Red Oak Seedling Development After Outplanting

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Abstract

Bareroot 1-0 northern red oak seedlings were root-graded and outplanted on 9 different sites in central Iowa. Survival after 2.5 years in the field is considerably greater for seedlings with 5 or more lateral roots >1mm in diameter at the time of lifting than for those seedlings with 4 or fewer permanent lateral roots. Biomass accumulation is also greater for roots and shoots of seedlings with more than 5 permanent lateral roots. Nursery grading procedures should include evaluation of seedling root systems to ensure selection of competitive seedlings.

Introduction

For the past 2 years, five northeastern area state forest nurseries (in Iowa, Illinois, Indiana, Missouri, and Ohio) have been involved in a cooperative research project aimed at improving seedling quality by manipulating the root systems of red oak, white oak, and black walnut bareroot stock (Schultz and Thompson, 1987). One goal of this cooperative research is to determine the effectiveness of using root system morphology as a grading criterion to ensure selection of high quality seedlings for outplanting. As part of the five-state cooperative project, a study is under way to evaluate the relative performance of 1-0 bareroot northern red oak seedlings with graded root systems of differing quality on a number of sites. The main objective of this research is to determine if seedling root morphology at the time of transplanting has a significant effect on seedling survival and growth in a new soil environment over the course of several years. A second objective is to determine whether seedlings with high quality root systems have an inherent competitive advantage in establishment regardless of the characteristics of the planting site.

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Methods

The seedlings used for this study were selected from nursery-run northern red oak 1-0 bareroot stock at the Iowa Department of Natural Resources State Forest Nursery in Ames. These seedlings were not undercut or top-pruned before lifting. Seedlings were divided into three groups according to number of first order lateral roots greater than 1 mm in diameter (these roots usually persist through the lifting, grading, storing, shipping, and field-planting processes and are thus permanent): seedlings with 0-4 large laterals, those with 5-9 permanent first order laterals, and those with 10 or more large first order lateral roots. Trees were tagged and planted on 30 April and 1 May 1987 as single tree plots on 9 different sites in central Iowa. At each site, 30 seedlings of each of the three root grade groups were auger planted at a 4' by 5' spacing, for a total of 810 trees.

Annual counts of survival and measurements of height and diameter growth began in the fall of 1987. Also beginning in the fall of 1987, a number of trees have been periodically excavated (Oct.-Nov. 1987, June-July 1988, and May-June 1989), taking care to preserve as much of the root system as possible. Excavated seedlings were measured to determine height, diameter, and numbers of roots, and were oven-dried to determine root and shoot dry weights.

Results

Field survival. Results of annual survival counts for all planting sites are summarized in Figure 1A. Data for 1987 and 1988 were collected at the end of the growing season, 1989 data were collected in mid-July. Separate data for the three root grade groups show that trees from all three groups had better than 90% survival in the first year after outplanting. After the second year in the field, survival for seedlings with less than 4 large first order laterals dropped to 79%, while 92% of those with more than 5 large laterals survived. By July of the third field season, survival of seedlings with fewer than 4 permanent lateral roots was down to 62%, and for those with more than 5 large laterals survival decreased to 75%. Drought conditions across much of the midwest in 1988 and early 1989 probably contributed to the increase in mortality in 1989. Thus far, the most significant differences in survival are for

the root grade group with 0-4 large laterals versus those with more than 5 permanent first order roots.

Figure 1B shows survival data as of July 1989 separated by planting site for 4 of the 9 sites studied. Again, results are stratified according to root grade group. Site H1 is a coarse-textured, alluvially derived soil on a floodplain and has the lowest overall average survival at 30%: 11% survival for seedlings with 0-4 large lateral roots, 52% for those with 5-9 permanent first order laterals, and 40% for seedlings with 10 or more large laterals. Sites F3 and R2 are silt loam textured soils, site F3 in a closed depression and R2 at the base of a slope. Both of these sites have average survival rates of at least 90% well into the third growing season. Site R4 has a silt loam topsoil over a heavy clay subsoil in a well-drained upland position. Average survival is 48%: seedlings with 0-4 large laterals have a survival rate of 36%, while those with root grades greater than 5 have better than a 50% survival rate.

To summarize, for the first 2.5 field seasons, greater survival rates are associated with greater numbers of permanent first order lateral roots, and differences in survival become more pronounced over time. In addition, there are differences in overall survival rates related to site, and there is much greater survival of seedlings with more than 5 large first order laterals on particular sites. To date, it seems that seedlings with 5 or more large lateral roots at the time of lifting will be much more likely to survive after outplanting.

Seedling development. This summary of seedling development is based on characteristics of seedlings that have been excavated during the course of the study. Results of analyses of seedling dry weights are presented in Figure 2. Each value represents an average for 16 trees of each root grade group (2 from each of 8 of the planting sites) for the year indicated. Average dry weights of seedling root systems (Figure 2A) range from a low of 7.1g (for seedlings with <4 large laterals at the end of the first growing season) to 23.4g (for seedlings with >10 large laterals midway through the third growing season). In any given year, the most significant difference in dry weight is between seedlings with 4 or fewer large roots and those with more than 5 permanent lateral roots. By the third growing season, dry weights for the roots of seedlings with 5-9 large laterals are not significantly different from seedlings with more than 10 permanent lateral roots.

Dry weights for the shoots of the same seedlings (Figure 2B) show trends similar to those for roots, in that the greatest differences occur between the <4

and >5 root grade groups. So far, however, the greatest annual shoot growth occurred during the second growing season (1988), whereas the greatest increment of root growth (particularly for seedlings with 5-9 large laterals) occurred late in the second and early in the third growing season.

Generally, trends in the dry weight data so far corroborate the evidence based simply on survival rates for the three root grade groups: seedlings with more than 5 large first order lateral roots have been more successful in terms of biomass accumulation since outplanting than those with 4 or fewer permanent first order roots.

Total numbers of first and second order lateral roots for seedlings excavated in fall 1987 and spring 1989 are shown in Figure 3. Values represent the average for 16 trees of each root grade group for the year indicated. Figure 3A shows the total number of first order laterals (this includes both small, ephemeral first order roots and the larger permanent roots) separated by root grade group. The number of first order lateral roots is reasonably constant from year to year: about 20 for seedlings with 0-4 permanent lateral roots, 26 for seedlings with root grades 5-9, and 30 for seedlings with 10 or more large first order laterals. Earlier work with newly germinated red oak seedlings also indicated that the total number of first order lateral roots is established very early in seedling development and does not change over time (Thompson and Schultz, unpublished). Although some of the very small first order roots may die and be sloughed off, they are replaced such that the total number remains nearly constant.

Numbers of second order lateral roots are shown in Figure 3B. The average number of second order roots ranges from 108 (for the 0-4 root grade group at the end of the first growing season in the field) to 313 (for the >10 root grade group after the third season in the field). The increase in numbers of second order lateral roots between the two sample dates shown is 40 for the 0-4 root grade group, 80 for seedlings with 5-9 large laterals, and 110 for seedlings with >10 large first order roots. Again, many of these roots may be ephemeral (e.g. Perry, 1982), but seedlings with greater numbers of permanent first order lateral roots at the time of outplanting have many more sites for initiation of second order laterals that are important in exploiting the soil environment.

Summary and Conclusions

Field survival data for 2.5 years after outplanting indicate that red oak seedlings with 5 or more large lateral roots at the time of lifting have a much greater probability of survival than seedlings with 4 or fewer permanent lateral roots, and that the competitive advantage of seedlings with larger root systems is more pronounced as time passes and on particular planting sites. Growth of seedlings as evidenced by dry weight accumulation is also greater for seedlings with 5 or more large lateral roots. These data indicate that the root system a seedling forms in the nursery bed can determine the success of that seedling in the field. Kormanik and others (Kormanik, 1986a b; Kormanik and Muse, 1986; and Ruehle and Kormanik, 1986) have already suggested that this is especially true with respect to the number of relatively large permanent first order roots that a seedling develops. Preliminary results of this study continue to emphasize that a competitive seedling must have a large trellis root system with at least 5 lateral roots >1 mm in diameter. Thus, using root morphology as an additional nursery grading criterion for evaluation of bareroot stock would ensure more uniform selection of high quality competitive seedlings for most planting sites.

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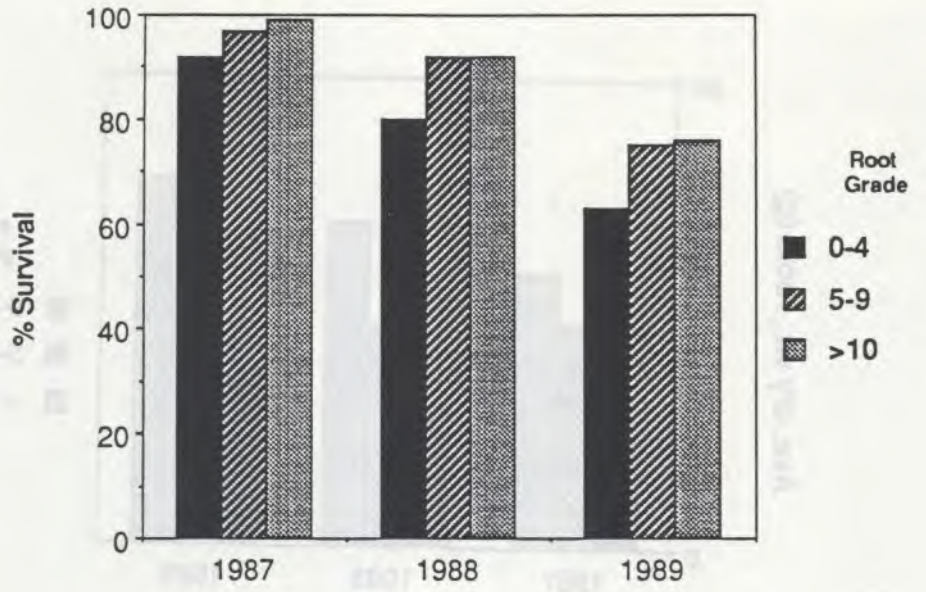

Figure 1A. Annual survival rates for 1-0 bareroot red oak

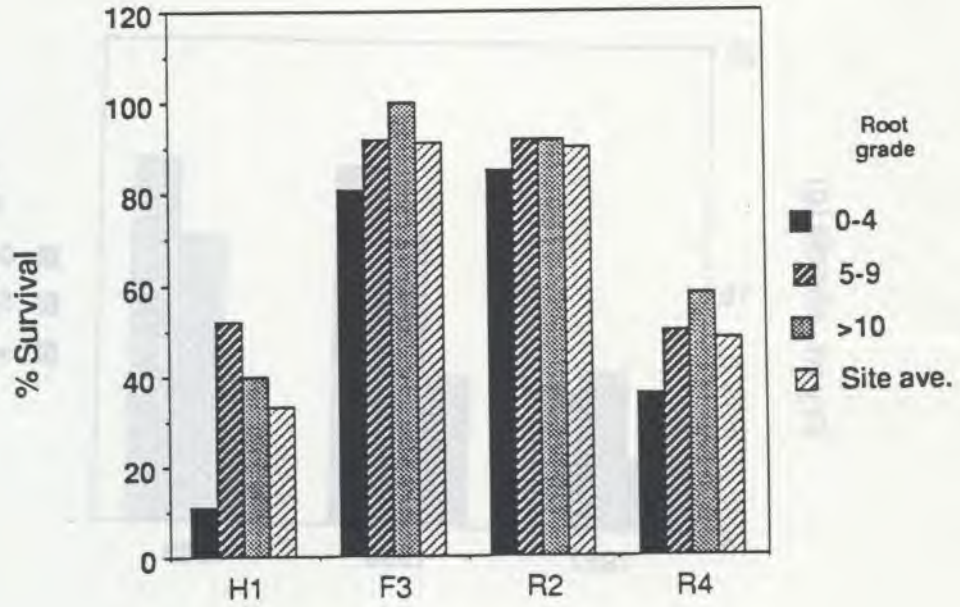

Figure 1B. Red oak survival rates by site, July 1989

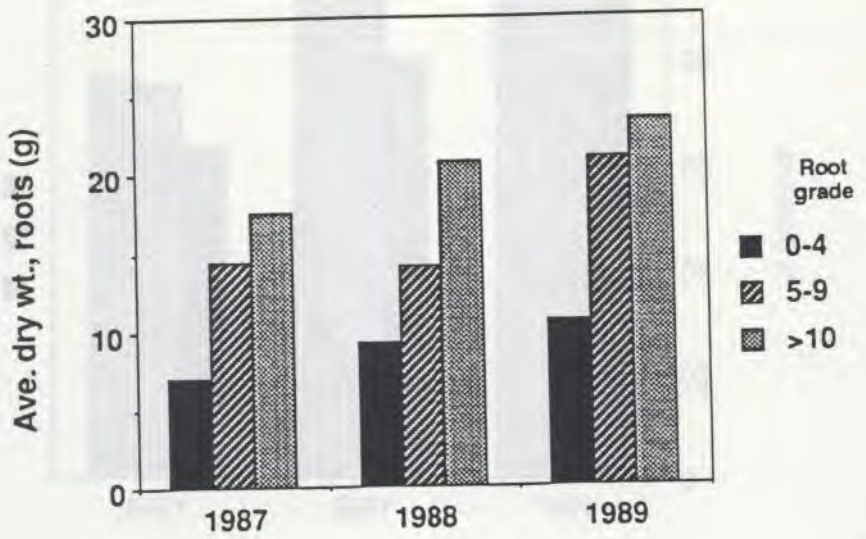

Figure 2A. Root dry weight for excavated red oak seedlings

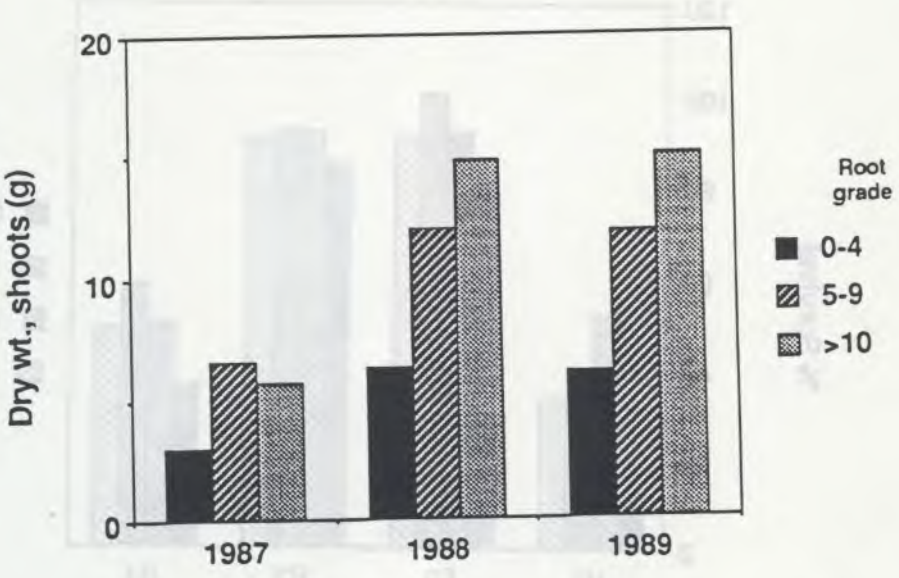

Figure 2B. Shoot dry weight for excavated red oak seedlings

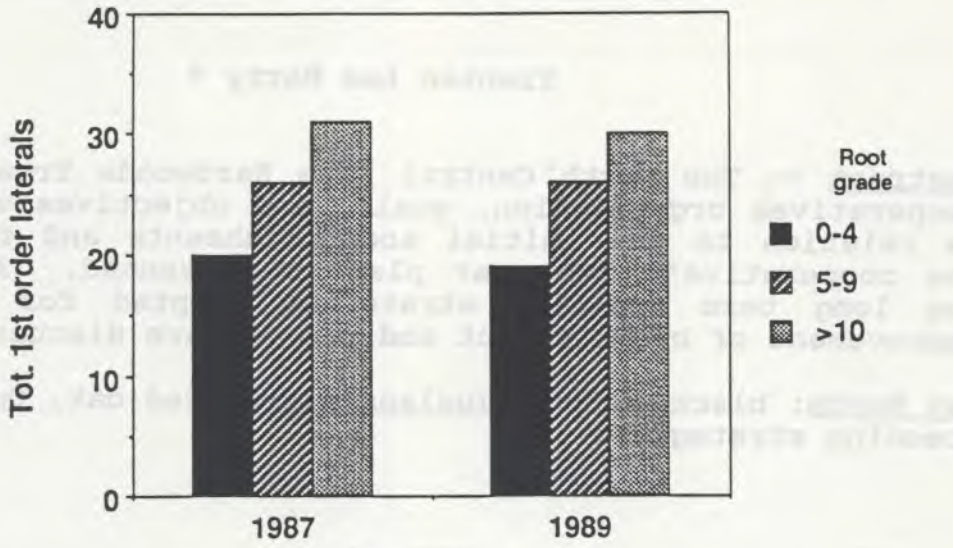

Figure 3A. Total number of first order lateral roots for excavated red oak

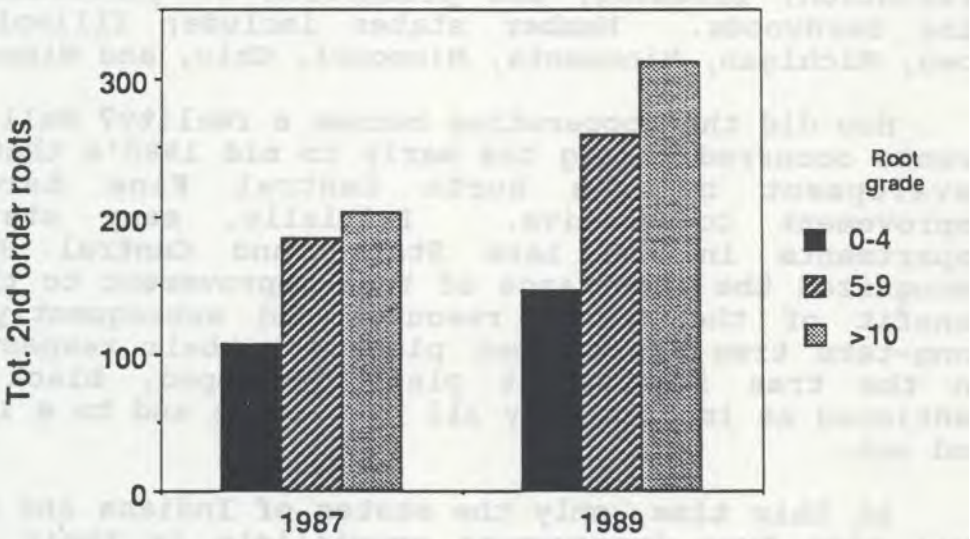

Figure 3B. Total second order laterals for excavated red oak