The Sprouting Potential of Loblolly and Shortleaf Pines: Implications for Seedling Recovery from Top Damage

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Abstract

Loblolly (*Pinus taeda* L.) and shortleaf (*P. echinata* Mill.) pine seedlings are frequently top damaged during their first few years by browsing animals, insects, or forestry operations, but little quantitative information exists on the factors affecting recovery. Thus, we conducted two separate studies to evaluate potential recovery of seedlings from top damage under controlled conditions. The first study evaluated the effect of season of burn on recovery of 1-year-old shortleaf pine seedlings. Although 99% of the seedlings were topkilled by the fires, survival of sprouting rootstocks exceeded 95% the year following the winter burn. However, no seedlings sprouted following the summer burn. Results indicate that winter prescribed fires have considerable potential in establishing natural shortleaf pine regeneration. The second study evaluated the effects of the extent and season of simulated browse damage on the recovery 1-year-old loblolly pine seedlings. Seedlings were clipped in both winter and spring at five positions: at the midpoint between the root collar and cotyledons, and so that 25, 50, 75, and 100% of the height between the cotyledons and the terminal remained after clipping. All seedlings clipped below the cotyledons died. Survival at 3 years for seedlings clipped above the cotyledons was 97% following winter clipping and 96% following spring clipping. Seedlings clipped in winter were larger at 3 years than those clipped during spring. Results of this study suggest that planting loblolly pine seedlings deep, with the cotyledons below ground level, may be an advantage in areas where browse damage is common.

INTRODUCTION

Loblolly and shortleaf pines (*Pinus taeda* L. and *P. echinata* Mill., respectively) are the most commercially important tree species in Arkansas, and stands may be successfully regenerated by either natural or artificial methods. In regenerated stands, pine seedlings are frequently top damaged by a wide variety of animals (rabbits (*Sylvilagus* spp.), white-tailed deer (*Odocoileus virginianus* Zimm.), and domestic livestock), insects (e.g., tip moths (*Rhyacionia* spp.)), forestry operations (harvesting, site preparation, release, and prescribed fire), and wild fire. Seedlings in natural stands may be at greater risk than in plantations, because they remain in size classes vulnerable to browsing for a longer period of time, and natural reproduction cutting methods frequently involve harvesting sawlogs in the vicinity of seedlings. Recovery from top damage depends on a species' sprouting ability. Although anecdotal observations indicate that the potential for recovery of both loblolly and shortleaf pine seedlings is good, there is little quantitative information on the factors affecting the recovery process. Thus, we conducted two separate studies over the last 5 years to evaluate potential recovery of seedlings from top damage under controlled conditions. The first study evaluated the effect of season of burn on the recovery of 1-year-old shortleaf pine seedlings (Cain and Shelton 2000). The second study evaluated the effects of the extent and season of simulated browse damage on the recovery 1-year-old loblolly pine seedlings (Shelton and Cain 2002). In this paper, we summarize results from the shortleaf pine study and update the loblolly pine study with an additional year of field measurements.

METHODS

Study Site—Both studies were located at the same study site on forest lands of the School of Forest Resources, University of Arkansas at Monticello. Elevation is 320 feet with a rolling topography. The soil is a Sacul loam (clayey, mixed, thermic, Aquic Hapludult), which is a moderately well-drained upland soil with a site index of 78 feet for loblolly and shortleaf pines at 50 years (Larance et al. 1976). The growing season is about 240 days with seasonal extremes being wet winters and dry autumns. Annual precipitation averages 53 inches. The study site was a 0.2-acre cleared area at the edge of a 10-year-old, naturally regenerated loblolly-shortleaf

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pine stand. The area occasionally received shadows from adjacent trees during the winter months but was in full sunlight during summer.

The Shortleaf Pine Study—After stratification, seeds collected in 1996 were sown in containers with a 1:1 peat-vermiculite mixture on December 31, 1996. Seedlings were grown indoors under 10 hours of full-spectrum fluorescent light from January to March 1997. In early April 1997, seedlings were transplanted to field beds at a density of 21 per bed. Each of the nine 6- by 7-foot beds was assigned one of three treatments: control, where no burning was done; summer burn on August 19, 1997; and winter burn on January 31, 1998. A pine forest floor was reconstructed within each bed using litter collected from a nearby stand. All burns were simulated headfires with wind provided by three electric box-fans.

Seedling height was measured before burning. After burning, crown scorch was ocularly estimated. At the end of the 1998 growing season, groundline diameter and height were measured for the largest sprout from each seedling. Additionally, all sprouts were clipped at groundline, and their weight was determined on an oven-dry basis.

Data were analyzed using analysis of variance for a randomized complete block design. This analysis differed from the overall study presented in Cain and Shelton (2000), which involved two oak species in addition to shortleaf pine. The blocking factor was position along the site's slope. Significance was accepted at $P \leq 0.05$.

The Loblolly Pine Study—Seedlings were grown in eight 6- by 7-foot beds. After stratification, seeds collected in 1998 were lightly pressed into the soil at an 8- by 8-inch spacing in late March 1999. At the end of the first growing season, seedlings were numbered using aluminum tags, and measured for groundline diameter, total height, and height to the cotyledons. Before applying treatments, the eight beds were assigned within four blocks based on seedling height, and then the blocked beds were randomly assigned to winter and spring treatments. The clipping that simulated browse damage was applied on February 15, 2000 for the winter treatment beds and April 4, 2000 for the spring treatment beds. Five clipping treatments were randomly imposed within each bed: at one-half the distance between the root collar and cotyledons, and to retain 25, 50, 75, and 100% of the height from the cotyledons to the terminal's winter position. Living seedlings were remeasured for height and diameter in November 2001 when they were 3-years old. In addition, seedlings were evaluated for multiple stems (when one or more stems were within 10% of the seedling's tallest stem) and damage to the terminal or associated buds by tip moths.

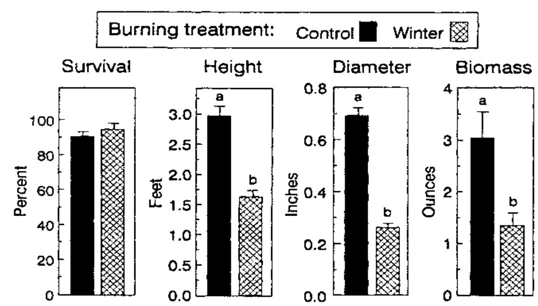
Nonlinear regression (SAS Institute 1988) was used to predict the third-year height of individual seedlings from their first-year height; the percent of height above the cotyledons remaining after clipping; and the season of clipping, which was entered as an indicator variable. Second and third order interactions of independent variables were also tested in the full model. Variables were retained in equations if their regression coefficient significantly differed from zero at $P \leq 0.05$.

RESULTS AND DISCUSSION

Shortleaf Pine—Following both the summer and winter burns, 99% of the seedlings were classified as being top killed. Survival was excellent (>95%) for seedlings in the winter burn (Figure 1) because of sprouts that developed near the end of the basal crook that occurred in the stem at groundline. This crook brought dormant buds in contact with the lower parts of the forest floor and the soil surface, which provided protection during the fire. However, all seedlings died in the summer burn even though the basal crook had formed. Sprouts developing after the winter fire were one half the height and mass of unburned seedlings at the end of the first growing season after burning (Figure 1). However, groundline diameter of the dominant sprout was only one third of that of unburned seedlings.

Shortleaf pine is unique among the southern pines because seedlings have the ability to sprout prolifically when the crown is killed or badly damaged (Lawson 1990). This sprouting characteristic is attributed to dormant buds that are associated with primary needles and the formation of a sharp J-shaped crook in the stem at groundline (Stone and Stone 1954). The dormant buds affiliated with this crook are apparently protected from fire by the forest floor and soil surface. According to Harlow et al. (1979), shortleaf pines that are up to 10 years old retain this ability to sprout after their main stems have been destroyed by fire or cutting. Fowells (1965) reported that trees up to 6 to 8 inches in diameter may sprout. However, Moore (1936) reported that sprouts developing from trees 4 or more inches in diameter were poor in form and vigor. Although the sprouting ability of shortleaf pine is widely recognized among foresters in the South, there have been no controlled experiments to assess the effects of growing season fires on survival and growth of shortleaf pine regeneration (Williams 1998).

Figure 1. Mean properties (+1 standard error) of shortleaf pines one growing season after conducting a winter controlled burn when the seedlings were 1-year-old. All seedlings died during the summer controlled burn. Bars for a property with different letters are significantly different at α=0.05. (Adapted from Cain and Shelton (2000)).



Mattoon (1908) also observed that sprouting of shortleaf pine is restricted following summer burning. The lethal effects of summer burning have been presumed to be due to the higher temperatures reaching lethal thresholds even at the crook's location. However, other factors may also be involved. For example, Campbell (1985) observed that 5- and 6-year-old shortleaf pines cut at different heights (0, 2, and 6 inches) to simulate precommercial thinning did not produce successful sprouts when cut in September but did so when cut in February (46 to 84% survival after 2 years). Tree age and extent of damage may also be factors in producing successful sprouts when damage occurs in September; survival of 4-year-old trees was 40% after 2 years for 2-inch cuts and 60% for 6-inch cuts but was 0% for cuts at 0 inches (Campbell 1985). At 4 years, cuts made at 0, 2, and 6 inches in height during February resulted in 61 to 92% survival.

Results of our study suggest that rootstocks of topkilled shortleaf seedlings may resprout following low-intensity burns that occur in the winter following seedling establishment. This creates the opportunity of using winter burns in stands with marginal stocking of shortleaf pine regeneration to produce favorable seedbed conditions and to control non-pine competing vegetation without killing the existing pine stocking. The timing of burns before the peak dispersal of shortleaf pine seeds in late October and early November (Wittwer and Shelton 1992) will maximize establishment of new seedlings. Summer burning is an option if no advanced regeneration exists. Summer burns result in much more suppression of competing vegetation than winter fires (Cain and Shelton 2000).

Loblolly Pine—We found no significant differences for first-year total height and diameter among clipping treatments before implementation. On average, 76% of the seedlings had set a terminal bud before their first winter. Diameters in spring had increased by an average of 0.04 inches. There were also some changes in foliar conditions between winter and spring for the 25% clipping treatment. The percentage of seedlings with live primary foliage decreased from 69% in winter to 41% in spring, and seedlings with no live foliage increased from 18% in winter to 34% in spring. When the spring treatment was implemented, terminal growth averaged 4.3 inches in length, and needles averaged 1.1 inches long. On the new growth, there was an average of 2.9 lateral shoots developing with the terminal.

The point of attachment of the cotyledons is critical to evaluating the potential for recovery, because this marks the beginning of the foliated portion of the stem. The hypocotyl, which extends from the root collar to the cotyledons, does not produce foliage. For all living seedlings during first year measurements, the average height of the cotyledons, or the length of the hypocotyl, was 1.1 inches with a range of 0.6 to 1.6 inches. Mann (1976) reported slightly longer hypocotyls (averaging 1.5 inches) for newly germinated loblolly pine seedlings under greenhouse conditions.

All seedlings clipped below the cotyledons died indicating that dormant buds associated with foliage or branch whorls are required for recovery. Adventitious buds, which commonly develop in damaged hardwoods (Kramer and

Kozlowski 1979), do not occur in either loblolly or shortleaf pine (Stone and Stone 1954). Wakeley's (1954) observation that seedlings may recover when clipped as low as 0.25 inch above the ground applies only to seedlings that are planted with the cotyledons below the soil surface. In contrast, survival of seedlings clipped above the cotyledons was excellent at 3 years—97% for winter clipped seedlings and 96% for summer clipped seedlings.
Recovery from clipping was observed to be a combination of activation of dormant buds associated with foliage and development of lateral buds/shoots into a dominant position. An average of 56% of the seedlings was classified as having no lateral buds/shoots on the clipped seedling; so recovery of at least this proportion of the seedlings had to be from dormant buds associated with foliage.

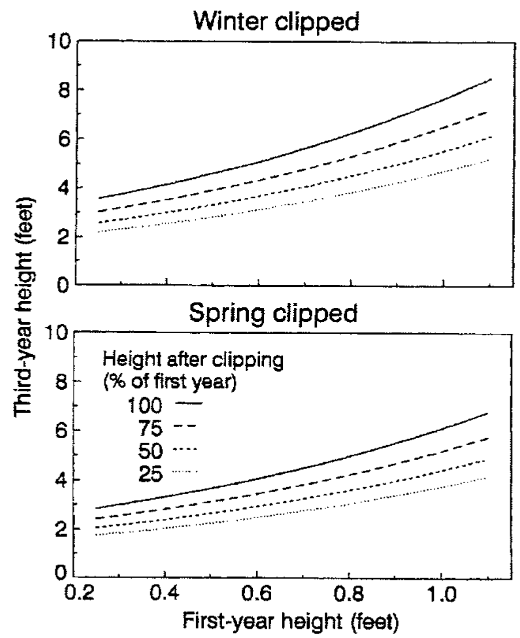
The equation predicting third-year height from first-year height, the severity of the clipping treatment, and the season of clipping follows:

$$H_3 = \exp(0.3661 + 1.023H_1 + 0.006498P - 0.2270S)$$

where: H_3 is third-year total seedling height (feet), exp is the exponential function, H_1 is first-year total seedling height (feet), P is percent of first-year height remaining above the cotyledons after clipping, S is 0 for winter and 1 for spring, and the regression coefficients were fit by nonlinear regression. The number of observations was 295, root mean square error was 0.924, and fit index was 0.55. The ranking of independent variables explaining variation in third-year height was as follows: first-year height > percent of height remaining > season. Hunt and Gilmore (1967) also found the first-year size was a good predictor of future growth of loblolly pine seedling.

We solved this equation for a reasonable range of values, and values are plotted in Figure 2. An average first-year seedling (0.5 foot of total height) grew to a height of 4.6 feet at the end of the third year. If the seedling was severely damaged (25% of height remaining), height at 3 years was reduced by 39% if damaged in winter and 52% if damaged in spring.
Of the surviving seedlings, 9% were classified as having multiple stems at 2 years, but this declined to 1% at 3 years. This trend resulted from the strong apical dominance expressed by loblolly pine. Of the surviving seedlings, 19% were classified as having damage from tip moths at 2 years, but this increased to 68% at 3 years. The probability of a seedling having insect damage at 3 years increased with seedling height. Tip moth damage has often been shown to vary with the intensity of silvicultural manipulations (Nowak and Berisford 2000).

Figure 2. Effects of first-year total height, percentage of first-year height remaining above cotyledons after clipping, and clipping season on third-year total height of loblolly pine seedlings subjected to simulated browse damage during their first year.



This study demonstrated that the recovery of loblolly pine seedlings from simulated browsing damage strongly depends on the extent of damage. If seedlings are clipped below the cotyledons, mortality is inevitable because all dormant buds in loblolly pine are associated with either primary or secondary foliage or branch whorls. If seedlings are damaged above the cotyledons, the potential for recovery is good in 1-year-old seedlings, especially if the damage occurs during the dormant season. Browse damage reduces subsequent seedling growth, which reduces a seedling's ability to compete with herbaceous and non-pine woody vegetation. Reduction in competitive ability would probably be more of a disadvantage in natural stands, where low-intensity site preparation methods are more often used than in intensively site prepared plantations. In dense natural stands, browse damaged seedlings would also be at a competitive disadvantage with undamaged pine seedlings, but this might actually improve overall stand development by reducing intraspecies competition.

Although our results suggest growth reductions of up to about 40% through the third year from first-year browse damage, Hunt (1968) found that rabbit-damaged loblolly pines in plantations were within 17% of the height of undamaged seedlings after 4 years. Wakeley (1970) reported that growth reductions from rabbit damage to 1-year-old loblolly pine seedlings were negligible after 30 years. Thus, the long-term potential for a full recovery from browse damage appears to be good for loblolly pine. In reviewing planting practices, Schultz (1997) recommended planting pine seedlings 2 to 4 inches deeper than normal to improve survival on well-drained soils. There may be an added advantage to this practice in areas with a high potential for browse damage, so that the seedlings cannot be clipped below the cotyledons and lose all their dormant buds.

The relationship between seedling age and sprouting is not well established for loblolly pine, although loblolly's sprouting potential undoubtedly diminishes through time. Campbell (1985) reported that trees 4- to 7-years old produce some successful sprouts (2 to 20% survival after 2 years) when stems were cut at 6 inches in height during February, but no sprouts survived when cut at 2 inches. Stems cut at either 2 or 6 inches during September did not produce successful sprouts.

MANAGEMENT IMPLICATIONS

If live foliage exists below a damaged top, the potential for recovery of loblolly and shortleaf pine seedlings is excellent because of dormant buds associated with the foliage. Recovery will be more rapid if the damage occurs in the winter, when carbohydrate reserves in the roots are high, than in the spring when reserves have been reduced to produce new foliage. Sprouting along the base of the stem is considerably better for shortleaf pine than for loblolly, as dormant buds remain viable for a longer time. Sprouting in shortleaf is promoted by a basal crook that brings dormant buds in contact with the soil surface. This allows shortleaf to sprout near groundline, whereas sprouting in loblolly pine is restricted to the portion of the stem above the cotyledons. Sprouting can also occur from dormant lateral buds located at branch whorls and from dwarf or short shoots located on the lower portions of some stems. Lateral branches are another potential mechanism for recovery. For shortleaf pine, controlled winter burns have considerable potential in establishing natural regeneration. Winter burns control non-pine competing vegetation and prepare a favorable seedbed for seeds dispersed after the burn without killing existing advanced regeneration. Conducting multiple controlled burns at 2- to 3-year intervals would allow shortleaf regeneration to build up before carrying out a natural reproduction cut, making stand establishment less reliant on seed crops produced after harvesting. Although our results for loblolly pine apply to seedlings grown in-place, they also have application to plantation establishment. Planting loblolly pine seedlings deep, with the cotyledons below the ground, may promote sprouting in areas with high levels of browse damage.

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