Root Stripping Reduces Root Growth Potential Of Loblolly Pine Seedlings

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*ABSTRACT. Stripping short roots from individual loblolly pine (*Pinus taeda *L.) seedlings was accomplished by pulling the root system through a closed fist either 1, 2, or 4 times. The root growth potential (RGP) of the seedlings was directly related to the intensity of stripping. One stripping removed approximately 2% of the total root weight, yet reduced the number of root apices by 22% and caused a 47% reduction in RGP. Four strippings removed approximately 11% of the root weight, reduced the root/shoot ratio by about 9% and resulted in a 69% reduction in RGP. Although stripping of roots reduced both shoot and root growth, the relative effect on new shoot growth was not as great as with new root growth. Root stripping effectively eliminated any correlation between seedling diameter and RGP.*

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Several studies have demonstrated that injury to roots during or after lifting can reduce outplanting survival of southern pine seedlings. Unfortunately, injury to roots is inherent for bareroot seedlings because it is impossible to harvest and separate them without removing some of the roots. Rowan (1987) found that operational lifting practices can remove 35% to 77% of the small roots. As a result, in some cases root stripping during lifting can increase seedling mortality by 5 to 50 percentage points (Bernard et al. 1981, Langdon 1954, Rowan 1987, Wakeley 1965, Xydias 1981).

There are several possible explanations as to why loss of roots prior to planting would increase seedling mortality. It is possible that in cases where a large proportion of roots are removed by pruning (Wakeley 1954, Rowan 1983, Dierauf and Garner 1978, Wilder-Ayers and Toliver 1987), the increased mortality could simply be related to differences in seedling morphology. Better survival would be expected from unpruned seedlings since they exhibit a better balance between roots and shoots, uptake of water is greater for seedlings with greater root volume (Carlson 1986), and seedlings with larger root systems often exhibit greater root growth potential (Barden 1987, Carlson 1986, Larsen and Boyer 1986, Larsen et al. 1989, Williams and South 1988, Williams et al. 1988).

However, in cases where root injury does not greatly reduce the amount of root biomass, it has been postulated that the decrease in survival may be related to the removal of ectomycorrhizae and, as a result, a reduced production of lateral roots (Marx and Hatchell 1986). An alternative hypothesis is that the reduction in survival may result from a decrease in root growth potential. Although some have speculated that injury to roots would result in an initial proliferation of new roots, it seems more likely that injury would cause an initial decrease in new root growth. Therefore, a study was conducted to determine the effect of root stripping on the root growth potential of bare-root loblolly pine seedlings.

MATERIALS AND METHODS

Improved loblolly pine seedlings were grown at the Stauffer Nursery in Opelika, AL. On March 29, 1989, seedlings from a portion of one bed were undercut with a Fobro lifter and carefully hand-lifted. Seedlings were placed in plastic bags and transported to a cold storage unit at Auburn University.

Seedlings were sorted to obtain seedlings of similar root-collar diameter. After sorting, roots were carefully washed, and the selected seedlings (ranging in diameter from 4 to 5 mm) were randomly divided into four lots. Treatments consisted of four levels of root stripping. Stripping of mycorrhizal and nonmycorrhizal roots was accomplished by running the wet, individual root system through a closed fist (thumb against fingers with fairly strong pressure). Seedlings of each lot were stripped by hand either once, twice, four times, or not at all. Root biomass removed during the stripping process was dried and weighed.

Seedlings in each treatment were divided into two subgroups. Twenty seedlings were selected at random and were used to determine the effect of root stripping on the amount of short roots removed. On each seedling, two or three segments of first-order lateral roots were removed, and the number of short root apices for a 25-cm length was recorded. An additional 20 seedlings were used in a root growth potential test. The number of short roots that were mycorrhizal was not determined on seedlings before the RGP test since this would require exposing the roots for a long period of time.

On March 29, 80 seedlings for the RGP test were measured for root collar diameter and height,

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and the taproot and long lateral roots were trimmed to a maximum length of 20 cm. For each seedling, all new, white root tips were pinched off (Ritchie and Dunlap 1980). Seedlings were potted in coarse sand in 2-liter containers with drainage holes and were placed on a rooting bed in a greenhouse (under natural photoperiod) for 27 days. Seedlings were watered every day or every other day to keep the sand moist. After removal from the containers, the following measurements were obtained for each seedling: root collar diameter, new and total shoot length, number of all white root tips (≥0.5 cm), and dry weights of the root, old shoot, and new shoot growth (i.e., new flush).

The study was set up as a completely randomized design. The General Linear Models (GLM) procedure of the Statistical Analysis System (SAS Institute Inc. 1982) was used to test for linear and quadratic relationships. In addition, correlation analyses were used to examine the potential relationships between seedling diameter and RGP. Root growth potential in this test was defined as the number of white root tips greater than 0.5 cm.

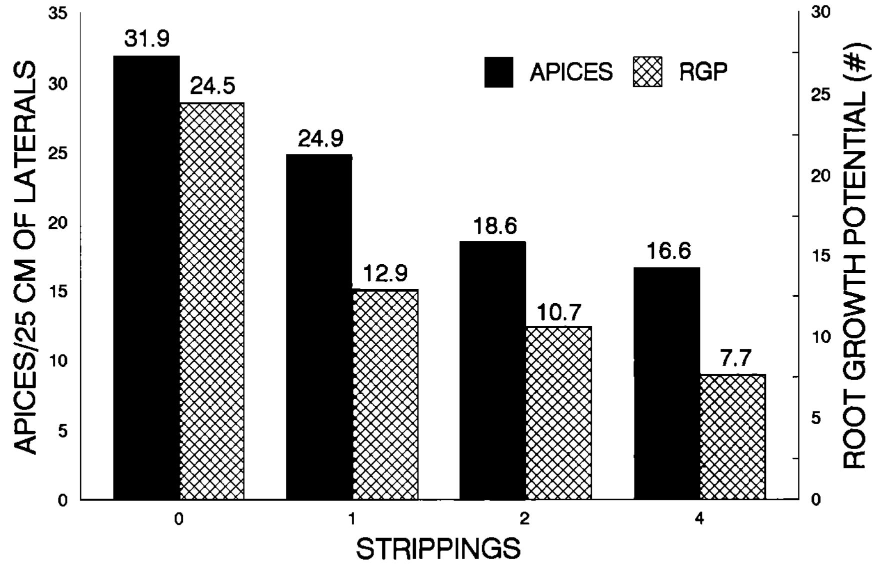

Figure 1. The effect of root stripping on the number of root apices and the number of new roots (RGP) of loblolly pine seedlings. The General Linear Models Procedure of the Statistical Analysis System (SAS Institute Inc. 1982) indicates a linear relationship between root stripping and the number of root apices (P > F = 0.0001) and a linear relationship (P > F = 0.005) between root stripping and RGP.

RESULTS AND DISCUSSION

The stripping treatment removed numerous "short roots" as well as a few higher order "long laterals" (*sensu* Sutton 1980). The effect of stripping on the number of root apices (Figure 1) was basically linear ($P > F = 0.0001$), although there was a slightly curvilinear trend ($P > F = 0.067$ for the quadratic variable). A single stripping removed at least a fifth of the root apices while four strippings removed about half. A number of roots remaining on the seedlings were also injured during the stripping process.

Although the number of roots removed was significant, the amount of root weight removed was minimal (Table 1). One strip reduced the number of apices by at least 22% while only affecting root weight by approximately 2.3% and the root/shoot ratio by approximately 2.4%. Of course, stripping had no effect on initial foliage biomass, seedling diameter, or seedling height. Therefore, it can be safely stated that the greatest effect of root stripping on seedling morphology was on the number of root apices. Some of these root apices had root caps and therefore would have had the ability to elongate.

Although the stripping treatments did not remove foliage and only slightly affected the root/shoot ratio, the RGP of the seedlings was reduced by half with only one stripping (Figure 1). Additional stripping removed more root apices and resulted in a linear reduction in RGP. Injuring the root system by root stripping did not result in an immediate proliferation of new roots. Other researchers have also reported a decrease in RGP when injury occurred just prior to testing (Burdett 1976, Deans et al. 1990, Tabbush 1986). New shoot growth was also reduced by four strip-

Table 1. Morphological measurements of loblolly seedlings subjected to four levels of root stripping.

Stripping	Initial diameter	Diameter growth	Initial height	Height growth	Roots stripped	Final root weight	Final shoot weight	New shoot growth	Final root/shoot ratio
	.... (mm)		.... (cm)		.... (g)				
0	4.65 a	0.05 a	36.6 a	0.46 a	0.000	1.39 a	4.38 a	0.29 a	0.32 a
1	4.83 a	0.03 a	37.6 a	0.37 ab	0.031	1.32 ab	4.49 a	0.22 ab	0.30 ab
2	4.84 a	−0.06 a	35.6 a	0.30 b	0.078	1.38 a	4.55 a	0.20 b	0.30 ab
4	4.65 a	0.00 a	37.2 a	0.34 b	0.148	1.19 b	4.10 a	0.19 b	0.29 b

Values within a column followed by the same letter are not significantly different at the 0.05 level of probability as determined by Duncan's New Multiple Range test.

Table 2. Effect of stripping level on simple linear correlations among root growth potential, seedling root weight, and seedling diameter (N = 20).

Stripping level	RGP vs. diameter	Root weight vs. diameter
	.... (correlation coefficient ($P > r$))	....
0	0.44 (0.05)	0.87 (0.01)
1	0.04 (0.86)	0.48 (0.03)
2	0.36 (0.11)	0.65 (0.01)
4	−0.07 (0.76)	0.72 (0.01)

pings, but the percentage reduction in weight (34%) was not as great as the reduction in RGP (69%).

For conifers, the number of roots that are actively growing within a month of transplanting depends on the number of sites available for new root growth. Deans et al. (1990) reported that RGP of *Picea sitchensis* was related to the number of fine root apices. They concluded that most of the new root growth produced occurs by the renewed elongation of pre-existing root apices. Work by others support this conclusion (Stone and Schubert 1959, DeWald and Feret 1987). DeWald and Feret reported that during the first 2 weeks, most of the new roots of loblolly pine originate from the ends of long laterals. In contrast, roots that elongate within the first month after transplanting do not originate from short roots that are ectomycorrhizal (Stone and Schubert 1959, Stone et al. 1962).

In this study, RGP of control seedlings was also positively correlated with final seedling diameter even though the initial variation in diameter was deliberately minimized by sorting prior to the study. In several previous studies, RGP has also been positively correlated with root collar diameter of loblolly pine seedlings (South et al. 1989). However, this study demonstrates that the positive correlation between seedling diameter and RGP can be eliminated by stripping (Table 2).

Results reported here are similar to those reported by Marx and Hatchell (1986). In both studies, root stripping removed similar amounts of short roots (Table 3) and subsequent root growth was reduced. Marx and Hatchell reported that two months after planting, naturally inoculated loblolly pine seedlings with stripped roots had only half the number of new second- and third-order lateral roots as seedlings without stripping. Although stripping by Marx and Hatchell purportedly removed only short roots that were ectomycorrhizal, stripping of roots in our study was not as selective. Our stripping removed both ectomycorrhizal and nonmycorrhizal short roots as well as a few second- and third-order long laterals.

Marx and Hatchell (1986) indicated that new growth of lateral roots in their study was directly related to the degree of removal of the ectomycorrhizal short roots. However, if this is the only cause for a reduction in new root growth, then stripping root apices from nonmycorrhizal seedlings should not reduce RGP. Future research with nonmycorrhizal seedlings could determine if there is any nonmycorrhizal effect of stripping on new root growth. If a nonmycorrhizal effect exists, it might be due to a reduction in the number of pre-existing root apieces that have root caps (which can elongate). RGP might also be reduced if photosynthesis decreases (due to a reduction in water uptake) or if photosynthates are reallocated for wound repair instead of for new root growth. However, the pragmatic forestland manager does not need to know why root stripping reduces root growth and survival. Regardless of the reasons, root stripping is detrimental and should not be done by tree planters since it results in an initial reduction in root growth. □

Table 3. A comparison of the effects of stripping level on the percentage of short roots removed from naturally inoculated loblolly pine seedlings. (Auburn = this study; USFS = study by Marx and Hatchell 1986.)

Stripping level	Auburn	USFS
	.... (% of short roots removed)	....
1	22	20
2	42	35
4	52	44

Data from the study by Marx and Hatchell (1986) calculated assuming the number of nonmycorrhizal short roots on the lateral roots was approximately the same regardless of the amount of stripping.

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Directed Foliar Sprays of Forestry Herbicides for Loblolly Pine Release[1]

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ABSTRACT. Six herbicides were compared as directed foliar sprays applied in May, July, and September on seven hardwood species and on loblolly pine. Equal-cost mixtures that met or exceeded minimum labeled rates were tested for Weedone 2,4-DP, Garlon 4, Garlon 3A, Arsenal Applicator Concentrate, Roundup, Escort, and Roundup + Escort. Test hardwoods were sweetgum, southern red oak, water oak, red maple, pignut hickory, dogwood, and yellow poplar. Crown volume reduction and rootstock reduction after one growing season were the main indicators of efficacy. Using directed sprays, yellow poplar was the easiest species to control, and pignut hickory was the most difficult. Control of sweetgum was most effective with Weedone, Arsenal, and Roundup. For control of oaks, the most effective applications were in July with Arsenal, Garlon 4 and 3A, and Roundup; but these and other hardwood species tended to refoliate 2 years after Arsenal treatment. Herbicide safety to loblolly pine was best with Arsenal and Escort, while injury was greatest with Roundup and Garlon 3A, which might have potential use in precommercial thinnings.

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Directed foliar sprays are low cost alternatives to aerial applications of herbicides for releasing pines from competing hardwoods and shrubs (Thomas et al. 1989, Lowery 1981). Directed sprays also could be used in site-preparation treatments, precommercial thinnings, hardwood regeneration management, and cover maintenance of wildlife openings, scenic vistas, and recreational areas. Applications of directed sprays with backpack sprayers are usually made before target stems exceed 6–8 ft in height. A commonly used herbicide for directed sprays has been Weedone 2,4-DP, with the application period restricted to April through June (Williamson and Miller 1988, Gonzalez and Evans 1986). Because of the economical treatment costs associated

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