Oak Regeneration -Why Big Is Better

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Abstract- it is generally accepted that large preharvest advanced oak regeneration is required for maintaining a significant oak component in future stands. However, developing advanced oak regeneration on productive sites has been difficult because stand prescriptions encouraging oak regeneration are the same conditions that favor development of potentially faster growing competitor species. It is now practical to produce in the nursery oak seedlings that duplicate the sizes suggested for natural advanced oak regeneration. These large Northern red oak seedlings have been successfully established in small research plantations and in harvested stands where they have shown good to outstanding growth. However, they have preformed poorly when used as underplanting stock, where the understory has insufficient overhead sun to maintain stem elongation or root growth.

INTRODUCTION

This paper does not review the hundreds of articles written about oak regeneration. Instead, it reviews the research done, since we first proposed the first-order lateral root (FOLR) competitive ability hypothesis at the Institute of Tree Root Biology (ITRB) USDA Forest Service, Athens, GA. This hypothesis states that regardless of the phenotypic attributes of mother trees, their progeny can be stratified by number of first-order lateral roots (FOLR) and those with the greatest number will be the most competitive in the nursery and after out-planting in a forest environment (Kormanik and Muse 1986). We have examined at least 30 species in various nursery locations and have never found a single exception; i.e., those seedlings with the greatest number of FOLR are always the largest in stem caliper and height. We followed survival and growth of sweetgum *(Liquidambar styraciflua* L.) and loblolly pine (*Pinus taeda* L.) in the field for several years and found a positive correlation between the number of FOLR at the time of outplanting and the growth several years after outplanting. Limited research with Northern red oak (*Quercus rubra* L.) and white oak (*Q. alba* L.) shows a similar correlation.

Initially, our research was concentrated on improvement of nursery planting stock, emphasizing seedling developmental morphology. We later concentrated on developing a fertility level in nursery soils to ensure that all fields in a nursery are comparable. This latter research eliminated the field to field variation in seedling sizes that severely limited developing grading standards for seedlings in general and hardwood seedlings in particular. Subsequently, we concentrated on growing season management practices that allowed us to produce seedlings of specific sizes. This ability has enabled us to introduce larger-size oak plantings to our basic biological research on species physiological requirements for optimum development. The concept that large seedlings provide better oak regeneration is not new, however, the concept of producing this advanced regeneration as nursery stock is new. Large seedlings even show promise in regenerating Northern red oak on highly productive sites.

This paper discusses **"Why Big is Better."** This approach appears to be working in the South and may be equally effective in other oak growing regions.

WHERE WE ARE

Practically all oak stands regenerated on the better quality sites have developed after clearcutting of existing stands or developed after chestnut blight *(Crythronectria parasitica)* decimated stands once dominated by American chestnut *(Castanea dentata* (Marsh.) Borkh). In most cases, we know little about specific stand conditions before oaks became an important component. However, because of their biological requirements for reproduction and regeneration, oak probably did not dominate the previous stands. Furthermore, unless we alter future stand development by proper management, oak is not likely to be a significant component in the future (Clark 1993).

However, when many of the more productive oak stands have been harvested, regenerating these stands back to oaks has been difficult. On the good sites, various methods of natural and artificial regeneration have experienced varying degrees of limited success (Johnson 1993). Regenerating oaks is not a problem on the least productive oak sites where they can readily dominate a stand. Currently, no regeneration procedure is widely adaptable or acceptable throughout the range of a single oak species. The situation is discouraging for species like Northern red oak and white oak where extensive study has not resolved the problems associated with regeneration. Recently, these two species have been the focus of our basic and applied oak research. We strive to understand the metabolism requirements of these species and use this knowledge to increase regeneration success.

WHAT WE FOUND

The absence of successful regeneration on the most productive oak sites is a complicated silvicultural matrix that can no longer be viewed as a single species problem. Mensurational aspects of stand development have been emphasized in order to develop what appears to be a single viable oak regeneration prescription (Bums and Honkula 1990; Sanders and Grancy 1993; Sanders 1990). However, most oak species have such a broad geographic range or are so site specific that a single management protocol for even one species is probably impossible. Research emphasizes the importance of advanced regeneration but does not adequately define "advanced regeneration" and does not describe how much and how best to obtain it (Sanders 1990). However important advanced regeneration may be, the reproductive and establishment requirements of the oak species may render total reliance on natural reproduction a questionable endeavor, because the problems associated with oak regeneration start with the acorn (Cecich 1993; Cecich 1994; Barber 1994).

The silvical requirements of 25 different oak species as we currently understand them, are well covered in Agricultural Handbook 654 (Bums and Honkula 1990). The 1992 Oak Regeneration Proceeding which describes the current status of oak regeneration is a second source of our review (Loftis and McGee 1993). These manuals document that good oak seed years in nature usually occur at 2-5 year intervals. After predation by insects, diseases, rodents, birds, large and small mammals and unfavorable weather conditions during acorn drop, virtually no sound seed are available for regenerative purposes during the "off seed" years. In a good seed year, producing a single seedling probably requires 500 viable acorns because over 80% of the acorns are damaged or may be nonviable for a number of reasons (Sanders 1990).

This single seedling faces a bleak future because virtually all 25 important oak species require more than 35% of full sunlight to become established. However, even when only 28% of the canopy remained, light intensity was inadequate for successful oak regeneration (Clark 1993). Few naturally regenerated oak seedlings will obtain 35% of full sunlight and in a few years, they will dieback and disappear. This may well be the reason in the words of Kellison (1993) that there is danger of the Northern red oak becoming the "California Condor" of the Eastern deciduous forests.

WHAT HAPPENS

Examination of oak regeneration in the South before and after harvesting or selective cutting was revealing and directly affected how we approached potential oak regeneration. Similar observations have also been reported for other areas of the United States (Johnson 1993; Sanders 1990). If 10-30 cm tall seedlings of unknown age are sufficient for potential reproduction then many oak stands have enough oak seedling for future stand development. After a good seed year, many such seedlings are normally present but their numbers decline over a few off seed years. This decline in seedling numbers was especially prevalent in white oak stands where a literal carpet of seedlings practically disappeared in a few years. Northern red oak seedlings seldom develop in such abundance. Advanced natural oak reproduction in excess of a meter in height is rarely observed in fully stocked stands in most regions.

Post harvest vegetation on productive oak sites results in lush sprout and seedling reproduction of shade tolerant species, as well as seedling reproduction of yellow poplar *(Liriodendron tulipifera* L.) from the abundant seed stored in the duff and litter layers (Beck 1990). Within a short period of time sprout and vigorous yellow poplar seedling development results in a uniform canopy and oak is unable to become dominant because of its low preharvest position. This is so commonly known that a reference source is not required, however, this fact is often overlooked when discussing regeneration options.

When stands are selectively harvested or thinned to encourage growth in small oak seedlings or underplanted to establish advance reproduction where natural reproduction is lacking, long-term success has been questionable. Conceptually, these practices will result in vigorous root systems that will provide the growth potential for the seedlings when the mature trees are removed (Clark 1993; Johnson 1993). The success of these practices is questionable because the first ignores the effect of partial thinning on potential competitors and the second ignores the amount of sunlight needed by oak seedlings.

WHAT WE HAVE DONE

Over a period of years, we developed a nursery management protocol that permitted 4-7 growth flushes by most oak species with 1 -0 nursery stock (Kormanik et al. 1994a; Kormanik et al. 1994b). For most oak species, heights of the best 50% of the seedlings can easily reach 1-1.5 meters. We found that multiple flushes and large stem sizes resulted in significant increases in root development of the most competitive seedlings (Ruehle and Kormanik 1986; Kormanik et al. 1989). We also found that large multiple flushes were accompanied by distinct "growth" rings in the tap roots which alternated with stem growth flushes.

We then began to study transplanted and nontransplanted seedlings in the nursery. With small non-transplanted seedlings we found that root development did not improve the second year in the beds and that their relative crown competitive position declined in relationship to larger individuals. When transplanted into adjacent nursery beds where lateral root development could be observed, the development of the individuals with low FOLR numbers remained intermediate or suppressed and did not compete with transplanted seedlings with higher FOLR numbers. Invariably, new root development occurred in abundance not only from the severed tap root of the large seedlings but also from the severed end of the FOLR. For seedlings with 0-4 FOLR, few new lateral roots developed from severed ends of FOLR and new roots from the severed tap root were few and appeared less vigorous. We found the lower the FOLR number at lifting, the poorer the root development on the smaller transplanted seedlings.

In 1989, we established our first Northern red oak plantation, using 866 graded 1 -0 seedlings from 8 half-sib seedlots in a traditional plantation configuration with 3.3 x 3.3 in spacing. At age 3, the plantation was vigorous and apparently disease free, with 60% of the individuals taller than 3.0 m tall (Fig. 1). The plantation was developing well and showed promise of being one of the most productive Northern red oak plantations in the South if not in the country.

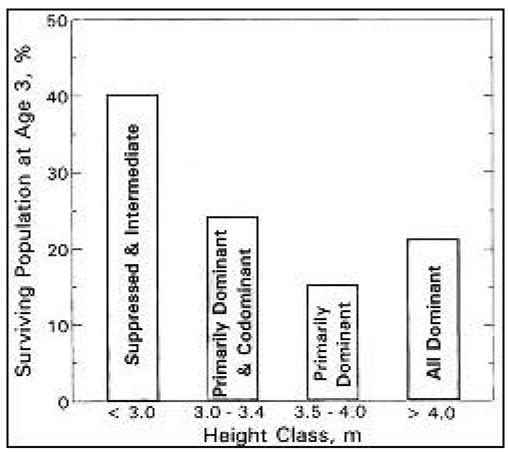

Figure 1. Percentages of surviving Northern red oak seedlings by height classes: suppressed, intermediate, codominant, and dominant canopy three years after outplanting.

At that time, the survival was 88%, and the number of seedlings in height classes 3.0-3.4, 3.5-3.9 and > 4.0 meters were 182, 118, and 159, respectively. Mortality occurred primarily in seedlings with the lowest FOLR numbers or when voles (*Microtus* spp.) consumed the roots during the initial outplanting year. Interestingly, the vole damage was almost entirely limited to large individuals with high numbers of FOLR while normal mortality was usually restricted to individuals with the fewest numbers of FOLR.

In 1992, we observed dead branches on the upper third of the crown, of two good-looking seedlings. From these dead branches we isolated a fungus *Boftyospaeria* spp. and decided to follow its progress for a year or two before reporting on the plantation. The following year, significant cankers developed on branches and main stems of many other individuals. Cankers on the main stems resulted in dieback affecting up to 50% total height. By age 5, the entire plantation was affected with this fungal pathogen which resulted in dieback and mortality of many individuals.

In 1995, at age 7, dieback, resprouting and mortality continue to occur. However, individuals that show no dieback are 7.5-9.0 in tall even though the mainstem may have several cankers. This plantation demonstrates that large Northern red oak seedlings can be established and show significant growth on a high quality stream bottom.

While this plantation was developing, a second outplanting was undertaken in North Carolina, on the Grandfather district of the Pisgah National Forest in cooperation with the North Carolina Division of Forestry. The site index (50 years) was 100 for yellow popular which comprised a significant component of the preharvested stand. We established this outplanting simply to compare seedling development in the understory planting with plantings in an adjacent clearcut, across the road using seedlings of different heights and FOLR numbers.

No post harvest treatment occurred in the clearcut. The underplanting site was thinned leaving a residual basal area of 70 sq. ft with understory vegetation removed before the seedlings were planted. Seedlings were classified as good, medium or poor based on FOLR numbers of > 12, 7-11, and 0-6, respectively. Heights of the seedlings were directly related to FOLR numbers (Ruehle and Kormanik 1986). In both areas, seedlings were planted in rows at a specific spacing regardless of potential competition from sprout origin materials or overhead shade. In both cases, all good and medium seedlings initially exceeded 1.25 in in height when outplanted. The poor ones, depending upon FOLR numbers, were 30-70% smaller.

First year mortality was insignificant in both planting situations with almost all seedlings surviving. As previously observed, little first-year height growth occurred in either situation as the roots became established and individuals recovered - from transplanting shock. In the clearcut, few if any of the large seedlings were overtopped by competing sprout and seedling reproduction but many of the small seedlings and most of the small, naturally regenerated seedlings fell behind sprout growth. None of the seedlings in the understory planting experienced direct competition from competing understory growth.

The second year growth in the clearcut was good, with many of the large seedlings almost doubling in height. In the understory planting, few individuals grew more than 10-20 cm and seldom produced more than 10 leaves. In the fall following the second growing season, a severe epidemic of 17 year locusts occurred and severely impacted over 90% of the individuals in the clearcut plantings but no seedling damage occurred in the understory planting. Early in the third growing season, seedlings in the clearcut that had not died back almost to the ground were severely damaged along their entire length.

In the third through the fifth year, the seedlings in the understory began to dieback and the number of leaves that developed decreased each year. At the end of the fifth year, these seedlings were essentially the same size as when outplanted. Survival of the understory planting remained relatively good with only 3.8, 3.8, and 18% of the good, medium and poor individuals dropping out of the planting.

A number of seedlings had been established in the underplanting to evaluate root development as our underplanted "advanced" regenerated material developed. In February, 1995 some of these seedlings were excavated after 5 years in the understory. We unexpectedly found that almost the entire original lateral root system had atrophied and was replaced by a few poorly developed new roots that had developed where the taproot had been severed before outplanting. The taproot had essentially the same diameter it had when it was planted. In our plantation and other trial plantings where we routinely excavate seedlings to follow FOLR development we have never observed similar reductions in root mass. A more extensive lifting of more seedlings is planned for fall and winter 1995-1996.

In the clearcut, competition at the end of the fifth year was extensive with approximately 30,000 stems per acre present. The poor seedlings with low numbers of FOLR experienced 65% survival, but only 6% were free to grow. The survival rate for the medium and good seedlings was 66% and 70%, respectively. However, 52% of the good seedlings were free to grow and 28% of the medium seedlings were so classified. In most cases, the free to grow oak seedlings were the same height (3-4 in) as the better naturally regenerated yellow poplar seedlings. The sprout material of some species were up to 5 in but were not impacting the free-to-grow Northern red oak seedlings. Unlike the root systems from the understory planting, those from the clearcuts were making root growth commensurate with their impressive height growth.

A detailed report of this cooperative study is being prepared. Based upon its performance to date and the performance of other smaller studies, the ITRB, Region 8 and the University of Tennessee have undertaken an extensive region wide study to test the effect of large Northern red oak seedlings on both timber and mast production. The seedlings from 78 different half-sib seedlots were grown at the Georgia Forestry Commission Flint Nursery in 1994 and were out planted on 18 different ranger districts from Virginia, south to Georgia, and west to Kentucky in February 1995. At each location 1,250 seedlings from 25 different families were planted in small 3-5 acre clearcuts.

In this region-wide planting, at 18 different sites, we have had preliminary reports of total deer browse on 18 plantings, gypsy moth on one and 17 year locust damage on two. Early reports indicate the majority of the large seedlings are not being overtopped by competing natural vegetation. However, the extended drought during the 1995 season may be impacting survival.

SUMMARY AND CONCLUSIONS

In the South, underplanting of any oak may not result in development of advanced regeneration whose root system is developed well enough to permit a significant number of seedlings to compete after the stand is harvested. The small (5-30 cm) oak regeneration characteristically present in the understory of mixed hardwood-oak stands have little chance of competing on high quality sites because they quickly become overtopped by the dense canopy of woody sprout and herbaceous material. Large 1 -0 seedlings with suitable FOLR development have one or two years to become established before intensive competition for sunlight and root growing space occurs. This may be sufficient time to permit the planted seedlings to act like true advanced regeneration and become part of the newly developing stand. This concept is new, and we can now produce advanced regeneration in our nurseries and identify the most competitive ones.

Plantation performance of these large Northern red oak seedlings has been outstanding even though the oldest plantation has been essentially destroyed by *Botryospaeris spp.* Even in this plantation, the largest individuals have attained heights of 7-9 in which is outstanding by any standard. We are constantly monitoring our other Northern red oak outplantings to evaluate this disease. Several seed orchards were established at the Georgia Forestry seed orchard adjacent to the Flint Nursery complex using these large seedlings. These orchards have also been having outstanding seedling development.

Because acorn predation is high and seed years are infrequent natural regeneration will probably not provide ample material for consistent success on the better quality sites. Moreover, small seedlings, even those with good root development, will probably not overcome transplanting shock and become established before sunlight is limited. Large seedlings, however, have demonstrated an ability to overcome transplanting shock and become established before they are overtopped by competing vegetation. After 5 years, these seedlings attain heights commensurate with sprouts and other competing regenerated vegetation.

Successful Northern red oak regeneration on the more productive bottomland, mesic and cove sites may ultimately depend upon nursery production of large competitive seedlings and using only the best for artificial regeneration prescriptions. The silviculture prescriptions must in turn be dictated by biological not political considerations. If this does not occur, Northern red oak may indeed become the "California condor" of the Eastern deciduous forest (Kellison 1992).

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