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Seedling mortality can be caused by root pruning.

Survival of the Fittest:

Pine Seedling Survival Increased by Machine Planting Large Seedlings

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For several decades, AAES researchers have been trying to improve the survival of pine seedlings. Several important factors have been identified, including proper nursery management practices, good planting supervision, and sufficient soil moisture at time of planting. Two very important factors are seedling size and planting method. Research has shown that seedling survival can be significantly improved by machine-planting larger seedlings.

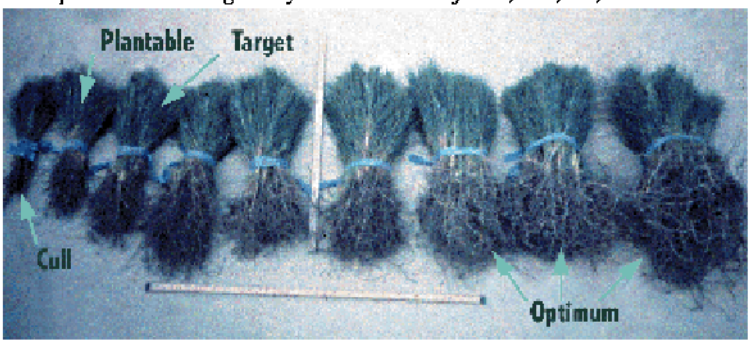
Larger seedlings survive better because they have more roots. Seedlings with more fibrous roots can quickly produce new roots soon after planting. This ability is related to a seedling's root growth potential, which is a measure of the new root growth under controlled conditions. Theoretically, seedlings that can produce many new roots within four weeks of planting will survive better than seedlings that produce only a few new roots. Some researchers believe that seedling morphology has little to do with the ability of a seedling to quickly produce new roots. However, AAES studies have demonstrated a positive correlation between root mass and root growth potential. Apparently, the more fibrous lateral roots a seedling has, the more sites are available for new root growth. Seedlings that produce more new roots have a greater ability to extract water from the soil.

In Alabama nurseries, seedlings of longleaf pine and various hardwood species are grown at a low seedbed density (less than 10 plants per square foot of growing area). In this roomy growing environment, plants produce larger root systems, which increases field performance potential of the seedlings. However, loblolly and slash pine seedlings are more commonly grown in crowded seedbeds (containing 25-30 plants per square foot). The primary reason for this has been a lack of demand for morphologically improved seedlings of these species (see Table 1 for definitions). Many tree-farmers do not request seedlings grown at low seedbed densities (less than 20 plants per square foot) because foresters haven't informed landowners about the benefits of using these plants.

Table 1. Definitions of Seedling Terms for Bare-root Loblolly Pine

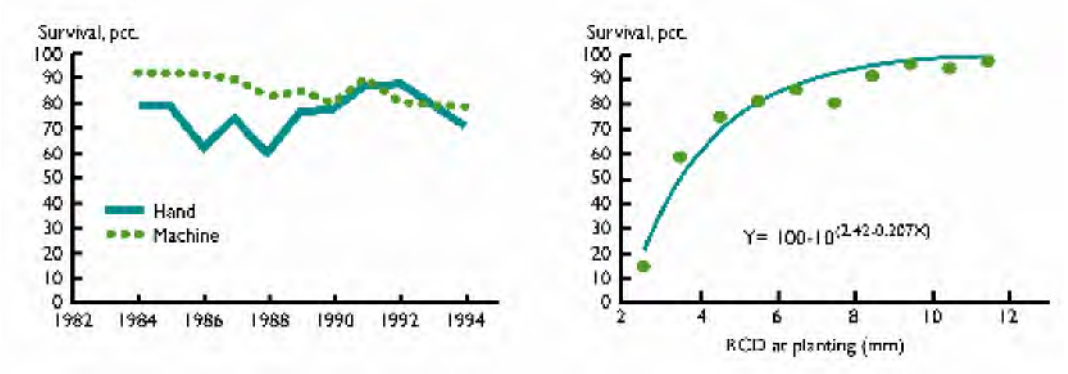
Term	Definition
Cull seedling	An unacceptable seedling that does not meet a certain size standard (e.g. has a root-collar diameter (RCD) less than 3 mm).
Plantable seedling	A seedling that is slightly larger than a cull. Typically these seedlings will have RCDs of 3 mm or more.
Grade 2 seedling	A seedling that has a RCD ranging from 3.2 to 4.7 mm. This seedling size is commonly used by most tree planters.
Grade 1 seedling	A seedling that has a RCD greater than 4.7 mm.
Regular seedling	The average loblolly pine seedling planted by most researchers in the South; typically has an average RCD of about 3.9 mm.
Target seedling	The seedling that the nursery manager would produce the most of under ideal weather conditions; the "target seedling" at certain industry nurseries is much larger than at others.
Morphologically improved	These are grown at low seedbed densities (less than improved seedlings or equal to 20 per square foot) and at least half of the seedlings have RCDs greater than 5 mm and none less than 3 mm. These seedlings have a higher root weight ratio, have been cultured to give more fibrous roots, and are not taller than regular seedlings.
Optimum seedling	This seedling will minimize overall reforestation costs while achieving established goals for initial survival and growth. For some organizations, this means the seedling will have a RCD of about 7-10 mm.

Each bundle of seedlings represents 50 seedlings. Cull seedlings have a RCD of 2.5 mm while optimum seedlings may have a RCD of 7.5 ,8.5 ,9.5, and 10.5 mm.



Pine seedlings are planted either by hand or by machine. The choice between the two depends on a number of factors, including roughness of the terrain, availability of vendors, cost per acre, and a desire for success. There is considerable variation in the quality of service as well as the price charged by vendors. The price of planting with a machine may be 6.5 cents per tree, while the price of hand planting is sometimes 6 cents per tree. For both, the cost is lower for agricultural fields than for forest sites. Although there are exceptions, in general survival rate is better with machine planting. On average, the difference in some regions may be 10% higher for machine planting. However, in years with a summer drought (1986, 1987, and 1988), machine planting in one region of Alabama averaged 16% to 29% higher than hand-planting (see Figure 1).

Figure 1 (left). Comparison of average survival for hand and machine planting for one company in Alabama (Grade 2 seedlings).
Figure 2 (right). Relationship between seedling root-collar diameter at planting and survival of machine planted slash pine seedlings.



Typically, loblolly pine seedlings that are planted by hand are Grade 2 seedlings, which have a stem thickness of about 4 mm root collar diameter (RCD). However, landowners also can purchase morphologically improved loblolly and slash pine seedlings with stem measurements of about 7 mm RCD. One reason landowners do not plant the larger seedlings is that they

perceive this practice to be more expensive in the short-term. In addition, they may not realize some of the benefits provided by planting better stock.

At first glance, morphologically improved seedings appear more expensive than Grade 2 seedlings. For example, at one nursery in Alabama, a morphologically improved seedling will cost the landowner 1.7 cents more than a Grade 2 seedling. Grade 2 seedlings are cheaper because they are produced in the nursery at high seedbed densities. However, because these seedlings have small roots, survival rates under less than ideal conditions may be poor. Several studies demonstrate better survival from seedlings grown at wide seedbed spacings (Table 2). When soil moisture is favorable and average survival is high (greater than 96%), seedbed density will have little or no effect on survival. However, when the average survival is less than 90%, morphologically improved seedlings exhibit better survival than Grade 2 seedlings. Hand planting seedlings from low seedbed densities usually increases survival by four to 10 percentage points over that of seedlings grown at 30 per square foot (Table 2).

Table 2. Increase in Seedling Survival by Using Loblolly Pine Seedlings Grown in Low Seedbed Densities

Researcher/year	Low density	Medium density	Survival gain
	#/sq.ft.		percentage points
Rowan 1986	15	30	14
Shoulders 1961	14	38	12
Shoulders 1961	10	30	9
Rowan 1986	15	30	8
Leach 1986	20	30	4
Shoulders 1961	13	35	3
Rowan 1986	15	30	2
Shoulders 1961	12	31	1
Shipman 1964	20	40	1
Carneiro 1985	15	26	-3

AAES studies have shown that machine planting large-diameter seedlings (with many fibrous roots) can greatly improve the survival potential. Results of this combination are shown in Figure 2. In this example, slash pine seedlings were planted by machine in October. About 38% of the Grade 2 seedlings died in the first year after planting. However, the seedlings that were 8 mm or larger at root-collar had 90% or better survival rates. Although not all sites will show this exact relationship, this does illustrate a pattern that has been observed over the past 50 years. When properly planted, the large diameter seedlings (with higher root-weight ratios)1 typically survive better than Grade 2 seedlings.

There are several reasons why seedling survival may be higher with machine planting. The most obvious factor is that machines plant seedlings deeper. Average depth of planting may be six inches with a machine, while hand-planters often plant seedlings only one or two inches deep. Many tree-planting guides say this is the correct depth, so tree planters use these guides as justification for making shallower holes. However, on many sites, planting the roots deeper in the soil will keep the roots closer to zones of moist soil, and planting roots closer to soil moisture will improve the chance of survival.

Another reason for higher survival with machine planting is caused by differences in the way seedlings are handled. For example, sometimes hand-planters will prune or strip roots to facilitate more rapid planting. In several cases, AAES researchers have visited sites where poor survival resulted from root pruning by hand-planters. In some studies, pruning roots just before planting has reduced survival by 5% or more. Stripping roots can reduce survival by 10% or more.

On flat ground, some hand-planters can plant 300 Grade 2 seedlings per hour. Planting seedlings with larger roots will reduce the rate of planting by hand. On some sites, a morphologically improved seedling can be planted with a shovel at a rate of 150 trees per hour. However, some tree planters prefer to make a smaller hole and therefore will prune roots or strip roots in order to speed up the planting rate. In some cases, pruned roots (and subsequent smaller holes) can speed up tree planting by 30 trees per hour or more. Small roots can be planted in small holes (which are quicker to make than deep holes). When tree planters are paid by the tree (or by the acre), they will make more money in a day by making only small, shallow planting holes. In contrast, removing roots does not speed up the rate of machine planting. Therefore, most machine planters do not prune or strip roots. Less root pruning means less mortality.

Seedlings planted with a machine typically have higher survival than hand-planted seedlings.

Foresters working for one corporation in Alabama have seen the benefits of planting morphologically improved seedlings with large roots. As a result, the company-owned nursery grows seedlings at densities of 15 per square foot. In some fields, the average RCD is 7 mm or greater. To help ensure good survival, half of their seedlings are planted using machines. When the site is too steep to plant with a machine, hand planters are used to plant the seedling deeply (with the

root collars about five inches below ground). The main reason this company produces larger seedlings is to increase early growth.

On some sites, planting 7-mm seedlings can reduce the rotation length by one year. In fact, in some cases Grade 2 seedlings may not achieve a 7-mm diameter after one year's growth.

These results suggest that, since large seedlings do not increase the cost for machine planting, farmers should consider machine planting old fields using large planting stock. The overall cost may be less than expected (especially when reducing the number of trees planted). In fact, in some years, the cost per surviving seedling may even be less! The cost per acre of machine planting 500 morphologically improved seedlings might be cheaper than planting 726 Grade 2 seedlings by hand (Table 3). As the old saying goes, you get what you pay for.

Table 3. Costs for Planting Grade 2 Seedlings By Hand and Planting Optimum Seedlings By Machine

Seedling type	Avg. RCD	Trees planted per acre	Seedling cost per acre	Hand planting cost per acre	Machine planting costs per acre	Survival after 1 year	Cost per surviving tree cents	Cost per acre
Grade 2	4mm	726	$26.14	$43.56	--	62%	15.5	$69.70
Morphologically improved	7mm	500	$27.50	--	$38	90%	14.5	$65.50

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