Relationship Between Initial Seedling Height and Survival and Growth of Loblolly Pine Seedlings Planted During a Droughty Year[1]

C. L. Tuttle, D. B. South, M. S. Golden, *and* **R. S. Meldahl,**
School of Forestry and Alabama Agricultural Experiment Station, Auburn University, AL 36849.

*ABSTRACT. Loblolly pine (*Pinus taeda *L.) seedling height (measured immediately following planting) was significantly related to survival after two growing seasons. This relationship was negative on sites classified as adverse, with shorter seedlings having better survival than taller ones. On nonadverse sites, taller seedlings survived as well or better than shorter seedlings. On all sites, initial height was inversely related to total seedling height growth during the first two seasons, permitting shorter seedlings at planting to reach the same total height as taller ones by age two. As a result, at age two, initial field height was not significantly related to total height.*

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Seedling morphology has long been used as an indicator of seedling growth potential. Early grading guidelines (established in the 1920s) used the presence or absence of secondary needles, winter buds, and stem bark as criteria for separating seedlings (Wakeley 1949). By the middle 1930s, root collar diameter was also included in grading rules. These early grading procedures were based on studies showing that seedlings with larger root collars were of higher quality and could grow more rapidly. Currently, many seedling growers and users think of a "larger" seedling as being "taller," which can lead to confusion.

Studies examining seedling planting depth have shown that deep planting may result in increased survival and early growth (Slocum 1951, Slocum and Maki 1956, Shipman and Hatcher 1957, McGee and Hatcher 1963, Swearingen 1963, Harms 1969). Planting depths that minimize shoot exposure seem beneficial except on poorly drained sites (Switzer 1960), where soil aeration is limited. However, some planters object to the use of deep planting due to problems with small planting holes (e.g., J-rooting and exposed roots) and time limitations associated with making a deeper, larger planting hole. Therefore, the advisability of planting shorter seedlings at "normal" depths on adverse sites is an important issue in planting operations.

There is a lack of quantitative data on the relationship between seedling growth and initial field seedling height. This paper summarizes data relating planting height to early growth and survival of loblolly pine planted on eastern Alabama sites.

METHODS

Seedlings planted at five sites were examined for seedling survival and growth. Two sites were on the lower Piedmont and three on the Hilly Coastal Plain regions of Alabama (Hodgkins et al. 1979). The sites used were a combination of old field sites and recently cutover pine stands (Table 1). Soils on the two Piedmont sites were Gwinnett sandy clay loams (clayey, kaolinitic, thermic, Typic Rhodudult) with a water-holding capacity in the upper 36 in. of 0.13 in. water per inch of soil. The coastal plain sites were all located on Marvyn loamy sands (fine loamy, siliceous, thermic, Typic Hapludult) with a water-holding capacity of 0.11 in. water per inch of soil. Slopes were all less than 5%, and all 5 study sites were located within a 20-mile radius of Auburn, AL. Precipitation during the 1981 planting year fell well below the long-term average (−9.38 in.), with most of the deficit occurring in June and July (−4.90 in.).

All the areas were hand planted with 1-0 planting stock using dibbles. Seedlings used were Livingston Parrish stock grown by the Alabama Forestry Commission near Atmore, AL. On each site, 216 seedlings were planted at a spacing of 6 × 8 ft. During planting, planters were instructed to plant the seedlings to root collar depth.

A total of 1,080 loblolly pine seedlings were used in this analysis. Prior to analysis, seedlings were separated into 1 in. height classes on each site, and any height class with less than 3 seedlings was deleted. The sites with 2-year survival less than 75% and total 2-year height growth less than 30 in. were classified as "adverse." Those sites with higher survival and growth were classified as "nonadverse" (Table 1). The soil physical conditions at planting time that would limit seedling survival and growth (e.g., surface bulk density, soil texture, soil moisture, topsoil depth) were examined to document the adverse conditions that reduced survival and growth (Coile 1948, Foil and Ralston

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Table 1. Former land use, seedling initial height, total height growth (planting to two seasons), total height, and survival by site after two growing seasons.

Site	Former land use	Mean initial height	Mean total height growth	Mean total height	Survival	Classification
		....	inches	....	%	
3	Coastal Plain Old Field	8	36	44	85	Nonadverse
1	Piedmont Old Field	7	31	38	81	Nonadverse
4	Coastal Plain Cutover Forest	7	26	33	70	Adverse
2	Piedmont Old Field	8	26	34	70	Adverse
5	Coastal Plain Cutover Forest	8	15	23	73	Adverse

1967, Stone and Jenkinson 1970, Carmean 1975, Mitchell 1979). Sites 1 and 3 were classified as "nonadverse," and sites 2, 4, and 5 were classified as "adverse." Site 2 was adverse due to low soil moisture levels occurring at planting. Site 4 was located facing southwest and had a loamy sand to sandy loam soil texture for the upper 18 in., resulting in low soil moisture levels. Site 5 was located on former log decks having a surface bulk density over 1.6 g/cc.

For each site class (adverse or nonadverse) average survival, total seedling height, total growth (planting to 2 years) and a survival-volume index (after two seasons) were calculated for the various height classes. The survival-volume index was calculated using the following expression: Survival-volume index = percent survival × root collar diameter^2 × height. The survival-volume index is similar to a plot-volume index (Ruehle et al. 1984), but the survival-volume index has the advantage of being comparable among sites since it is not dependent on the number of planted seedlings per plot. General linear models procedure (GLM) of SAS were used to perform regressions and analyses of variance tests on the data (Freund and Littell 1982). Several forms of survival and height growth models were evaluated, including simple linear, log, and exponential models. In general, a weighted regression (weighted by the number of observations per height class) of the form $Y = b_0 + b_1(HtO)$ or $Y = b_0 + b_1(HtO) + b_2(HtO)^2$ (where HtO = total seedling height following planting in inches and Y = survival, total growth, total height, or the survival-volume index) performed best.

RESULTS AND DISCUSSION

Survival

Seedling heights immediately after planting ranged from 2 to 14 in. Height at planting was significantly correlated to seedling survival after two seasons. On adverse sites, survival was negatively related to initial seedling height, while on nonadverse sites, survival had a slight positive relationship (Figure 1). These results parallel those of Stonecypher (1966), where first-year survival of identical loblolly pine progenies was negatively correlated ($R = -0.57$) with initial seedling height on an adverse (very sandy) site and was positively correlated ($R = 0.39$) on a nonadverse site.

Second-year survival on our adverse sites was 18% higher for 8-in. seedlings than for 14-in. seedlings. However, on nonadverse sites, survival for 8-in. trees was 10% lower than for 14-in. seedlings. The relationship on adverse sites is similar to that reported for loblolly pine seedlings in east Texas (Hunt and Gilmore 1967) and in North Carolina (Beineke and Perry 1965). Planting seedlings that were 8 in. instead of 14 in. tall increased first-year survival by 10% in Texas and 7% in North Carolina. The present results show that after two seasons, there is still a large survival increase by using 8-in. seedlings instead of 14-in. seedlings on adverse sites. Therefore, on the adverse sites examined, there is no apparent advantage in using taller bare-root seedlings. On these sites, shorter seedlings likely undergo

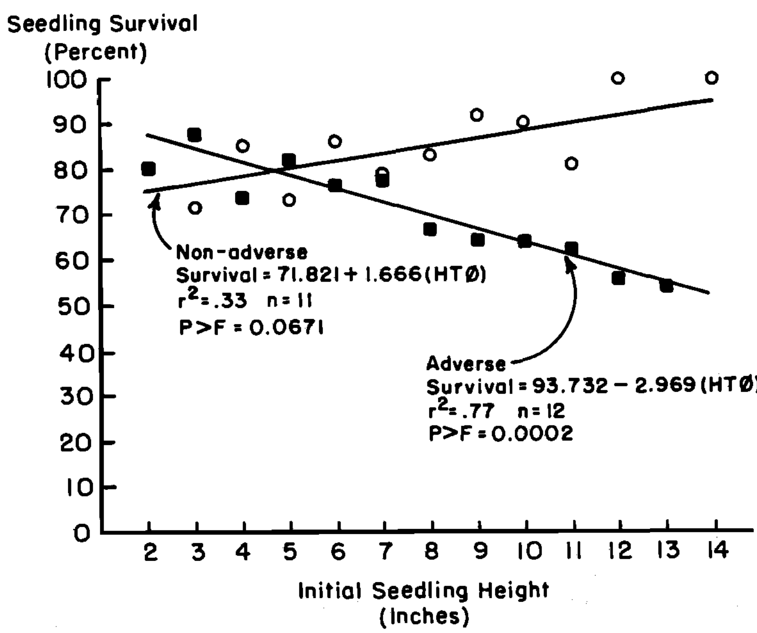

*Figure 1. Relationship between seedling survival after two seasons and initial seedling height (*HtO*) for adverse and nonadverse sites.*

less transplant shock, resulting in better survival.

Growth

Total loblolly pine seedling height growth after two growing seasons was also correlated to planting height (Figure 2). On adverse sites, total growth was negatively related to initial seedling height. These results are similar to those reported for slash pine (*Pinus elliottii* Englm.) when planted on adverse sites in Australia (Bacon et al. 1977). Thus, as with survival, use of taller seedlings on adverse sites proved to be a disadvantage. However, on nonadverse sites, the height growth pattern was curvilinear. Seedlings that were shorter than 4 in. or taller than 10 in. exhibited less growth than seedlings between 4 and 10 in. tall. A similar curvilinear relationship between shoot length and height growth has been reported for Caribbean pine (*Pinus caribea* Morelet) (Bacon 1979).

For the adverse sites, total seedling height after two seasons was not significantly related to initial seedling height (Figure 3). On these sites, the shorter seedlings grew faster and were able to equal the heights of the slower growing taller trees. On the nonadverse sites, seedlings shorter than 4 in. were not able to grow faster than seedlings between 4 and 10 in. and therefore the shorter seedlings were not able to gain equality.

Analysis using a survival-volume index also shows that on adverse sites the shorter planted seedlings had produced the same relative volume as taller ones after two seasons (Figure 4). Thus, on adverse sites, no volume advantage occurred when taller seedlings were planted. On nonadverse sites however, seedlings 7 to 10 in. tall had a higher survival-volume index than did most of the other seedlings.

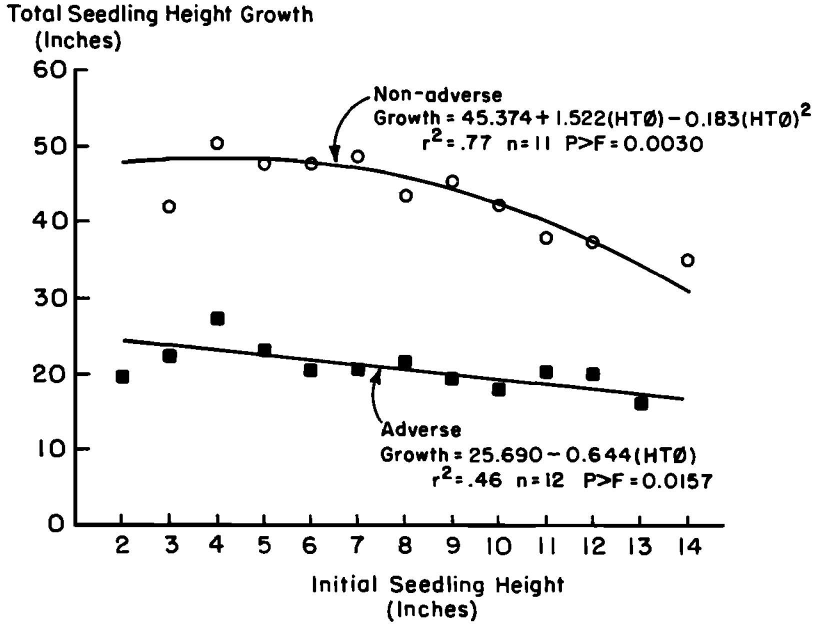

Figure 2. Total seedling growth (planting to end of second season) relationships to loblolly pine initial height (HtO) for adverse and nonadverse sites. The (HtO)² term was nonsignificant at the 0.05 level for adverse sites.

IMPLICATIONS AND RECOMMENDATIONS

Use of the term "large seedling" can have two distinct meanings. "Large" may be considered in terms of diameter or it may imply a taller seedling. For many years, foresters have known that seedlings of the same height with larger root collar diameters will perform better than seedlings with smaller diameters (South et al. 1985). However, this study indicates that when large refers to seedling height, the use of taller seedlings does not necessarily mean better growth and survival. When other morphological characteristics are similar (e.g., root collar diameter, root mass, etc.), planting a "taller" seedling on an adverse site may result in lower survival.

Because of the opposite effect

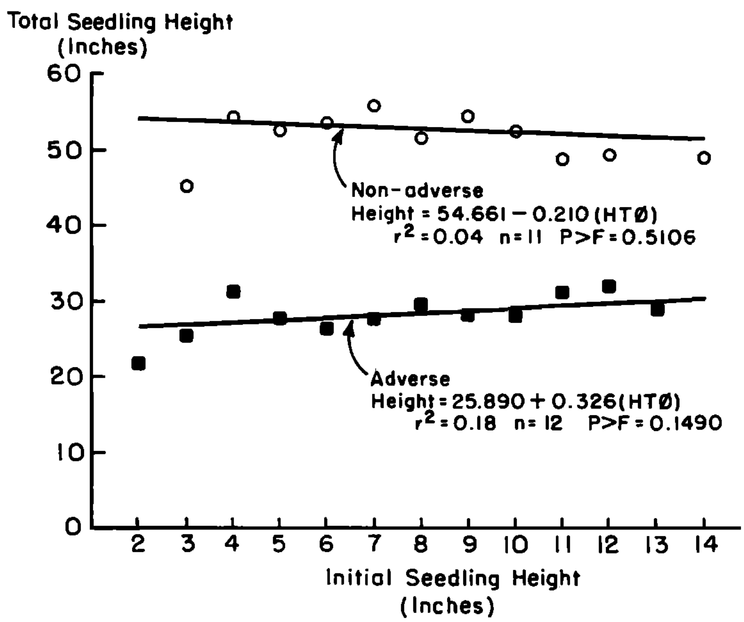

Figure 3. Relationship between total seedling height after two seasons and initial seedling height (HtO) for adverse and nonadverse sites.

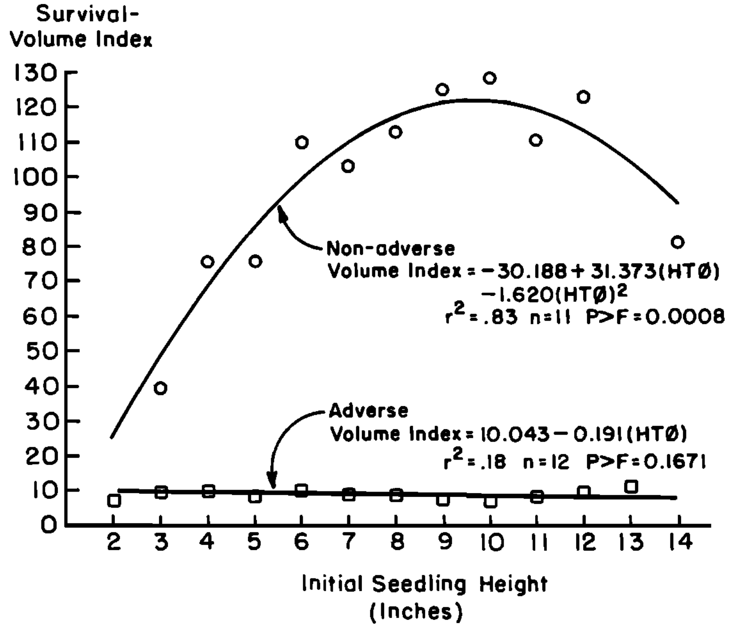

Figure 4. Relationship between survival-volume index after two seasons and initial seedling height (HtO) *for adverse and nonadverse sites.*

that large diameter and large height can have on seedling quality, the terms "large seedling" or "small seedling" are confusing and should not be used to describe seedling quality. Unfortunately, Wakeley often described seedlings as being "large," "intermediate," or "small." For example, in a study on slash pine, Wakeley (1949) stated that the data show ". . . a superiority of intermediate over large sizes. . . ." Average survival was 86% for plantable seedlings greater than 8 in. tall ("large size"), 90% for plantable seedlings 5 to 8 in. ("intermediate size"), and 84% for seedlings shorter than 5 in. ("small") tall. Perhaps Wakeley should have stated that taller seedlings did not survive better than shorter seedlings. The realization that taller seedlings can reduce survival might explain why in some cases Grade 2 seedlings have survived better than taller Grade 1 seedlings (Venator 1983). Apparently, Wakeley did not fully realize the potential negative impact that tall seedlings can have on seedling survival. However, his morphological grades do indicate that for loblolly pine, seedlings taller than 12 in. are not considered Grade 1 seedlings (Wakeley 1954).

When describing seedling morphology, the terms "large," "small," or "big" should not be used. Use of these terms can be confusing since large diameters can positively influence seedling growth while tall shoots can negatively affect seedling growth. Terms that more accurately describe the seedling's height, diameter, and root system should be used.

Planting crew supervisors should be aware of the interaction between site and seedling heights. On adverse sites, planting seedlings with too much exposed shoot can reduce survival and total growth. Seedling survival can be increased by deep planting on such sites (McGee and Hatcher 1963), and where deep planting is not practiced, planting short seedlings may help ensure better survival.

Adverse forest sites can be found throughout the southern United States. These areas can be defined as "adverse" for planting due to soil and environmental factors limiting tree growth. Reasons for considering loblolly pine sites as "adverse" include a lack of rainfall, low water holding capacity, too much vegetative competition, periodic flooding, poor aeration, pollution problems, nutrient imbalances, or having high soil bulk densities. The "adverse" sites reported here were adverse due to problems relating to high soil bulk densities and low moisture levels, due to sandy soil textures, low rainfall, and thin surface horizons. Therefore, we do not expect our results to be applicable to sites with other types of problems that the forester may recognize. □

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Measuring Wildfire Impacts: Method and Case Study[1]

W. L. Mills, Jr., *Department of Forestry and Natural Resources, Purdue University, West Lafayette, IN,* **S. D. Shnitzler,** *USDA, Foreign Agricultural Service, Washington, DC, and* **R. S. Meldahl,** *School of Forestry, Auburn University Agricultural Experiment Station, Auburn, AL.*[2]

ABSTRACT. A discounted cash flow model called the Impact Appraisal Model (IAM) computes the economic impact due to a change in timber production caused by a wildfire. Data requirements for the IAM can be obtained using standard inventory procedures to estimate the pre- and post-fire stand conditions needed to initiate a growth and yield simulator. The model is demonstrated using five loblolly plantations that burned in 1980 and 1981.

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Forest managers must decide what action, if any, to take after a stand is changed by an external unexpected agent—wildfire, insects, disease, or storm. The manager should weigh many different economic and biological considerations when deciding whether to liquidate the damaged stand and start over, to perform remedial action, or to do nothing. One component of the needed information is an estimate of the loss caused by the external agent. Until recently, foresters have seldom used appropriate procedures to appraise fire damage (Flora 1968, Bellinger 1983). Noste and Davis (1975) noted that damage appraisal systems have not been effective in accurately determining the level of fire damage or level of protection needed. Most wildfire appraisals have focused on the immediate loss or mortality caused by a fire.

However, wildfire damage appraisal requires an estimate of the change in volume and quality of the future, as well as the present, timber production, and the valuation of that production change (Crosby 1977). The value of timber lost in a wildfire is the market value of that timber at rotation age (Flint 1924, Simard 1976). Estimation of these future market values requires the adoption of a discount cash flow analysis. Mills and Flowers (1985) describe a present net value (PNV) approach that is very similar to the model presented in this paper. They use their model to derive estimates of present net value as a function of fire sizes, stand conditions, management regimes, and site qualities in the Northern Rocky Mountains of the United States. Less emphasis is placed on stand decisions such as stand retention after a fire. The model described in this paper emphasizes individual stands and the managerial decisions required after each fire. For example, determining whether to retain the stand or liquidate the stand after a fire is one of the specific uses of the model described in this paper.

The method described in this paper estimates the economic impact (loss or gain) due to a wildfire's impact on a stand's biological conditions to the extent that growth and yield models adequately represent the development of damaged stands. At the present time this is a heroic assumption since most growth and yield modeling is just beginning to incorporate controlled impacts such as thinnings and other cul-

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