Excessive Seedling Height, High Shoot-to-Root Ratio, and Benomyl Root Dip Reduce Survival of Stored Loblolly Pine Seedlings

James N. Boyer and David B. South

School of Forestry, Alabama Agricultural Experiment Station, Auburn University, Auburn

Excessively tall seedlings of loblolly pine (Pin us taeda L.) with high shoot-to –root ratios survived poorly compared with shorter, more balanced trees when planted in coarse sand in a droughty year after 12 weeks of cool storage. Tall seedlings with roots dipped in a clay surray containing benomyl fungicide before storage showed poorer survival than tall seedlings dipped in clay surray alone. Tree Planters' Notes 38(4):19-22; 1987

Loblolly pine (Pinus taeda L.) seedling morphology has been found to correlate significantly with outplanting survival (7). Seedling height and shoot-to-root ratio are particularly important to survival, especially under droughty conditions (4,5). Tall seedlings that have a large amount of foliage and transpirational surface area and a relatively small root system cannot meet the demand for water replenishment, and thus are susceptible to moisture stress.

Additionally, seedling storage may affect outplanting performance. Improper timing of storage may result in seedling deterioration, possibly because of molds or other pathogens. Benomyl fungicide applied in a root dip prior to planting has been shown to control brown-spot needle blight (*Scirrhia acicola* (Dearn.) Sigg.) on longleaf pine (*Pinus palustris* Mill.) seedlings (3). Barnett and Kais (1) demonstrated that benomyl added to a clay slurry applied to longleaf pine roots prior to 1 or 3 weeks of storage improved survival. This fungicide was tested to determine if it could improve the survival of stored loblolly pine seedlings. A second objective was to test the effect of seedling morphology, as affected by sowing date, on survival after outplanting.

Materials and Methods

Seeds from a single half-sib family of loblolly pine were sown at three different times: February 20, April 3, and May 15, 1985. The seeds were treated with Bayleton (50 WP, 0.25 g/100 g seed) and thiram (Arasan) (42 S, 8.3 ml/100 g seed) to protect against fusiform rust and as a bird repellent, respectively. Seeds were sown in rows 15 cm apart with 3 cm between seeds in a row for a sowing density of 215 seeds/m^2 Seeds were sown outside in 1.22 by 1.22 m soil boxes filled with coarse sand. Seeds were pressed slightly into the sand and covered with approximately 1 cm of pine bark as a mulch. Seeds for one sowing date occupied one soil box, and there were four replicate boxes.

Seedlings were watered daily throughout the germination period and early growth phase. As roots grew deeper into the sand, the seedlings were watered less frequently. Plots were sprayed with captan (50 WP, 11.2 kg/ha) when germination was complete to control damping off.

During the fusiform rust spore flight (early April through late June), Bayleton (50 WP, 0.56 kg/ ha) was sprayed approximately once every 3 weeks. The seedlings were fertilized weekly with 20-20-20 (N-P-K) fertilizer at about 130 kg/ha.

On December 3 to 4, 1985, about 80 seedlings were lifted from each box. Half of these had their roots dipped in a slurry of 427.5 g kaolinite plus 22.5 g benomyl (19:1 ratio) in 1.5 liters of water (300 g solid/liter). The other half had their roots dipped in a slurry of 450 g kaolinite in 1.5 liters of water. All seedlings were then placed in plastic bags and stored at 2 °C for 12 weeks (until February 25, 1986). After storage 25 seedlings from each replication of sowing date and root treatment were planted 1 foot apart in rows 2 feet apart in deep coarse sand on February 25, 1986. The height of each seedling was measured after planting, and survival was checked on March 28,

April 22, and June 2, 1986. Seedlings that were left over in the soil boxes were lifted in mid-February 1986, and ovendry shoot weights and root weights were measured.

Results and Discussion

Seedlings from the latest sowing date survived significantly better than seedlings from the middle sowing date, and those survived better than seedlings from the earliest sowing date (table 1). Precipitation for March 1986 was slightly above normal (19.5 cm), and survival in late March was generally good although there was about 10% mortality for the earliest sowing date. April and May, however, were exceptionally dry, with only 1.5 and 2.7 cm of rain, respectively. Survival dropped sharply after these 2 months, especially for the earlier sowing dates.

These differences in survival appeared to be related to the morphology of the seedlings. Seedlings from the earliest sowing date were very tall, with shoots out of balance in proportion to the roots (table 1). Combining data from the three sowing dates and dividing the trees into 4-cm height classes showed that survival decreased steadily with increasing height (figure 1).

Table 1—*Survival of seedlings at various times after outplanting, mean height of seedlings after planting, and shoot-to-root ratio of seedlings lifted in February*

Sowing date/ treatment	Percent survival: March 28	April 22	June 2	Height after planting (cm)	Shoot/root (g/g)
February 20					
Control	91 bc	76b	60 c	47.2 a	4.16 a
Benomyl	89 c	55 c	28 d	46.6 a	
April 3					
Control	97 ab	93 a	76 b	41.5 b	3.02 b
Benomyl	98 a	86 ab	65 c	40.4 b	
May 15					
Control	100 a	97 a	93 a	30.2 c	2.34 c
Benomyl	99 a	98 a	85 a	29.2 c	

Means followed by the same letter within a column do not differ significantly at the 5% level of significance (Duncan's multiple range test).

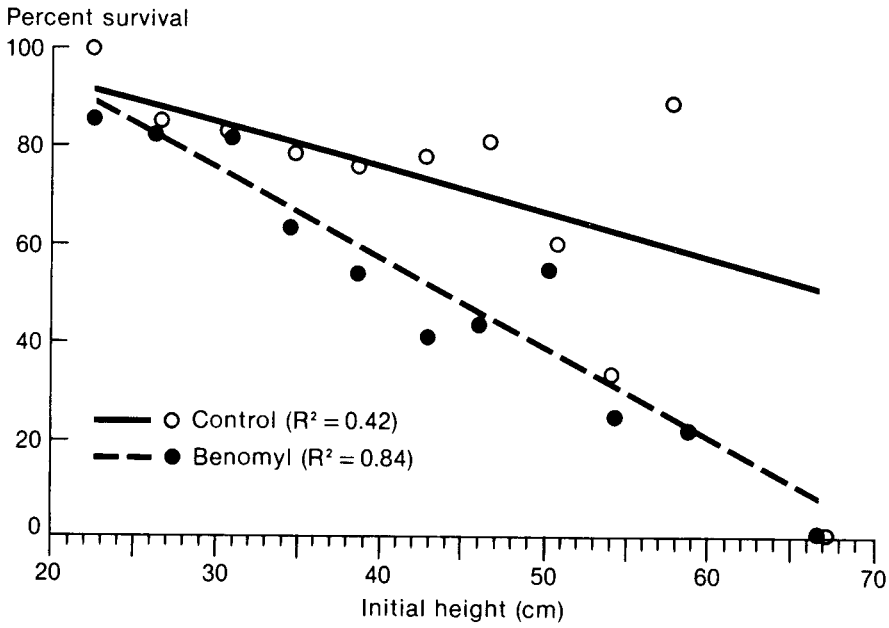

Figure 1—*Survival of seedlings in 4-cm initial height classes for control seedlings (clay dip only) and seedlings dipped in a clay slurry with benomyl added. All seedlings stored for 12 weeks after dipping.*

Adding benomyl to the clay root dip slurry reduced survival of the seedlings, especially for the tallest trees with the highest shoot-root-ratios (table 1). However, the fungicide did not significantly reduce survival for shorter, more balanced seedlings.

Larsen and others (4) found that initial seedling height and shoot-to-root ratio were negatively correlated with outplanting survival. Mexal and Dougherty (5) demonstrated that shoot-to-root ratios correlated with survival in a droughty environment. Tuttle and others (8) found that seedling height was negatively correlated with survival on adverse sites. Our results seem to corroborate these findings and demonstrate the importance of seedling morphology in outplanting survival, particularly under adverse conditions.

It is impossible to say for certain why the fungicide treatment reduced survival, particularly for the tall, unbalanced trees. Cordell and others (2) found poor survival of longleaf pine stored with clay slurry containing benomyl. After 12 weeks of storage with benomyl, survival was approximately 40%, compared with 80% for the clay slurry alone. It is possible that the extended storage with benomyl and clay in contact with the roots had some effect on the seedlings. However, Kais and others (3) state that it is safe to store longleaf pine seedlings treated with benomyl.

It should be noted that while Cordell and others (2) found decreased survival when storing with benomyl plus clay, a treatment of peat moss plus benomyl prior to storage increased survival compared with benomyl alone. Pawuk and others (6) found that benomyl applied as a soil drench had no detrimental effect on outplanted longleaf pine seedlings and actually increased mycorrhizal development. Furthermore, in our study, benomyl did not significantly reduce survival of shorter seedlings, so the compound apparently had some interaction with poor seedling morphology.

Conclusions

The results presented here confirm the importance of seedling morphology for survival on less than optimum sites. In order to assure good seedling survival following outplanting, especially on droughty sites, it is best to use seedlings with a height of less than 30 cm and a shoot-to-root ratio (grams per gram dry weight) of less than 2.5. It is unknown why a benomyl root-dip prior to storage reduced survival. Based on the results of this study, such a treatment would not be recommended to improve storability of loblolly pine seedlings.

Literature Cited

1. Barnett, J.P.; Kais, A.G. Longleaf pine storability and resistance to brown-spot disease improved by adding benomyl to the packing medium. Proceedings, Fourth Biennial Southern Silvicultural Research Conference, 1986 November 4-6. Atlanta, GA. 1986. Gen. Tech. Rep. SE-42. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeast Forest Experiment Station; 1987: 222-224.
2. Cordell, C.E.: Kais, A.G.; Barnett, J.P.; Affeltranger, C.E. Effects of benomyl root storage treatments on longleaf pine seedling survival and brown-spot disease incidence. Proceedings, 1984 Southern Nursery Conference, 1984 June 11-14. Alexandria, LA. 1984: 84-88.
3. Kais, A.G.; Cordell, C.E.; Affeltranger, C.E. Nursery application of benomyl fungicide for field control of brown-spot needle blight (*Scirrhia acicola* (Dearn.) Sigg.) on longleaf pine (*Pinus palustris* Mill.). Tree Planters' Notes 37(1):5; 1986.
4. Larson, H.S.; South, D.B.; Boyer, J.N. Root growth potential, seedling morphology, and bud dormancy correlate with survival in a December planting of loblolly pine seedlings in Alabama. Tree Physiology 1:253-263; 1986.
5. Mexal, J.G.; Dougherty, P.M. Growth of loblolly pine seedlings. 4. Performance in a simulated drought environment. Tech. Rep. 050-1422/6. Hot Springs, AR: Weyerhaeuser; 1981. 26 p.

6. Pawuk, W.H.; Ruehle, J.L.; Marx, D.H. Fungicide drenches affect ectomycorrhizal development of container-grown *Pinus palustris* seedlings. Canadian Journal of Forest Research 10:61-64:1980.
7. South, D.B.; Boyer, J.N.; Bosch, L. Survival and growth of loblolly pine as influenced by seedling grade: 13-year results. Southern Journal of Applied Forestry 9:76-81: 1985.
8. Tuttle, C.L.; South, D.B.; Golden, M.S.; Meldahl, R.S. Relationship between initial seedling height and early loblolly pine seedling survival and growth. Southern Journal of Applied Forestry 3; 1987 (In press).