NORTHERN RED OAK FROM ACORNS TO ACORNS IN 8 YEARS OR LESS

Paul P. Kormanik, Shi-Jean S. Sung, Taryn Kormanik, Tom Tibbs, and Stanley J. Zarnoch[1]

Abstract—The intrinsic factors affecting acorn production in oak trees need further study. Common knowledge holds that an oak requires a minimum number of years to begin flowering, with 30 to 50 most frequently reported. Recently, the Institute of Tree Root Biology has been studying the development of northern red oak (*Quercus rubra* L.) in the nursery and in outplanting situations. The goals are (1) refining a silvicultural system for oak regeneration on high-quality mesic sites, and (2) pinpointing nursery seedlings most likely to develop into competitive forest trees. Over the course of these studies, we have noted precocious acorn production from these seedlings deemed most competitive in the nursery. Therefore, we speculate that the minimal physiological maturity necessary for flowering to initiate may be more closely related to carbohydrate production than to age.

INTRODUCTION

Northern red oak (*Quercus rubra* L.) (NRO) is the premier multiple-use forest species throughout its range in the Eastern United States. It reaches its maximum productivity for mast and timber on high-quality mesic sites. Throughout NRO's range, its acorns are as highly prized as its timber because of the important role mast crops play in supporting a diverse, healthy wildlife population. However, the environmental and edaphic factors affecting acorn production, and their interactions with oak biology, are poorly understood (Cecich 1993).

Early reports correlated initiation of acorn production primarily to tree age: 40 to 50 years was considered to be the average time needed for a NRO to begin mast production (Busgen and Munch 1929). More recent studies in the United States have reported 20 to 40 years as the age of acorn crop initiation (Beck 1993, Cecich 1993, U.S. Department of Agriculture 1974). However, individual oaks exhibiting exceptional early growth may produce acorns much sooner.

Beck (1993) reported the extrinsic and intrinsic factors influencing acorn production and concluded that the extrinsic factors, such as weather, insects, and wildlife, while more commonly studied, were secondary in importance to the roles intrinsic factors, such as genetics and physiological condition, play in the initiation of acorn production. Early identification of those individuals predisposed to precocious acorn production would be of considerable value to silviculturists and wildlife biologists, who could then keep those crowns free of competition to enhance consistent mast production (Cecich 1993).

The Institute of Tree Root Biology (ITRB) and the Georgia Forestry Commission (GFC) have developed nursery protocols for evaluating competitive potential of individual oak seedlings when lifted from the nursery bed as 1-0 stock. Several years ago, we established and maintained small plantings (1 to 3 ha) of these graded seedlings from over 100 open-pollinated half-sib mother trees under various management intensities to evaluate field performance. These early studies were not implemented specifically to elucidate factors affecting mast production but rather to develop technology for establishing young stands on high-quality mesic sites. Early acorn production was an unexpected bonus with significant practical as well as biological implications.

The purpose of this report is to describe what has been observed about early acorn production when NRO seedlings are grown following the ITRB nursery protocol and evaluated on specific morphological characteristics prior to outplanting.

METHODS

Acorns

Acorns for the three studies were collected from specific NRO mother trees from either the USDA Forest Service's Watuga Seed Orchard in eastern Tennessee, from individuals in the Chattahoochee National Forests in Georgia, or from the National Forests in North Carolina. The acorns were floated in water, and those that sank were presumed sound (Olson 1974) and placed in cold storage (4 to 6 ^{o}C) until sown. Sowing took place in early to mid-December either at the GFC Flint River Nursery near Montezuma, GA, or the ITRB Whitehall Experimental Nursery, Athens, GA. Nursery management practices at both locations follow the same protocol as described in the next section.

Bed densities are selected to achieve a seedling density of 54 to 57/m^2. Acorns from specific mother trees are sown continuously within a bed, with a 2-m void between individual half-sib seedlots. Well-decomposed sawdust was then applied to all beds to a depth of 2 to 3 cm.

Nursery Protocol

Before sowing, nursery soils were sampled for nutrient status and then adjusted to the Flint River soil baseline fertility level for calcium, potassium, phosphorus, magnesium,

[1] Principal Silviculturist and Research Plant Physiologist, Institute of Tree Root Biology, USDA Forest Service, Southern Research Station, Athens, GA 30602; Research Technician, University of Georgia, Athens, GA 30602; Regional Geneticist, Silviculture and Genetic Resource Management, USDA Forest Service, Region 8, Atlanta, GA 30309; and Station Statistician, USDA Forest Service, Southern Research Station, Asheville, NC 28802, respectively.

Citation for proceedings: Connor, Kristina F., ed. 2004. Proceedings of the 12th biennial southern silvicultural research conference. Gen. Tech. Rep. SRS–71. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 594 p.

copper, zinc, and boron: 600, 130, 100, 75, 0.3 to 3, 3 to 8, and 0.4 to 1.2 parts per million, respectively (Kormanik and others 1994). Nitrogen was applied as NH_4NO_3 at 10- to 14-day intervals throughout the growing season, beginning about the time of first flush in mid-May until early September. The rates were gradually increased as the seedlings developed and were able to more efficiently absorb the top dressing. The first two applications were at approximately 22 kg/ha, the 3rd at 56 kg/ha, the 4th through the 10th at 168 kg/ha, and the final two at 116 kg/ha. Irrigation was provided throughout the growing season to supplement rainfall when < 2.5 cm/week occurred. Irrigation continued as needed until the leaf abscission layer developed following several frosts in late November.

Seedling Grading

All seedlings were root pruned at approximately 30-cm depth prior to lifting in mid-February. The seedlings were lifted, graded, and their first-order lateral roots (FOLR) were cut to 15 cm length. The seedlings used in the Flint River Seed Orchard had minimum FOLR numbers of 15 and the minimum height (HGT) and root-collar diameter (RCD) at 1.25 m and 15 mm, respectively. The planting at the Beech Creek Seed Orchard located in North Carolina and the Blairsville Ranger District in north Georgia were both considered regular outplantings, and the minimum FOLR number of these seedlings was six and the minimum HGT and RCD were 0.70 m and 8 mm, respectively. These seedlings represented the top 40 to 60 percent of the progeny.

Outplanting

Seedlings were produced at the ITRB Nursery, and 5 of the best individuals were selected from each of the 14 mother trees for long-term developmental observation. A single individual from each mother tree was randomly outplanted at the Flint River Seed Orchard in each of five blocks at 4.5- by 9.1-m spacing.

The Flint River Seed Orchard soil fertility was tested biennially and maintained at levels comparable to those in the nursery beds. Nitrogen was applied at rates equivalent to 350 kg/ha of product during years 2, 3, and 4. Subsequently, fertilizer was applied only to correct any departures from soil protocol. Irrigation ceased after top dressing with NH_4NO_3. Progeny grown at the Flint River Nursery from 10 mother trees were outplanted in 3 replicates in a traditional progeny trial design, with 5 tree groups for each half-sib progeny at 4.5- by 9.1-m spacing. No fertilizers or irrigation were used at this orchard.

The Blairsville site involved 25 mother trees in 10 replicates also in a traditional progeny trial layout with 5 tree groupings, but at 3.1- by 3.6-m spacing. No fertilizer or irrigation was used at this site.

RESULTS AND DISCUSSION

It must be emphasized that the three plantings discussed here must be considered as individual case studies, and none of them was designed to study early acorn production *per se*. They have little in common except for being grown in the nurseries under an identical management protocol. Even the minimum acceptable measurements for FOLR, HGT, and RCD differed for each study. The Flint River Seed Orchard planting included selections from the top 5 percent of the progeny from selected mother trees. Those planted at the Beech Creek locations and Blairsville would more realistically represent those from the top 40 to 60 percent of progeny. Both the Beech Creek and Blairsville plantings were on good-quality mesic sites, and we wanted to determine how our selected trees would develop in the absence of irrigation and supplemental fertilization. Seedlings were anticipated to be competitive after outplanting, but those from the two latter plantings were not as uniform in morphological characteristics as those planted at the Flint River Seed Orchard.

The primary management tool during this establishment period was competition control, either by chemical or mechanical means. When the seedlings were outplanted, we expected that thinning would be required around age 10 to 15 to maintain thrifty crowns. Also, we planned to evaluate whether the stands needed other management treatments to enhance their acorn production potential. This approach in delayed anticipation of acorn production reflected the commonly held concept that initiation of acorn production was more a function of age than of individual tree vigor (Beck 1993, Busgen and Munch 1929, Cecich 1993, U.S. Department of Agriculture 1974). However, these reports did indicate acorn production as early as age 10 occasionally occurred on the most vigorous trees. On the other hand, Zimmerman and Brown (1971) suggested that it was crown size and vigor, rather than age *per se*, that may be involved in early initiation of seed production in trees. The three case studies reported here concur with the view on early acorn production by Zimmerman and Brown (1971). This information has significant ramifications for multiple-use management.

Flint River Seed Orchard

This outplanting was established in 1992. The nursery study was designed to determine the heritability of FOLR of this species, and no subsequent field testing was anticipated at the time of the study's initiation (Kormanik and others 1997, 1999). However, the GFC outplanted the best individuals at their newly developed hardwood seed orchard, the Flint River Nursery. The precise locations of the individual mother trees were unknown; only the general areas of collection in north Georgia and western North Carolina were available. Thus, 5 seedlings from each of the 14 mother trees were selected, but progeny identity within blocks was not maintained.

Midway through the fourth growing season, a small number of acornets were observed on individual trees in all five blocks. The acornet-bearing trees were marked, but no effort was made to evaluate the entire planting. Periodically, the trees were observed to determine if acornet abortion occurred during the intense heat of south Georgia summers. A few individuals retained a portion of their acornets, which matured during the fifth growing season.

Acorns were produced sporadically from the sixth to the ninth growing seasons, but characteristically, a significant percentage aborted during either the season of initial acornet production or during maturation. High summer temperatures accompanied by an extensive drought characterized all these years. In spite of the extended drought, a large commercial-size crop was produced during the 10th season (2002). Of the surviving 61 trees, 5 were classified as heavy producers, 9 as medium producers, 26 as light producers, and 21 as nonproducers. The average HGT, diameter at breast height, and mean acorn-bearing status for each of the five blocks are shown in table 1. Since the fifth growing season, 41 of the surviving 61 trees have produced acorns at least one time.

Beech Creek Seed Orchard

Beech Creek Seed Orchard, as well as the Blairsville planting, were established in 1995 and have never been fertilized or irrigated. The heavy fescue cover at the Beech Creek location was treated with herbicide to maintain a 2-m-wide grass-free strip along each row of trees. No measurements were made on the young trees. The trees have remained free of intraspecies competition because of the wide spacing and mortality from animal damage. Survival was very good, but excessive deer (*Cervidae* spp.) browsing adversely affected two progeny groups. None of the family 482 progeny recovered height growth from browsing, and only 45 percent of family 427 progeny survived (table 2). The progeny from one mother tree (482 in this case) was especially susceptible to deer damage and was unable to recover from repeated browsing, severe drought, and high summer temperatures.

Table 1—Heights, diameters, survival, and estimates of acorn production for the 10th-year northern red oak at the Georgia Forestry Commission, Flint River Seed Orchard

Block	Height	D.b.h.	Survival	Acorn status[a]
	m	*mm*	*percent*	
1	6.2	124	86	1.3
2	6.8	133	93	1.3
3	6.8	142	79	0.5
4	7.0	129	93	0.8
5	6.2	119	86	0.9

[a] Acorn production of the 61 surviving trees was assessed on a relative, subjective basis as follows: 0 = no acorn production (1 tree); 1 = light production (26 trees); 2 = moderate production (9 trees); and 3 = heavy acorn production (5 trees).

Table 2—Height, diameter, and survival of the eighth-year northern red oak outplanting at the Beech Creek Seed Orchard

Family	Height	D.b.h.	Survival
	m	*mm*	*percent*
419	4.4	75.4	100
422	3.7	47.4	60
427	3.6	47.8	45
429	3.4	43.1	87
434	3.9	57.6	80
442	4.0	60.3	80
450	3.8	54.8	80
457	4.2	65.8	100
472	4.2	60.2	87
473	3.6	54.7	60
482	—	—	0

Until the end of the fifth growing season, the planting had not been surveyed for acorn development. In October 2000, we observed acorn production on approximately 10 percent of the trees but made no permanent record. We observed additional acorn production on other individuals in 2001 and again in 2002 when measuring the surviving trees. To obtain acorn production in this case, even in limited numbers, is quite impressive because of the record-breaking drought in progress for at least 6 of the 7 years since the trees were outplanted. Based on the Flint River Seed Orchard success, we will begin fertilizing Beech Creek at comparable rates to determine if acorn production can be increased to similar levels.

Blairsville Outplanting

The Blairsville outplanting, established in 1995, was an early effort to determine whether NRO could be artificially re-established on high-quality mesic sites in the Appalachian Mountain region of the Southeastern United States. Initially, interspecific competition was considerable, as thousands of germinated and stump-sprouted yellow-poplar (*Liriodendron tulipifera* L.) blanketed the study site. The competition was controlled both mechanically and with herbicide during the second and third growing seasons. The NRO oak responded to this release, and crown closure occurred by age 4. Since the third growing season, grape (*Vitis* spp.) vines have been a nagging problem along the outside perimeter of the planting. Vole (*Cricetadae* spp.) damage accounted for the vast majority of seedling mortality during the first 2 years in the field.

The first acorn production noted was at the end of the seventh growing season (2001), but crown closure prevented assessment of acorn production while the crowns were in full leaf. Acorns were observed on the ground below five or six trees in December 2001, but no intensive survey of the trees was made. The entire planting was surveyed for acornet development prior to bud break in spring 2002. Progeny from 16 of the 25 families had individuals with acornets (table 3). The poor performance of family 482 progeny observed at the Beech Creek Orchard did not occur at this location. Deer damage was minimal on this site, and maturing acorns were periodically observed throughout the summer. An extensive hot spell accompanied by drought resulted in some acorn abortion in early August 2002. All individuals we observed with acornets in the spring eventually produced some mature acorns in the fall. However, because of severe crown competition throughout the 2002 growing season, it was not practical to make assessments of acorn counts on an individual tree basis.

In early September we cleared vegetation beneath the trees in preparation for acorn collection. Unfortunately, when we revisited the site 2 weeks later to determine status of acorn drop, we found few acorns remained. Squirrels (*Sciuridae* spp.) had essentially consumed all the acorns—even the immature ones. Checking various oak species in the adjacent natural stand revealed that few acorns were present, and the 2002 season was to be a very poor mast year.

Table 3—Height, diameter, volume, and survival of the eighth-year northern red oak outplanting at Blairsville

Family	Height	D.b.h.	Volume	Survival
	m	*mm*	*cm³*	*percent*
435[a]	3.7	30	5069	72
439[a]	3.6	31	4822	86
442[a]	3.9	35	6401	82
443[a]	3.8	32	4691	78
448[a]	3.2	24	2825	72
473[a]	4.0	38	7822	56
479[a]	3.9	36	7651	74
482[a]	4.2	39	8469	84
419[a]	4.0	37	6902	86
421[a]	3.9	36	7031	72
423[a]	3.5	30	4533	74
441[a]	3.8	34	6787	78
450[a]	3.6	32	5551	68
459[a]	3.0	25	3388	68
468[a]	3.0	24	2468	84
483[a]	3.7	35	7930	72
438	4.0	34	5675	76
420	3.2	26	2939	68
437	3.5	31	4378	80
451	3.9	33	5785	82
469	3.0	24	2391	82
474	4.0	36	6976	70
480	3.2	26	3208	76
481	3.5	29	4615	84
484	3.1	27	3539	76

[a] Produced acorns.

The stand was thinned in December 2002 to permit greater crown expansion. No individuals with second-year maturing acorns or with acornets were removed in this thinning. Management of this outplanting will be directed toward acorn production for wildlife as well as a collection site to obtain acorns for nursery production.

CONCLUSIONS

In the past scientists may have overemphasized the effects of tree age on initiation of acorn production. After observing natural forest stands, scientists may correlate acorn production too closely with years after outplanting. Our observations clearly indicate that crown vigor, combined with genetic potential, may be an overriding factor in early acorn production. The potential of individuals to make accelerated growth can be predicted based upon their competitive behavior under specific nursery conditions. The genetic involvement in precocious acorn production is apparent, since some individuals make exceptional growth and produce acorns annually, but others of comparable vigor have not yet produced acorns. To obtain early acorn production even with the best quality seedlings, interspecific competition must be reduced so that the crowns are exposed to full sunlight during early development. It is unlikely that overtopped seedlings will develop the root systems necessary to allow initiation and sustenance of vigorous crowns that are essential to early acorn production.

Seedlings from the top 5 to 10 percent of a given crop, such as those at Flint River Seed Orchard, are very uniform and may contain the most potential acorn producers. However, even those from the top 40 to 60 percent of the crop, such as those at Blairsville and Beech Creek, if they meet minimum standards, have many individuals with the growth potential needed to maintain vigorous crown development necessary for genetic expression of early acorn production.

LITERATURE CITED

Beck, D.E. 1993. Acorns and oak regeneration. In: Loftis, D.L.; McGee, C.E. eds. Oak regeneration: serious problems, practical recommendations: Symposium proceedings. Gen. Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 96-104.

Busgen, M.; Munch, E. 1929. The structure and life of forest trees. New York: John Wiley. 436 p.

Cecich, R.A. 1993. Flowering and oak regeneration. In: Loftis, D.L.; McGee, C.E., eds. Oak regeneration: serious problems, practical recommendations: Symposium proceedings. Gen. Tech. Rep. SE-84. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment Station: 79-95.

Kormanik, P.P.; Kormanik, T.L.; Sung, S.S. [and others]. 1999. Artificial regeneration of multiple hardwood species to develop specific forest communities. In: Haywood, J.D., ed. Proceedings of the tenth biennial southern silvicultural research conference. Gen. Tech. Rep. SRS-30. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station: 132-135.

Kormanik, P.P.; Sung, S.S.; Kormanik, T.L. 1994. Irrigating and fertilizing to grow better nursery seedlings. In: Landis, T.D., tech. coord. Proceedings of the northeastern and intermountain forest and conservation nursery associations. Gen. Tech. Rep. RM-243. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station: 115-121.

Kormanik, P.P.; Sung, S.S.; Kormanik, T.L. [and others]. 1997. Heritability of first-order lateral roots in five *Quercus* species: effect on 1-0 seedling quality evaluation. In: Steiner, K.L., ed. Diversity and adaptation in oak species. Proceedings of the 2[d] meeting of IUFRO working party 2.08.05. University Park, PA: Pennsylvania State University: 194-200.

Olson, D.F., Jr. 1974. *Quercus* L. oak. In: Schopmeyer, C.S., tech. coord. Seeds of woody plants in the United States. Handb. 450. Washington, DC: U.S. Department of Agriculture, Forest Service: 692-703.

U.S. Department of Agriculture. 1974. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture. 883 p.

Zimmerman, M.H.; Brown, C.L. 1971. Trees: structure and function. New York: Springer-Verlag. 336 p.