

SURVIVAL AND GROWTH OF A *QUERCUS RUBRA* REGENERATION COHORT DURING FIVE YEARS FOLLOWING MASTING

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Post-harvest regeneration of oak in the mid-Atlantic region is often limited by an insufficiency of numbers and size of advance reproduction seedlings. In Pennsylvania, this problem is sometimes (but not always) associated with a dense ground cover of ferns that appears to inhibit tree seedling growth, both before and after harvest. An unnaturally dense population of white-tailed deer is at least partly to blame for weak levels of oak advance reproduction, and the paucity of low woody vegetation occasioned by deer browsing may contribute to the abundance of fern growth in some stands. This suggests the hypothesis that, in many mature hardwood stands, deer browsing has tipped the competitive balance between ferns and understory woody plants (including tree regeneration), with the result that the scarcity and small size of woody plant regeneration is both a cause and an effect of profuse fern growth.

If this hypothesis is correct, then what happens to seedlings that germinate under a fern cover and are protected from browsing? Can they survive and grow sufficiently to eventually dominate the fern, or do both deer browsing and fern competition need to be controlled to permit tree seedlings to establish? In this study we followed two "reproduction cohorts" for five years, from the time of masting in early autumn of 1990 until early autumn 1995. The objectives were 1) to document losses at various stages of the reproduction process and 2) to determine the ability of unbrowsed seedlings to grow out of dense fern ground cover.

The study was performed in two stands located 2.6 miles from one another on Moshannon State Forest in central Pennsylvania. Both stands were about 75 to 80 years of age at the beginning of the study. In the "Smith Road" stand northern red oak (NRO) represented 68 percent of the 96 ft²/acre basal area, and the forest floor was 43 percent covered with herbaceous vegetation (bracken fern, *Pteridium aquilinum*, and hayscented fern, *Dennstaedtia punctilobula*) and 19 percent covered with woody vegetation (predominantly *Vaccinium* spp.). In the "Firebreak" stand NRO represented 48 percent of the 139 ft²/acre basal area, and the forest floor was 65 percent covered with herbaceous vegetation (predominantly hayscented fern) with negligible woody ground cover. Site indices of the two stands are 63 and 73 ft, respectively. Advance reproduction of NRO for these stands in any

given year has been one to a few thousand, with no seedlings observed in excess of 30 cm in height. More information on these stands may be found in Steiner and others (1993).

The study reported here was prompted by heavy mast crops in both stands in 1990. Acorn production, autumn removals by vertebrates, and viability loss caused by insect or disease injury were determined by sampling as described by Steiner (1995). Winter removals by vertebrates were determined indirectly by the difference between potential germinants in November and actual germinants in May of the following year. Immediate post-germination losses (to both insects and vertebrate predation) were determined by successive visits in May and June. In June of 1991, 400 (200 per stand) first-year NRO seedlings were located, mapped, labeled, and measured for height. Study seedlings were fairly evenly scattered over an area of about 4 acres at each site but all were located within fern ground cover. To permit an examination of growth and survival in the presence and absence of deer browsing, half (100) of the study seedlings in each stand were protected by means of a 3.25 x 36-inch tubular plastic net (sold as a "Rigid Seedling Protector Tube") supported by two bamboo stakes. This material casts a measured 11 percent shade. Seedling heights and survival were determined 1.0, 1.5, 2.0, and 4.5 years after germination (up to 5.0 years following masting). Stand canopies remained essentially intact over the course of the study.

Survival of the reproduction cohort from fall 1990 until fall 1995 is shown in Table 1, and height growth of protected and unprotected seedlings is shown in Table 2. In general, the two stands were very similar in their overall pattern of acorn loss and seedling mortality, so only mean values will be presented. Of the average regeneration cohort of 141,075 filled acorns per acre, 90 percent were destroyed or consumed before germination in spring 1991 (as quantified in May), and 99 percent were lost by the end of the fifth growing season. Pre-germination losses to insects or disease (not tabulated separately in Table 1) accounted for an average of only 2.2 percent of the acorn crop. Some unquantified losses to insects occurred immediately after germination, but total cohort mortality attributable to insects or disease was no more than 11.2 percent and probably less.

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Table 1—Survival over 5 years of NRO reproduction cohorts in two Pennsylvania stands, beginning at masting in 1990

	Smith Road			Firebreak		Mean	
	Year	Number	Percent	Number	Percent	Number	Percent
Fall 1990 ^a	0	198,510	100	83,640	100	141,075	100
May 1991 ^b	0.5	23,390	11.78	5,130	6.13	14,260	10.11
June 1991 ^c		2,548	1.28	667	0.80	1,608	1.14
Spring 1992	1.5	1,631	0.82	360	0.43	995	0.71
Fall 1992	2.0	1,554	0.78	340	0.41	947	0.67
Spring 1993	2.5	1,249	0.63	240	0.004	360	0.26

^a Production of filled acorns (with naturally abscised caps), representing initial size of the reproduction cohort.

^b Percentage germination after losses to insects, disease, and consumption by vertebrates.

^c Seedling survival after immediate post-germination losses to insects and disease, and consumption by vertebrates. Subsequent survival figures are based on marked, unprotected seedlings selected in June 1991.

Table 2—Heights (cm) of advance reproduction of NRO in two Pennsylvania stands in June of first growing season (when protectors were installed) and after 1, 2, and 5 growing seasons, protected and unprotected against browsing by white-tailed deer

Seedling age	Smith Road		Firebreak	
	Unprotected	Protected	Unprotected	Protected
Years				
0	10.40 b	9.04 a	12.67 c	13.33 c
1	10.48 a	10.69 a	11.38 a	14.93 b
2	11.61 a	12.36 a	12.44 a	15.88 b
5	10.85 a	12.72 a	10.00 a	15.28 b

Means within a row not sharing the letter notation are significantly different at $P < 0.05$.

Fall and winter consumption (or removals) of acorns by vertebrates accounted for an average of 87.7 percent of the cohort. Among the animals known to consume NRO acorns in Pennsylvania are white-tailed deer, black bear, gray squirrel, white-footed mice, wild turkey, and ruffed grouse. However, deer were probably the major consumer of acorns in these stands for reasons discussed by Steiner (1995). Of 14,260 germinated seedlings per acre, only 995 (7.0 percent) were still alive after 12 months and only 360 (2.5 percent) were surviving after five growing seasons.

From June 1991 (when seedling protectors were installed) until the termination of the study in September 1995, survival was 72.3 percent for protected seedlings and 15.8 percent for unprotected seedlings (a significant difference

at $P < 0.05$), indicating approximately 28 percent mortality over five growing seasons from causes other than deer browsing and approximately 56 percent additional mortality from deer browsing. Seedlings exposed to deer browsing exhibited no net height growth between 1991 and 1995 and even became significantly shorter at Firebreak. Seedlings protected from deer browsing grew a small (but statistically significant) amount before age 2 years, but the seedlings were no taller at age 5 than at age 2. Of 400 marked seedlings, the tallest after five growing seasons was only 28 cm in height, and no seedling emerged from the fern cover.

The following are our conclusions:

- Despite an unusually large crop of acorns in both stands, advance reproduction after five years was inadequate in terms of quantity and size of seedlings.
- Survival of the reproduction cohort as a function of time since masting resembles a negative power function: only 10.1 percent of the cohort still survived at approximately the time of germination (7 months after masting), 0.7 percent survived at seedling age 1 (19 months after masting), and 0.3 percent survived at the end of the study (60 months after masting). In other words, losses occurred very rapidly at first and more and more slowly as time went on.
- The failure of advance reproduction to develop in these stands is overwhelmingly attributable to mammal and bird consumption of *acorns*, since the majority (87.7 percent) of the reproduction cohort was lost in this manner. Circumstantial evidence indicates that deer are the major single factor in this loss. By contrast, only a small fraction of the entire reproduction cohort (0.6 percent in this study) was lost because of browsing of *seedlings* after mid-summer of the first year.
- Although seedlings protected from deer had 72 percent survival after five growing seasons, they exhibited little

increase in height after June of the first year and none after age 2. In oak stands with a heavy ground cover of fern, deer fencing alone will not permit the development of strong advance reproduction. At a minimum, control of the ferns in addition to deer fencing will be necessary if the goal is to establish advance reproduction of NRO. A light thinning of the canopy may be necessary as well.

REFERENCES

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