THE NATURE OF HARDWOOD SEEDLING ROOT DEVELOPMENT
SECOND YEAR INSIGHTS FROM THE HARDWOOD NURSERY COOPERATIVE

Richard C. Schultz
Coordinator, Hardwood Seedling Quality Cooperative

Department of Forestry
Iowa State University
Ames, Iowa 50011

Abstract The Hardwood Seedling Quality Cooperative consists of the state forest nurseries in Illinois, Indiana, Iowa, Missouri and Ohio. Efforts are being made to improve the rooting characterisitcs of red and white oak and walnut. From work done to date, it seems that the development of large first-order laterals on 1-0 seedlings is both genetically and culturally controlled. Seedbed density and undercutting can be used to increase the size and number of laterals on a percentage of the seedlings in a seed lot. The presence of at least 6-8 large first-order laterals is needed for seedling survival and growth in the field. These roots provide the trellise from which new higher order roots develop.

INTRODUCTION

For the past two years, five Northeastern Forest Nurseries have been working on ways to improve the quality of hardwood seedlings (Schultz and Thompson, 1987). Most of the work has concentrated on the manipulation of root systems of red and white oak and walnut. This work has been prompted by increased demand for "quality" seedlings that survive and grow when outplanted.

The bare-root nursery profession has the ability to nurture many genetically inferior seedlings into seedlings with large good-looking tops. However, many of these seedlings are unable to compete once they are outplanted. We believe one of the most important reasons for this inability to compete is the lack of a competitive root system (Kormanik 1986a, 1986b, 1986c, Ruehle and Kormanik 1986).

Present nursery grading standards use mainly height and/or stem caliper as criteria for judging quality seedlings. Little, if any, attention is paid to the development of the root system. Recent work has shown that a competitive seedling must have a large trellis root system composed of numerous large first-order lateral roots (Kormanik 1986b). These laterals provide the initiation sites for new second-order roots that are necessary for water and nutrient uptake. The production of the large first-order lateral roots seems to be both genetically and culturally controlled and the critical number for a competitive seedling varies by species (Kormanik 1986b). This gives us the potential to manipulate root systems in the nursery bed.

Before we start manipulating a seedling root system, we should know what the target system should look like. To do this, we must consider the root systems of mature trees in the forest environment. Most successful forest trees are the result of hundreds or thousands of seeds that ultimately were shed on a site. Many these seeds and their ensuing seedlings are genetically inferior and unable to become established. The survivors become dominant and codominant trees in a stand and most have very similar root systems. The extent of taproot development is a function of soil conditions on a site. But the development of lateral roots is fairly consistent among all trees. Most trees have between 6 to 11 large first-order laterals. Our work suggests that these roots are established when the tree is just a seedling. These laterals extend away from the tree for up to one to two tree heights. Along these roots numerous second and higher order roots develop at the ends of which are mycorrhizal root fans. Most of these roots are not perennial but are lost and renewed each year (Perry 1982).

The same thing happens in the nursery bed. Most of the higher order laterals are naturally sloughed and many of the lower order roots are lost during lifting. It is imperative that more than 6-8 permanent first-order laterals be present on seedlings after lifting to produce trees in the field that will not only survive, but become competitive dominants and codominants. Again, the absolute number needed will vary by species. By permanent first-order laterals we mean those with a diameter of greater than or equal to 1 mm. This diameter assumption may not be valid for all species, but *we feel* roots of this size can tolerate lifting, handling and field planting and provide the needed sites for new root development.

The objectives of the cooperative are to determine if, in fact, root morphology is important in survival and subsequent growth of red and white oak and walnut. We hope to determine to what extent root morphology, especially development of permanent first-order lateral roots, is genetically and/or culturally controlled. Our ultimate goal is to develop grading criteria that take root morphology into account.

METHODS

A series of studies have been established at each of the cooperating nurseries in the Hardwood Seedling Quality Cooperative. These nurseries are: 1) the Mason Tree Nursery in Topeka, IL; 2) the Jasper Pulaski and Vallonia Nurseries in Medaryville and Vallonia, IN, respectively; 3) the Iowa Tree Nursery at Ames, IA; 4)the George 0. White Nursery in Licking, MO; and 5) the Zanesville Tree Nursery in Zanesville, OH.

Between 1,000 and 2,000 bed run seedlings of red and white oak and walnut were analyzed for top height, stem caliper and number of first-order lateral roots in the spring of 1987 to establish the distribution of root systems in bed run nursery stock. Seedling density plots that were undercut or not undercut were also established in the spring of 1987 at each nursery.

Seedling density plots that were undercut or not undercut were also established in the spring of 1987 at each nursery. Seedlings from these plots were lifted, analyzed and field planted in the spring of 1988.

Plots to look at the timing of undercutting as well as mother-tree seed source plots were established during the spring of 1988 and seedlings from these plots will be field planted in the spring of 1989.

A tri-weekly lifting study of planted 1-0 seedlings from the density and undercutting plots was done during the 1988 growing season to determine the timing and extent of new root development after outplanting. In addition, a weekly and biweekly lifting of rising red oak was completed to characterize the timing of seedling shoot and root development. Finally, seedlings have been field planted on numerous soil series in Iowa and excavated several times during the year to monitor root development in different soils.

The preliminary results of these studies have led us to develop the following concepts on hardwood seedling root development and our ability to modify it culturally.

RESULTS AND DISCUSSION

The root system that a seedling develops in the nursery bed will determine the success of that seedling in the field. Work by Kormanik and others (Kormanik 1986a, 1986b, 1986c, Ruehle and Kormanik 1986) suggests that this is especially true for the number of permanent first-order laterals that a seedling develops. From the work done with oak seedling development it is obvious that higher order roots are not long lived naturally and that many, if not most of them, die during the lifting, grading, shipping and field planting process regardless of the care taken at each step.

It also seems there are inherent genetic controls on the number of permanent first-order laterals that a seedling develops (Kormanik 1986a, 1986b, 1986c, Ruehie and Kormanik 1986). When we view hundreds of nursery run seedlings, we find a very skewed distribution of seedlings in terms of the number of permanent first-order roots that they have developed. Figure 1 and 2 show the distribution of laterals for unculled, randomly selected red oak and walnut from various state nurseries. Each nursery did

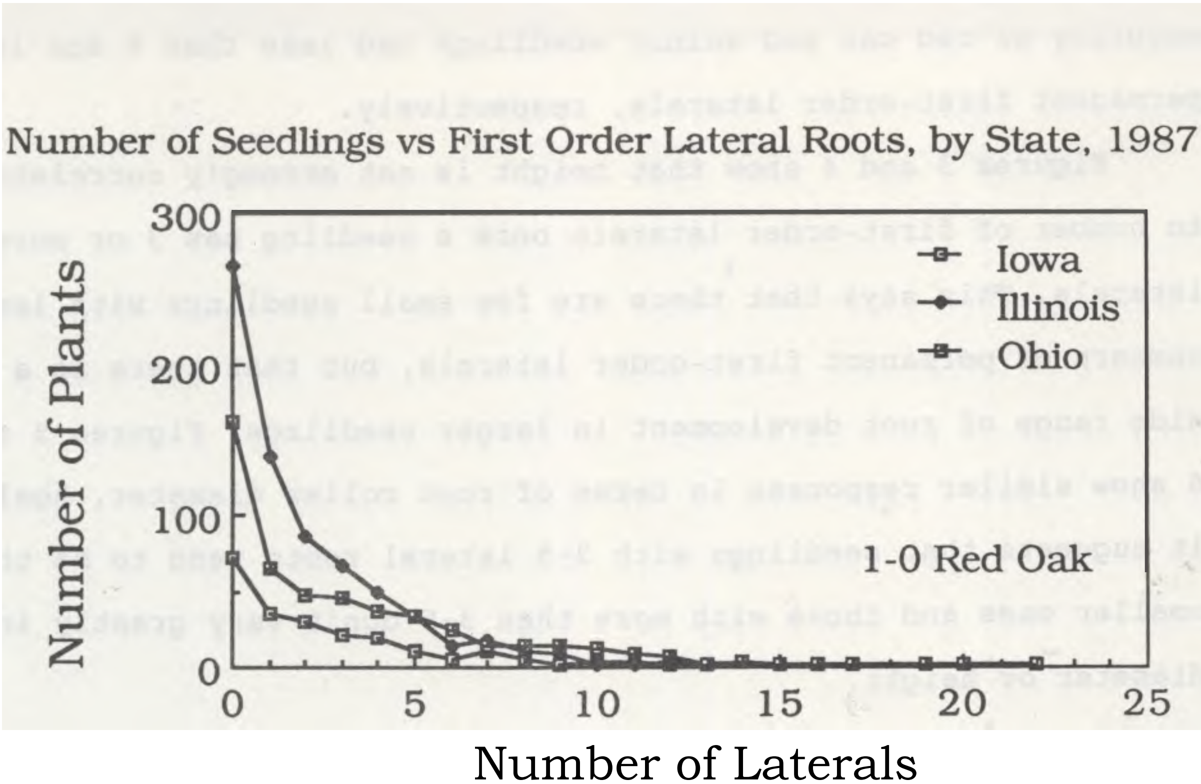

Figure 1. The distribution of 1,500 bed-run red oak seedlings based on the number of first-order lateral roots.

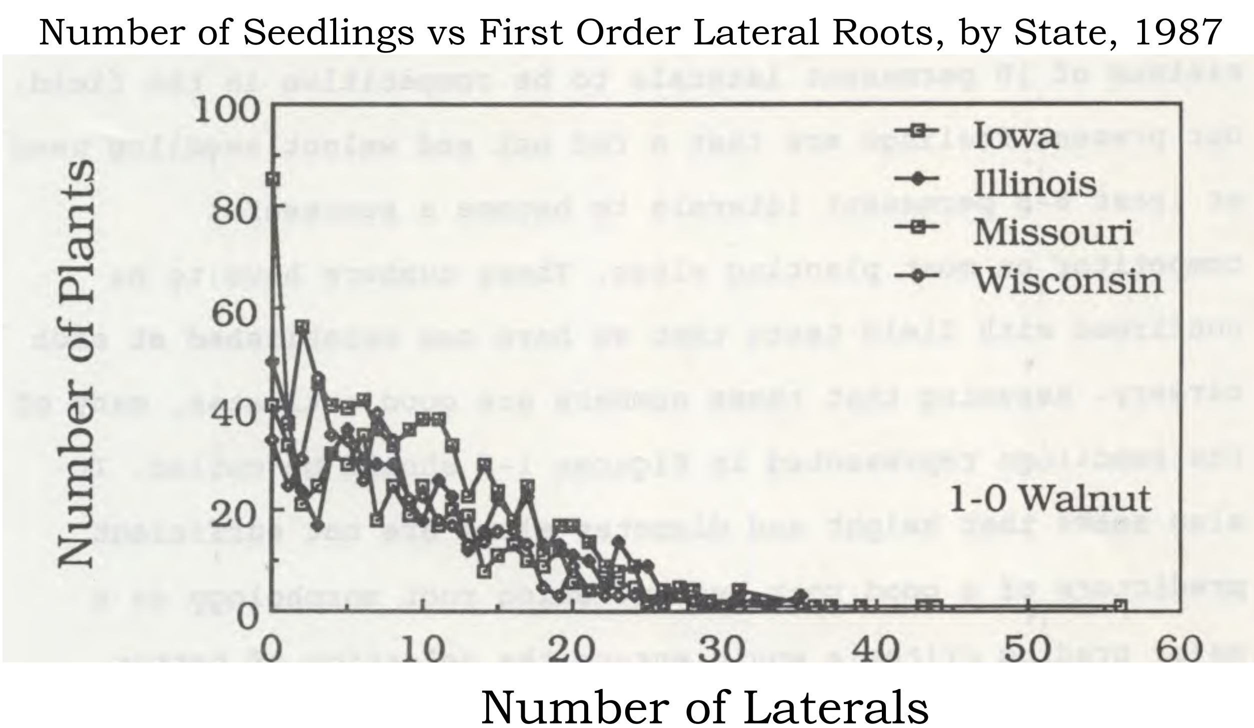

Figure 2. The distribution of 2,000 bed-run seedlings of walnut based on the number of first-order lateral roots.

not provide seedlings of each species. As can be seen. the vast majority of red oak and walnut seedlings had less than 5 and 10 permanent first-order laterals, respectively.

Figures 3 and 4 show that height is not strongly correlated to number of first-order laterals once a seedling has 3 or more laterals. This says that there are few small seedlings with large numbers of permanent first-order laterals, but that there is a wide range of root development in larger seedlings. Figures 5 and 6 show similar responses in terms of root collar diameter. Again, it suggests that seedlings with 3-5 lateral roots tend to be the smaller ones and those with more than 3-5 don't vary greatly in diameter or height.

These results tell us that height and diameter by themselves are probably not a good grading criteria if a root system with more than 3-5 laterals is needed for a seedling to be competitive. Kormanik (1986b) feels red oak and walnut need a minimum of 10 permanent laterals to be competitive in the field. Our present feelings are that a red oak and walnut seedling need at least 6-8 permanent laterals to become a successful competitor on most planting sites. These numbers have to be confirmed with field tests that we have now established at each nursery. Assuming that these numbers are good estimates, many of the seedlings represented in Figures 1-6 should be culled. It also seems that height and diameter alone are not sufficient predictors of a good root system. Using root morphology as a major grading criteria would ensure the selection of better quality seedlings in most instances.

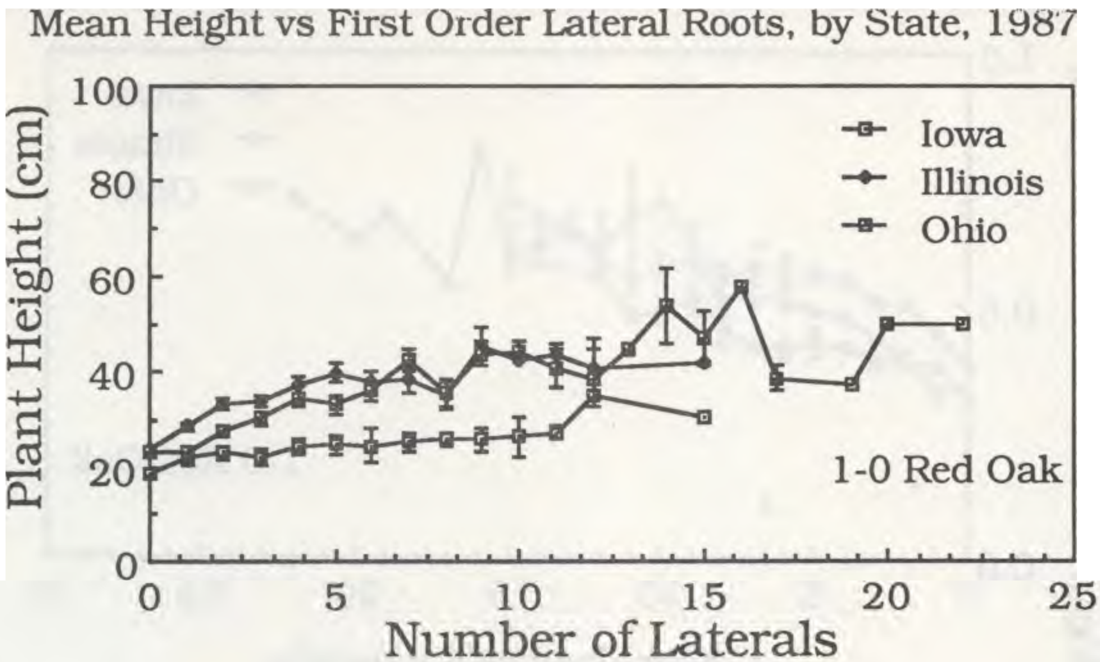

Figure 3. Mean height by lateral roots of 1,500 bed-run red oak seedlings.

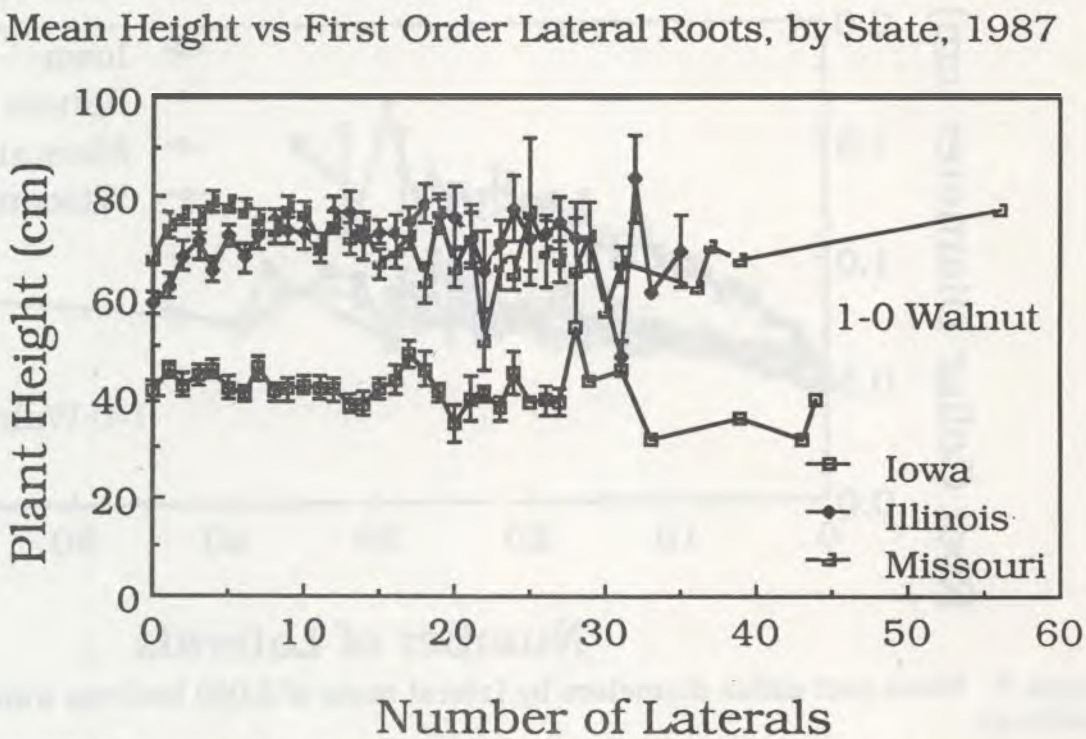

Figure 4. Mean height by lateral roots of 2,000 bed-run walnut seedlings.

Mean Root Collar Diameter vs First Order Lateral Roots, by State,1987

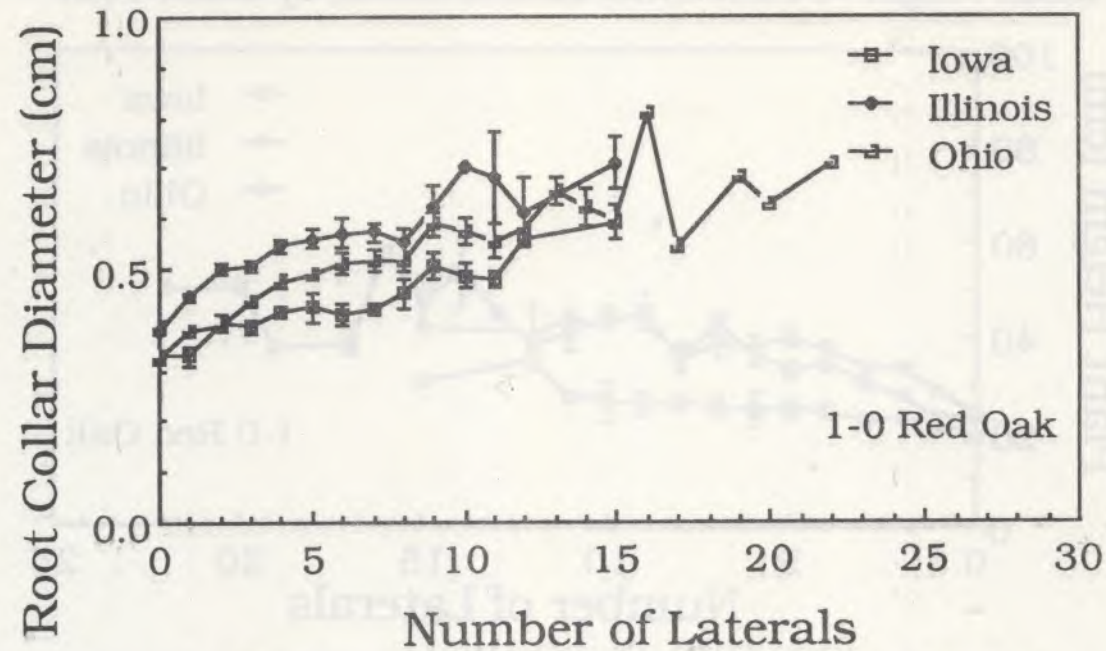

Figure 5. Mean root collar diameter by lateral roots of 1,500 bed-run red oak seedlings.

Mean Root Collar Diameter vs First Order Lateral Roots, by State, 198

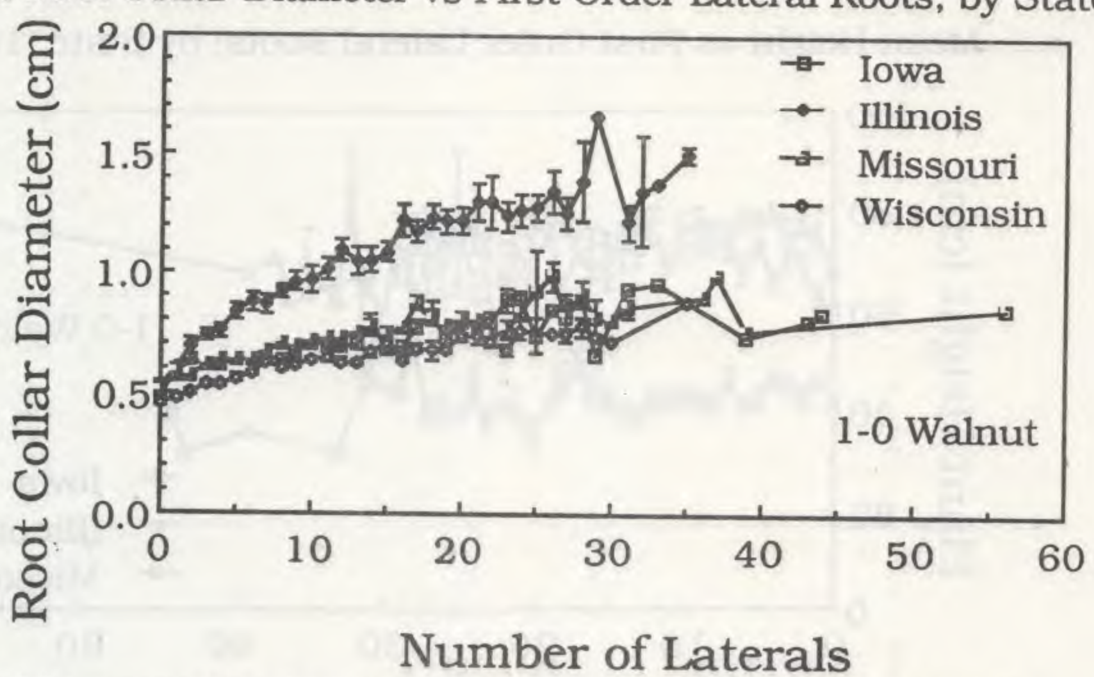

Figure 6. Mean root collar diameters by lateral roots of 2,000 bed-run walnut seedlings.

If we accept the cull level suggested by the data in Figures 1-6 we would lose a lot of seedlings. However, there are cultural practices that can stimulate additional development of permanent laterals in many of the border-line trees with only 3-5 roots. The first of these is density control. As density in the bed decreases, seedling root systems have a better chance of producing roots with larger diameters. Even with the additional thickening, however, there seems to be a genetic limit to the number of seedlings that will have more than 5 permanent laterals. These conclusions are preliminary and based on visual perceptions after grading over 12,000 seedlings during the spring of 1988.

Another cultural practice that shows real promise for increasing the number of first-order laterals in borderline seedlings is that of undercutting. Again, our conclusions are preliminary, but, it seems evident that producing a wound at the base of the taproot causes a major rooting response from the wounded region. Once a root has been undercut a callus may form. Either from or just above this callus several new adventitious roots will develop. If the undercutting is done early enough in the season these roots will develop into permanent first-order laterals. Work completed this summer suggests that undercutting may be done as late as the end of July to get good permanent root development. If undercutting is done much latter than this the likelihood exists that the roots will not have enough time to develop the proper diameter and suberization to be considered permanent.

We have also noted that the first-order laterals above the undercutting wound tend to show a thickening in diameter. Some of these roots may, therefore, become permanent as a result of the undercutting.

For the species we have worked with, it seems that a root diameter of at least 1/4 of an inch at 6-8 inches below the root collar produces the best undercutting results. For oak, which show very marked episodic growth (alternating root and shoot growth), it is imperative to undercut during a time when the shoot is not actively flushing. If undercutting is done during active top flushing, the new leaves wilt within hours and the whole top may die back within a day or two. Often, new shoots sprout from below the dieback, but this is counter-productive in producing a quality seedling. There is a lot of irregularity in the flushing pattern of a bed of oak seedlings. Undercutting must be done when the highest percentage of seedlings are not flushing. We must also look for ways to increase the uniformity of flushing in oak beds. Our work suggests that best results are obtained from undercutting if that cutting is done as soon as possible after the second top flush has been completed. This allows the photosynthetic products of the newly expanded leaves to be used for increasing the diameter of existing laterals and establishing new laterals from the area of the undercutting wound.

Field excavations of outplanted seedlings strongly suggest that at least for the first several years no new permanent first-order laterals are developed. Kormanik (1986b) also has shown a strong correlation between field survival and initial number of permanent lateral roots. Thus, the seedling goes to the planting site with it's trellise root system already determined. New root growth takes place as second and higher order roots originating from the existing first-order laterals or extension growth from the ends of the existing laterals. We have been impressed with the ability of these permanent laterals to grow out of the planting hole within the first growing season.

The observations that we have made of root morphology from this project have led us to develop the following model of seedling root system development (Figures 7 and 8). A very young root system has many small first-order laterals. A few of these rapidly begin to thicken and become the permanent first-order roots. These are the roots that the seedling takes to the planting site because these roots are large enough to survive the extensive handling process. These roots are also large enough to sustain a large higher order system in the field after planting. Seedlings that are undercut may develop additional permanent roots at the cut if the undercutting is done early enough in the season. Undercutting also may cause additional thickening in previously established laterals above the cut.

SUMMARY

Seedling survival and growth in the field seems to be strongly correlated to the number of permanent first-order lateral roots that are present at planting time. First-order lateral root development is under genetic and cultural control. In general, seedlings with larger tops tend to have greater numbers of permanent first-order laterals. But, significant nursery bed gradients and annual weather fluctuations result in average seedling heights and root collar diameters that vary greatly and make these parameters questionable as grading criteria. Height and diameter do not seem to be strongly correlated to the number of permanent first order laterals above some low threshold number of roots. This suggests that the number of laterals may be a consistent predictor of field success.

Early First Year Lateral Root Development

Note many small diameter laterals

Figure 7. A model of taproot and first-order lateral root development of red oak and walnut after germination in the spring.

End of First Year Lateral Root Development

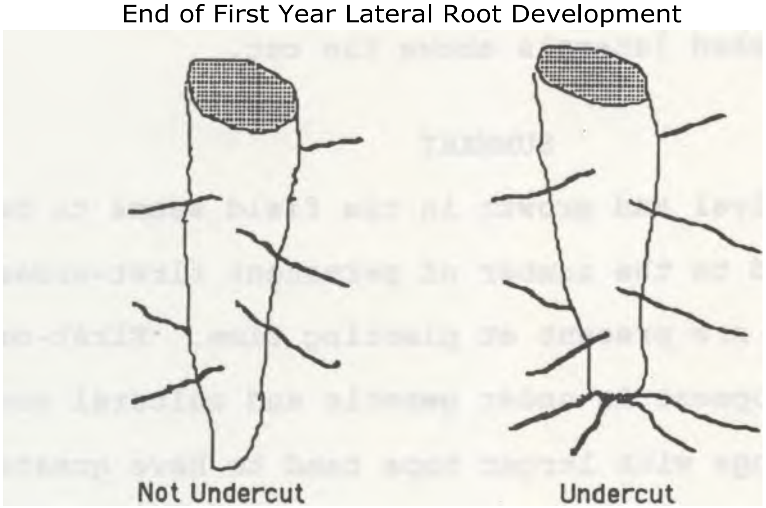

Figure 8. Model of taproot and first-order lateral root development tor red oak ana walnut at the end of the first growing season. Diagram on the right shows a root system that was undercut after the second top flush in red oak or about half-way through the growing season for walnut.

The absolute number of first-order laterals needed for field success will be difficult to define and will vary by species. This is because planting sites and planting seasons vary greatly and the same number of roots may not be needed in an ideal year as in the average or less than average year. We will, however, be able to define a range in the number of roots needed. Seedlings falling within this range will also be sensitive to cultural practices that can increase the number of laterals.

ACKNOWLEDGEMENTS

I wish to thank the nursery managers in the Hardwood Quality Cooperative for their ideas, assistance and support in doing the various projects that we have done to date. This project is funded by USDA Forest Service Focus Funds and the Iowa Agriculture and Home Economics Experiment Station.

LITERATURE CITED

Kormanik, P.P. 1986a. Lateral root morphology as an expression of sweetgum quality. Forest Sci. 32:595-604.

Kormanik, P.P. 1986b. Lateral root development-seedling quality-field performance. Proceedings N.E. Nurserymen's Conference. July 14-17, 1986, State College, Pennsylvania. p15-18.

Kormanik, P.P. 1986c Lateral roots a potential indicator of nursery seedling quality. TAPPI Proceedings p187-190.

Perry, T.O. 1982. The ecology of tree roots and the practical significance thereof. J. of Arboriculture 8:197-210.

Ruehle, J.L. and P.P. Kormanik. 1986. Lateral root morphology: a potential indicator of seedling quality in northern red oak. USDA Forest Service Research Note SE-344. 6pp.

Schultz, R.C. and J.R. Thompson. 1987. What is the Hardwood Quality Nursery Cooperative doing? Proceedings N.E. Area Nurserymen's Conference. Aug.17-20, 1987. Hayward, Wisconsin. p 103-106.