THE EFFECT OF ROOT PRUNING TREATMENTS ON RED OAK SEEDLING ROOT GROWTH CAPACITY[1]

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Abstract. -- The study evaluated the influence of pre-sowing radicle clipping and lateral root pruning in the nursery on shoot morphology, root morphology, and root growth capacity (RGC) of 1-0 northern red oak seedlings. The radicle clipping treatment produced multiple taproots. No root treatments adversely affected seedling shoot size when compared to the control treatment. There was a highly significant interaction ($p < .001$) between the radicle clipping and lateral pruning treatments, resulting in a doubling of RGC (number of new roots) in comparison to control seedlings. However, either treatment alone resulted in no significant increases in RGC. The results suggest that the treatments may be useful in improving northern red oak seedling field performance.

INTRODUCTION

The difficulty of regenerating oak stands after cutting is not a new problem facing foresters (Carpenter and Guard 1954). Studies have documented the need for adequate advance oak regeneration to be present before harvest in order to ensure that oak is a major component of the next stand (Clark and Watt 1971, Johnson 1979, Ward 1966). Artificial regeneration via planting of nursery stock has been proposed as a solution to the lack of adequate advance regeneration. However, with a few notable exceptions (Foster and Farmer 1970, Wendel 1980), survival and particularly growth of planted oaks has been poor (Farmer 1981, Loftis 1979, McGee and Loftis 1986).

The slow growth and poor survival of planted oaks may in part be due to the root system attributes of the seedling. The taproot of a one year old northern red oak (*Quercus rubra* L.) seedling may penetrate forest soils to a depth of 45 cm (Lyford 1980), whereas nursery lifting usually severs all roots at a depth of about 20 cm. The drastic loss of root area from lifting may have a long-term negative influence on shoot growth.

Carpenter and Guard (1954) proposed pre-germinating acorns and interrupting the radicle at the time of sowing to induce a more branched root system. More recently, Bonner (1982) reported that spring sowing of pre-germinated cherrybark oak (*Q. falcata* var. *pagodaefolia* Ell.) and Shumard oak (*Q. shumardii* Buckl.) acorns with damaged radicles resulted in a multiple, branched taproot. These seedlings were slightly, but not significantly smaller than seedlings grown from undisturbed spring-sown acorns.

We hypothesized that a multiple taproot system might result in more root area in the upper soil levels, which would be retained by the seedling during lifting. Farmer (1975) observed that most new roots in transplanted oaks arise from near the cut surface of the taproot; thus a seedling with multiple taproots would have more potential sites for root regeneration.

Root growth capacity (RGC) is the ability of a seedling to rapidly grow new roots when placed in a controlled environment (Stone 1955). RGC is measured by pruning the root system to a specified length, removing all new white roots from a seedling, and planting the seedling in a controlled environment for a set period, usually

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3-5 weeks. At the conclusion of this period the root systems are excavated and the new root growth quantified.

RGC studies for a variety of tree species have been reviewed by Ritchie (1985), and Ritchie and Dunlap (1980). Root growth capacity has been correlated with early survival and growth in the field with several species, including northern red oak (Webb and von Althen 1980) and loblolly pine (Pinus taeda L.) (Barden et al. 1987, Feret and Kreh 1985). The objective of this study was to determine if radicle clipping and lateral root pruning can influence the shoot morphology, root morphology, and RGC of 1-0 northern red oak seedlings.

METHODS AND MATERIALS

Acorns were collected from several planted northern red oak trees on the Penn State University campus in State College, Pennsylvania, during September and October of 1986. The acorns were held uncovered indoors for 2 weeks at room temperature, and overwintered in cold storage at 1°C in covered containers. They were removed from storage in May 1987, soaked in tap water for 24 hours at room temperature and allowed to sprout before planting. The emerging radicle on half of the acorns was clipped off by cutting with a razor blade. In June 1987 the acorns were planted into 3 replications within a nursery bed at Penn Nursery, operated by the Pennsylvania State Bureau of Forestry.

The seedlings were raised using operational nursery practices for irrigation, fertilization, weeding and insect control. In September 1987, half of the seedlings in both radicle treatments were lateral root pruned. This was done by vertically cutting between the rows of seedlings with a sharpened spade to a depth of 25 cm. The treatment combinations resulted in 4 classes of seedlings: (1) control seedlings which were not subjected to any treatment; (2) seedlings subjected to radicle clipping or (3) lateral root pruning; and (4) seedlings subjected to both treatments. All seedlings were machine lifted from the nursery in April 1988 and held in cold storage at 2°C for one month.

Upon removal from cold storage 60 seedlings from each treatment were root pruned to a length of 20 cm and planted into pots (10 seedlings per pot) containing Promix^{R} media[3]. They were held in a temperature controlled greenhouse for 5 weeks. At the conclusion of this period, several shoot and root characteristics were measured. RGC was measured as the total length or total number of new roots grown during the 5 week test period.

Shoot measurements included ground-line diameter, original shoot height, and length of the terminal flush. Leaf area was measured with a Li-Cor, Inc. 3100 Area Meter (Lincoln, Nebraska). The original root system was characterized by the number of taproots, and the number of large (proximal diameter ≥ 1 mm) lateral roots. All measurements were obtained from 60 seedlings per treatment.

Analysis of variance was used to ascertain significant treatment effects. Duncans New Multiple Range Test was used to evaluate treatment means. Correlation coefficients were calculated between RGC and the various morphological variables.

RESULTS

Seedlings produced by spring sowing of pregerminated northern red oak acorns had mean height (23.7 cm) and diameter (5.7 mm) values which were comparable to the mean height (25.6 cm) and diameter (5.0 mm) values from a sample of fall-sown nursery-run seedlings. Both seedling populations were 1-0 stock. The radicle clipping and lateral root pruning treatments had little effect on the mean height and diameter of the seedlings at the April lifting date. The only significant effect that root treatments had on shoot size was a slight increase in stem diameter for the lateral pruned seedlings with clipped radicles (Table 1). However, root morphology was strongly affected by the treatments. The average number of taproots per seedlings was increased 4-fold by the radicle clipping while the number of coarse lateral roots was decreased significantly by this treatment (Table 1).

All measures of growth in the greenhouse were increased significantly by one or both treatments (Table 2). The 5-week height growth increment (terminal elongation) was increased over 50% by the radicle clipping treatment, whereas lateral root pruning had no significant effect. Mean leaf area was significantly greater for the combined treatment than for either single treatment or the control. Either treatment alone resulted in nonsignificant increases in leaf area.

Root growth capacity, as measured by the number or length of new roots was not increased significantly over control seedlings by either the radicle clipping or lateral pruning used singly. However, the number of new roots was doubled over control levels for seedlings which were subjected to both the radicle clipping and lateral root pruning treatments (Table 2). The length of new roots was also significantly increased by the combination clipping and pruning treatment. The strong interaction

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[3] Promix^{R} is a plant growth medium consisting of shredded peat moss, vermiculite, perlite and nutrient amendments.

Table 1. -- Morphological responses of northern red oak seedlings to root pruning treatments.

Morphological Measure	--- Radicle not clipped ---		--- Radicle clipped ---	
	Unpruned laterals (control)	Pruned laterals	Unpruned laterals	Pruned laterals
Stem diameter (mm)	5.47 b[1]	5.53 b	5.86 ab	6.12 a
Stem height (cm)	23.6 a	23.8 a	23.0 a	24.2 a
Number of taproots	1.0 b	1.1 b	4.5 a	4.2 a
Number of coarse laterals	3.1 ab	3.5 a	2.2 b	2.5 b

[1] Means within a row followed by the same letter do not differ significantly at the .05 level based on Duncans New Multiple Range Test.

effect of the two treatments on RGC was highly significant ($p < .001$) based on analysis of variance.

The correlation coefficients between RGC and morphology are presented in Table 3 by radicle treatment. Among the measured responses, leaf area was most strongly correlated with RGC in both radicle clipped and unclipped seedlings. The magnitude of the r-values for the other morphological variables were very inconsistent between treatments. For unclipped seedlings the only other variable significantly correlated with RGC was the number of coarse lateral roots.

For seedlings subjected to the radicle treatment, every morphological measure except height was significantly correlated with either the number or length of new roots. Also, stem diameter was strongly correlated with new root length, whereas the number of taproots was the most strongly correlated variable with new root number.

Table 2.--Five-week greenhouse growth responses of northern red oak seedlings, by treatment.

Growth Measure	--- Radicle not clipped ---		--- Radicle clipped ---	
	Unpruned laterals (control)	Pruned laterals	Unpruned laterals	Pruned laterals
Number of new roots	18.9 b[1]	23.1 b	24.8 b	39.8 a
Length of new roots (cm)	70.4 b	65.1 b	86.0 b	130.4 a
Terminal elongation (cm)	9.2 b	9.8 b	14.3 a	13.9 a
Leaf area (cm^2)	307.2 b	317.1 b	374.0 b	447.7 a

[1] Means within a row followed by the same letter do not differ significantly at the .05 level based on Duncans New Multiple Range Test.

Table 3. Correlation coefficients (r) relating number or length of new roots (root growth capacity) to selected morphological and growth measures by radicle treatment (n = 120).

	--- Radicle not clipped ---		--- Radicle clipped ---	
Measure	Number of new roots	Length of new roots	Number of new roots	Length of new roots
	r			
Stem diameter	NS[1]	NS	.24 **[2]	.38 ***
Stem height	NS	NS	NS	NS
Number of taproots	NS	NS	.27 **	.26 **
Number of coarse laterals	.32 ***	.32 ***	.21 *	NS
Terminal elongation	NS	NS	NS	.20 *
Leaf area	.52 ***	.50 ***	.58 ***	.60 ***

[1] NS denotes no significant correlation at the .05 level.

[2] Asterisks denote a significant correlation at the .05 level (*), at the .01 level (**), and at the .001 level (***).

DISCUSSION

The root pruning treatments resulted in a strong interactive effect of radicle clipping and lateral root pruning on increasing RGC. However, neither root treatment alone had a significant effect on RGC. The increase in height growth and leaf area observed in the greenhouse further suggests the possibility of improved seedling field performance by employing the two root treatments. This study indicates that large vigorous 1-0 northern red oak nursery stock can be established by spring sowing of sprouted acorns. Root pruning treatments had little effect on the height and diameter of seedlings in the nursery, but the treatments did alter root morphology. Treatment induced changes in coarse lateral root and taproot number may have been the reason for the differential growth response after planting.

To accomplish the radicle clipping treatment on a large scale, the acorns need to be sprouted before sowing, allowing the radicles to emerge approximately 1-4 cm. Sufficient radicle breakage might be obtained by vigorously shaking acorns in a container to sever the brittle radicle tips. The acorns should then be immediately sown. Lateral roots could also be pruned by using a tractor-drawn cutting disk to slice between seedling rows in the nursery bed.

In conclusion, these root pruning treatments hold promise for improving RGC, and possibly outplanting performance of bare root northern red oak nursery stock. Currently, we have studies in progress to document the outplanting performance of seedlings so treated. Also, further nursery trials are being conducted to investigate the effect of several other root pruning combinations on various seedling attributes.

LITERATURE CITED

Barden, C. J., P. P. Feret, and R. E. Kreh. 1987. Root growth potential and outplanting performance of loblolly pine seedlings raised at two nurseries. In: Proc. Fourth Biennial South. Silv. Res. Conf. Atlanta, GA. pp 237-244.

Bonner, F. T. 1982. The effect of damaged radicles of presprouted red oak acorns on seedling production. Tree Planter's Notes. 33:13-15.

Carpenter, I. W. and A. T. Guard. 1954. Anatomy and morphology of the seedling roots of four species of the genus Quercus. J. For. 52:269-274.

Clark, F. B. and R. F. Watt. 1971. Silvicultural methods for regenerating oaks. In: Proc. Oak Symp. Morgantown, WV. pp. 37-43.

Farmer, R. E. 1975. Dormancy and root regeneration of northern red oak. Can. J. For. Res. 5:176-185.

Farmer, R. E. 1981. Early growth of black cherry, oaks, and yellow-poplar in southern Appalachian plantings. Tree Planter's Notes 32:12-14.

Feret, P. P. and R. E. Kreh. 1985. Seedling root growth potential as an indicator of loblolly pine field performance. For. Sci. 31:1005-1011.

Foster, A. A. and R. E. Farmer. 1970. Juvenile growth of planted northern red oak: Effects of fertilization and size of planting stock. Tree Planter's Notes 21:4-7.

Johnson, P. S. 1979. Regenerating oaks in upland hardwood forests. In: Proc. John S. Wright For. Conf., Purdue Univ., West Lafayette, IN. pp. 113-119.

Lyford, W. H. 1980. Development of the root system of northern red oak (Quercus rubra L.). Harvard Forest Pap. 21, Harvard Univ., Petersham, MA. 30 pp.

Loftis, D. L. 1979. Northern red oak performs poorly in a North Carolina planting. U.S.D.A. For. Serv. Res. Note SE-277. 3 pp.

McGee, C. E. and D. L. Loftis. 1986. Planted oaks perform poorly in North Carolina and Tennessee. North. J. Appl. For. 3:114-116.

Ritchie, G. A. 1985. Root growth potential: Principles, procedures and predictive ability. In: Duryea, M. L. (ed.). Evaluating seedling quality: Principles, procedures and predictive abilities of major tests. Oregon State Univ. pp 93-105.

Ritchie, G. A. and J. R. Dunlap. 1980. Root growth potential: Its development and expression in forest tree seedlings. N. Z. J. For. Sci. 10:218-248.

Stone, E. C. 1955. Poor survival and the physiological condition of planting stock. For. Sci. 1:89-94.

Ward, W. W. 1966. Oak-hardwood reproduction in central Pennsylvania. J. For. 4:744-749.

Webb, D. P. and F. W. von Althen. 1980. Effects of various storage regimes and packaging methods on root regeneration and hardwood seedling quality. U.S.D.A. For. Serv. Gen. Tech. Rep. NC-62 (abstract only), p 16.

Wendel, G. W. 1980. Growth and survival of planted northern red oak in West Virginia. South. J. Appl. For. 4:49-543.