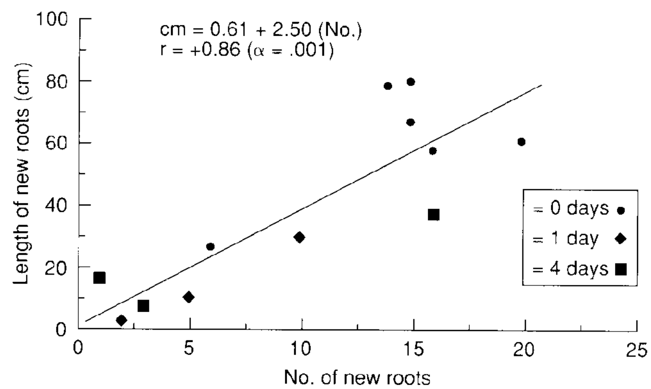

Figure 5— *Relationship between the number of new roots regenerating on* Pinus pseudostrobus *and the total length of those roots after 28 days.*

Table 1—*Survival, RGP, and growth of* Pinus pseudostrobus *seedlings after storage at 6 and 22 °C for different time periods*

Days	Temp (°C)	Survival (%)	RGP (no.)	Initial height (cm)	Height growth (cm)	Initial diameter (mm)	Diameter growth (mm)
0	—	97	9.7 (1.0)	16.7 (0.7)	7.4 (2.0)	3.8 (0.1)	0.48 (0.7)
1	6	80	7.3 (1.6)	18.5 (1.2)	5.8 (2.8)	3.8 (0.2)	0.63 (0.11)
1	22	60	3.6 (1.8)	17.7 (1.0)	3.9 (3.7)	3.6 (0.2)	0.55 (0.13)
4	6	20	6.0 (2.6)	17.8 (1.1)	5.0 (2.9)	3.8 (0.2)	0.66 (0.13)
4	22	67	2.9 (1.6)	18.5 (1.1)	3.0 (2.1)	3.6 (0.2)	0.54 (0.12)
7	6	7	7.0 (—)	17.9 (1.1)	5.0 (—)	4.0 (0.2)	0.52 (—)
7	22	0	0	18.0 (1.0)	0	3.7 (0.2)	0

Values in parentheses are standard errors of the mean.

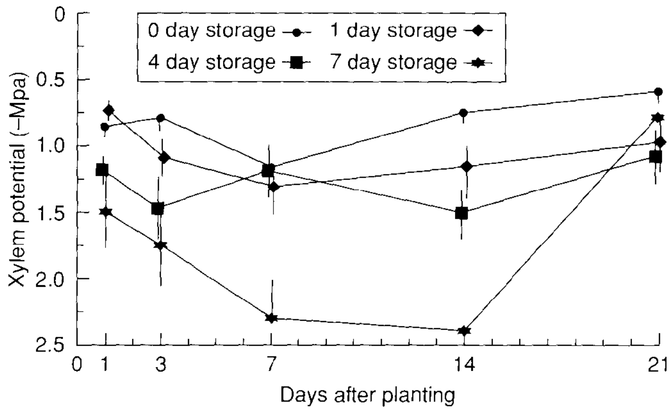

Figure 6—*Relationship between time after planting on seedling pressure potential (MPa) after different lengths of storage.*

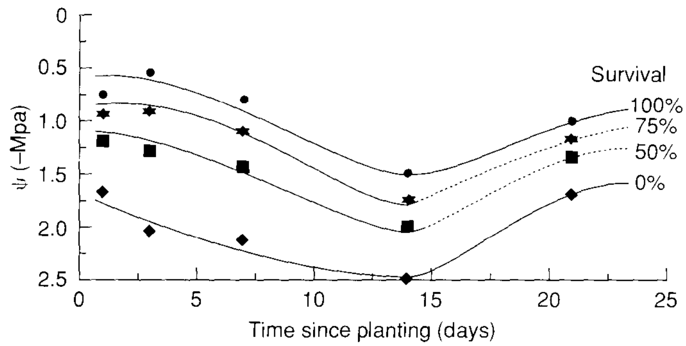

Figure 7—*Isolines of survival as a function of seedling pressure potential and time after planting for* Pinus pseudostrobus.

day after planting, seedlings had a R of 21.5 MPa that declined to 22.4 MPa on day 14. The lone surviving seedling from this treatment had a pressure potential of 20.8 MPa on day 21.

Seedling R appeared to be a good predictor of the survival potential of the seedling. Equations relating seedling R for each day to seedling survival on day 28 ($\%_{28}$) were

$\%_{28}$ = 159 +96 (MPa1) $r = 0.82$ ($p = 0.05$)
$\%_{28}$ = 138 +68 (MPa3) $r = 0.99$ ($p = 0.01$)
$\%_{28}$ = 159 +75 (MPa7) $r = 0.82$ ($p = 0.05$)
$\%_{28}$ = 250 + 100 (MPa14) $r = 1.00$ ($p = 0.01$).

These equations were used to construct isolines of survival versus seedling R (figure 7). Populations that had 100% survival had high R values throughout the study. One day after planting, these seedlings had R values greater than -0.75 MPa. By day-14, the predawn R of populations with 100% survival was -1.5 MPa. Populations that had 75% survival had R values averaging 0.25 MPa less than those of the population that had complete survival throughout the study. Populations with 50% survival averaged 0.55 MPa less than the population with 100% survival. Seedling populations which ultimately had 100% mortality had R less than -1.5 MPa on day 1, declined to -2.5 MPa on day 14, and recovered to less than -1.7 MPa by day 21.

Operational field trial. Performance of the jellyroll system was not as high as the performance of the polybag system with *P. ayacahuite* (table 2). Survival of the jellyroll seedlings was 68% compared to 96% for the seedlings transported as polybag seedlings. Growth was not significantly affected, although the jellyroll seedlings had less than 50% of the height growth of the polybag seedlings.

Table 2—*Survival and growth of* Pinus ayacahuite *var.* veitchii *seedlings using conventional polybags and the jellyroll system*

Stocktype	Survival (%)	Initial (cm + SE)	Height (cm + SE)	Initial (mm + SE)	Diameter (mm + SE)
Polybag	96	51.4±1.3	7.8±1.4	11.10±0.56	2.02±0.23
Jellyroll	68*	45.3±2.3	1.9±2.6	9.26*±0.76	1.84±0.42

* Significantly different at the 5% level according to a paired t test using the arc sin transformation of survival.

Discussion

Long-term storage of 30 to 90 days of dormant seedlings often has little effect on survival (Jiang and others 1994; McKay 1993). However, short-term storage of actively growing seedlings has not be examined, especially for a species from a subtropical latitude. Short term storage of *Pinus pseudostrobus* had the drastic effect on survival. Survival decreased linearly with increasing storage up to 7 days. Mortality was likely caused by the storage rather than by the medium removal and treating with hydrophilic polymer. Although problems with hydrophilic polymers have been reported (South and Lowenstein 1994), the high survival of the control treatment points to storage as the cause of poor survival. However, RGP was not correlated with survival. This finding is not unusual. Others have reported no or poor relationships between survival and RGP (Binder and others 1988; Feret and Kreh 1985). RGP was lower than reported for other species, which is probably a function of the sampling during the summer "monsoon" season, when RGP is inherently low for many species (Ritchie and Tanaka 1990). Donald (1988) found a similar response for *Pinus radiate,* a warm-temperate conifer. The fluctuation in RGP was not great, but RGP was low in the fall and summer and higher in the winter and early spring. Conifers from Mexico might behave similarly.

Seedling R was the best predictor of seedling survival potential. McCreary and Duryea (1987) also found Rto be a good predictor of survival of Douglas-fir— *Pseudotsuga menziesii* Mirb. (Franco). Seedling R measured 8 days after outplanting provided the best estimate of survival. In this work, a model was developed to estimate survival from R values measured during the first 14 days after outplanting. Tabbush (1986) found that rough handling could reduce predawn xylem pressure potential for at least 27 days after planting. In his study; rough handling reduced survival, RGP, mycorrhizal formation, and budbreak.

An inability to maintain seedling water balance may be caused by a loss of membrane integrity in the fine roots of recently planted conifers. McKay (1993) found long-term storage of conifers resulted in deterioration of fine roots as measured by electrolyte leakage. This loss of integrity would result in not only leakage of nutrients but also in an ability to absorb water to maintain water balance. This would lead to decreasing R and subsequent death if integrity was not restored. Early lifting during the dormant season resulted in the greatest damage. It might be expected that lifting in the latesummer, when seedlings are actively growing, would accelerate the progression of damage. This could explain the rapid decline in R and survival in this study.

It may be possible to develop a "jellyrolling" system for polybag nurseries in warm climates. The outcomes of the operational trial were marginally successful. In this particular trial, considerable delays in planting were caused by the lack of planting material. The horse could carry about 200 polybag seedlings/trip, which required about 1 hour. However, the planting crew could plant these seedlings in about 30 min. Thus, productivity was about half of what it could be. With the jellyroll system, the horse could carry over 1,000 seedlings. Jellyrolling the seedlings could result in significant improvements in productivity in remote sites if techniques can be developed to improve the performance of jellyroll seedlings.

Conditioning practices, such as undercutting of bareroot seedlings, improve the tolerance of fine roots to storage (McKay 1993). Conditioning practices for polybag nurseries, such as mild water stress or nutrient stress, may alter the sensitivity of Mexican conifers to removal of the medium and storage. The system would have to provide acceptable survival after 4 to 5 days storage before it could be recommended for operational use.

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