Effects of Fire Intensity on Competitive Dynamics Between Red and Black Oaks and Mountain Laurel

W. Keith Moser, Mark J. Ducey, *and* **P. Mark S. Ashton,**
Yale School of Forestry and Environmental Studies, 360 Prospect Street, New Haven, CT 06511.

ABSTRACT. *We investigated the competitive response of oak and mountain laurel to prescribed fire on two sites in northeastern Connecticut. After nearly a decade, the competitive position of oak on moderately burned portions of both sites was little better, and in some respects worse, than on adjacent unburned controls. However, on portions of both sites where fire had killed much of the overstory, oak regrowth was vigorous and had escaped the dense mountain laurel layer. The results suggest that light understory fires alone are not sufficient for oak regeneration, and that prescribed fire should be used only as part of an integrated strategy involving harvesting of the overstory. Ecologically, the results point to the importance of severe disturbances in maintaining the structure and function of oak ecosystems. North. J. Appl. For. 13(3):119–123.*

Although oaks form a significant portion of the overstory across much of their range in North America, successful oak regeneration has remained an elusive silvicultural goal in many ecosystems (Hannah 1987, Crow 1988, Abrams 1992). Fire, which is not a major feature of modern forest landscapes in the northeastern United States, appears to have been an important factor promoting oak dominance in both pre- and postsettlement forests (Abrams 1992). Despite some disagreement, a broad range of ecological and historical studies suggests early upland forests in the Northeast experienced understory fires with a return period between 1 yr and 15 yr (Day 1953, Buell et al. 1954, Little 1974, Russell 1983), although fire regimes may shift with both cultural changes and changes in the physical climate (Thompson and Smith 1970, Overpeck et al. 1990, 1991). Numerous authors have suggested that an absence of fire limits oak regeneration (Lorimer 1984, Host et al. 1987, Abrams and Nowacki 1992), while other authors have pointed to a broad range of problems with shrub competition and the accumulation of shade-tolerants in the understory (Hannah 1987, Crow 1988, Lorimer et al. 1994). However, experiences with prescribed fire in northeastern oak forests have been mixed (Niering et al. 1970, Nyland et al. 1982, Wendel and Smith 1986, Boerner et al. 1988).

An understory shrub of particular management concern in southern New England is mountain laurel. Mountain laurel's high shade-tolerance and aggressive vegetative growth habit make it a stern competitor for oaks on a variety of sites (Chapman 1950). In this study, we examined the results of two controlled burns on the competitive dynamics between red and black oaks and mountain laurel. The hypothesis driving the burns was that forcing the laurel to resprout from the ground surface would "level the playing field," allowing oak seedlings to gain a height advantage and eventually reach sufficient size to allow successful stand regeneration.

Study Area and Methods

Two sites were studied, both on the Yale-Myers Forest in northeastern Connecticut. Both sites were approximately 8 ac in size. Before the initial treatment, each site had been a single stand, with a dense understory of large mountain laurel, including numerous stems > 2 in. and over 6 ft in height. Prescribed burns were carried out during the spring on

NOTE: The authors thank Yale University and the Yale Forest for support during this research. W. Keith Moser's current address is Tall Timbers Research, Inc., Rte. 1, Box 678, Tallahassee, FL 32312. This research was sponsored by the U.S. Department of Energy, Office of Energy Research, Environmental Sciences Division, Office of Health and Environmental Research, under appointment to the Graduate Fellowships for Global Change administered by Oak Ridge Institute for Science and Education. Dr. David M. Smith and two anonymous reviewers provided valuable comments.

half of each site the Red Front site was burned in 1985, and the Buell Brook site in 1984. On both sites, the fire burned more intensely than planned on half of the burned area, resulting in near elimination of the overstory.

The Red Front site is located on well-drained and somewhat excessively well-drained Charlton-Hollis fine sandy loams (USDA 1981). At the time of the initial treatment in 1985, the stand was approximately 70 yr old. The prefire canopy had a basal area of 140 ft^2/ac, with a density of 225 stems/ac > 2 in., excluding mountain laurel. Species composition was dominated by black oak, white pine, white oak, and black birch. On the lightly burned portion of the stand, 40% of the basal area and 30% of the density were eliminated, chiefly due to girdling of the smaller stems. On the severely burned area, basal area, and density were reduced by 60% and 70%, respectively.

The Buell Brook site is located on moderately well drained Woodbridge extremely stony fine sandy loam (USDA 1981). The stand was 80 yr old at the time of treatment in 1984. The prefire canopy had a basal area of 165 ft^2/ac and 425 stems/ac > 2 in, and was dominated by northern red oak, white oak, black birch, and red maple. Little overstory mortality occurred on the lightly burned area, although scarring of some trees was evident. However, on the severely burned portion, basal area and density were reduced by over 95%.

We measured oak and mountain laurel regrowth on both sites during the 1993 growing season, as part of a broad study on fire and understory dynamics (Ducey et al. 1996). The three areas of each site (unburned control, moderate burn with little overstory damage, and severe burn with heavy overstory damage) were delineated, and four points were located systematically in each area. Around each point, four milacre plots aligned on the cardinal directions were used to estimate the height distribution of oak and mountain laurel. We measured the height of all individuals to the nearest 0.5 in., defining an individual as a group of stems either connected aboveground or by belowground parts discernible through vigorous shaking. We then divided a 1/50th ac circular plot centered on the plot point into quarters. On each 1/200th ac quarter, we measured the total height and basal diameter of the tallest red or black oak seedling and its tallest direct mountain laurel competitor, and removed basal sections which were aged in the laboratory under a microscope. Sections were not taken for first-year seedlings. If no mountain laurel was judged sufficiently close to shade the seedling or be shaded by it, or if no oaks were present on the 1/200th ac quarter, then no mountain laurel sample was taken.

Data from the plot quarters were analyzed in two ways. First, each quarter was classed in a table by two factors: presence or absence of oak, and dominance by oak or mountain laurel, based on height. If oak was absent, then the quarter was classed as laurel-dominated; the class of oak absent but dominant formed a structural zero in the table. The table was analyzed with site and treatment as dependent variables using maximum-likelihood logistic analysis for stratified samples; contrasts were Bonferonni-adjusted (SAS, SAS Inst, 1990) The second analysis involved calculating the mean annual height and basal diameter increment for the paired oak and mountain laurel, to assess the relative rates of growth of the two species Differences within treatments were assessed using Wilcoxon's signed rank test, and treatments were compared using the Kruskal-Wallis test. Both tests were Bonferonni-adjusted for multiple comparisons (SAS, SAS Inst. 1990).

Results

Density and stocking of oak on the milacre plots are shown in Table 1. The height distribution of oaks and mountain laurel based on the milacre plots is shown in Figure 1 Although the number of oaks observed was too small to permit rigorous statistical analysis, some qualitative features are common to both sites. First is the wide variability in size of mountain laurel, with large numbers of tall stems on the control plots. While the overall height of the mountain laurel was reduced on the moderately burned plots, so was that of the oaks. However, on the plots with heavy overstory damage, both oak and mountain laurel experienced more rapid regrowth, and the tallest oaks are bigger than the tallest mountain laurel. This effect is greatest on the Buell Brook site, which is more mesic and had the highest overstory mortality. Only severely burned plots had oaks over 4.5 ft tall

Presence and dominance of oak on the quarter plots is shown in Table 2. Stand effects and stand-treatment interactions were not statistically significant (likelihood ratio chi-square 8.78, 6 df, $P > 0.05$). However, overall treatment effects were highly significant (likelihood ratio chi-square 81.04, 6 df, $P < 0.0001$). Contrasts indicated that the control and moderate burns were not significantly different (chi-square 5.29, 2 df, $P > 0.05$). However, both control and moderate burns were significantly different from the severe burn (chi-square 20.21 and 11.01, 2 df, $P < 0.0001$ and $P < 0.05$, respectively).

Averages for mean annual height increment and mean annual diameter increment are shown in Figure 2 and Figure 3. Oak ages on the control plot quarters ranged from 1 to 18 yr old; mountain laurel ages ranged from 8 to 57. On the severely burned quarters, both oak and laurel showed rapid sprout re-establishment, with all laurel and all but one oak dating within 3 yr following disturbance. No oaks predated

Table 1. Density and stocking of red and black oaks by site and treatment.

Site and treatment	Density, #/ac	Stocking, all oak	% milacres oak >4.5'
Red Front			
Control	440	31	0
Moderate burn	310	25	0
Severe burn	1,500	63	6
Buell Brook			
Control	810	31	0
Moderate burn	2,600	75	0
Severe burn	10,100	100	69

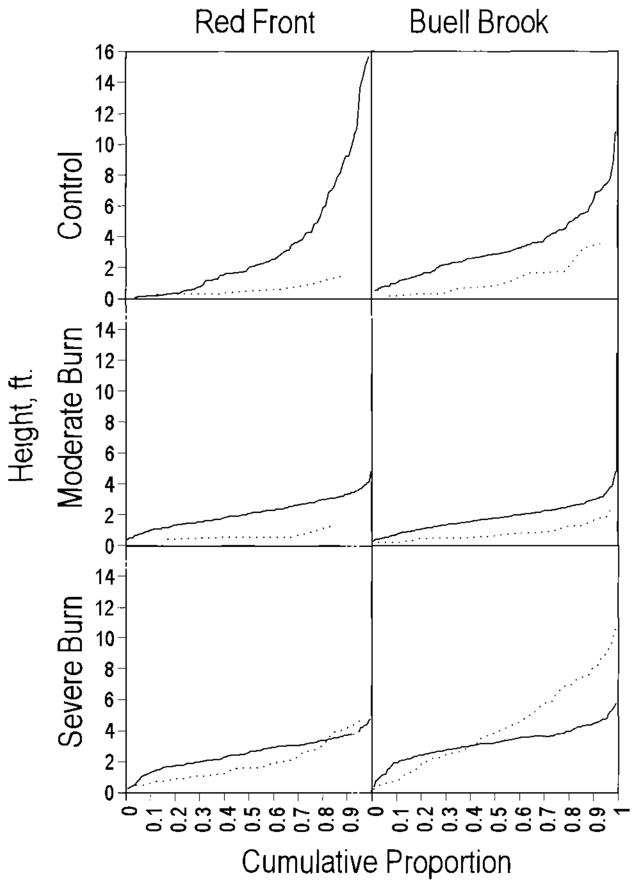

Figure 1. Height distribution of red and black oak (·····) and mountain laurel (——) by site and treatment.

the fire. Age distributions were similar on the moderately burned quarters, except that 30% of oaks were 2 yr old or younger. Most large oaks on the burned plots were resprouted advance growth.

Discussion and Applications

The combination of stocking, species height distributions, and the ages of the oak and mountain laurel indicate that the initial hypothesis behind the burns was incorrect. While burning did "level the playing field," on the plots where the burn went as planned, mountain laurel still won. It is only on the plots where significant amounts of sunlight were released to the forest floor that oak was able to compete effectively.

Table 2. Presence and dominance of oak on 1/200th ac quarter plots, by site and treatment.

Site and treatment	Oak present, oak dominant	Oak present, laurel dominant	Oak absent, laurel dominant
Red Front			
Control	6	38	56
Moderate Burn	13	44	44
Severe Burn	94	0	6
Buell Brook			
Control	6	50	44
Moderate Burn	31	63	6
Severe Burn	100	0	0

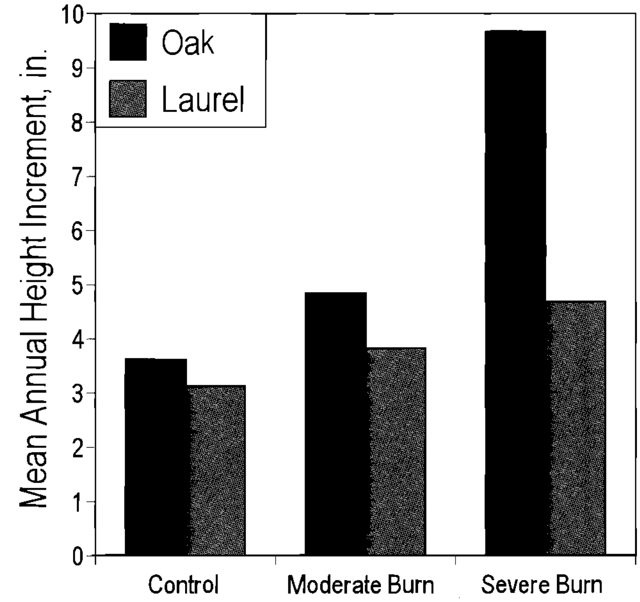

Figure 2. Mean annual height increment of oak and mountain laurel. Differences between oak and mountain laurel are significant only for the severe burn (Wilcoxon's signed rank test: severe burn, $P < 0.001$; control and moderate burn, $P < 0.05$). Differences between treatments are significant for both oak and mountain laurel (Kruskal-Wallis test: oak, $P < 0.001$; laurel, $P < 0.01$).

This is true despite the fact that mountain laurel itself grew best on the open plots (Figure 2 and 3); there is no evidence either that mountain laurel was strongly set back by severe fire, or that it is hampered in any way by the high light levels now on these sites. In this context, laurel can be seen as shade-tolerant rather than shade-demanding.

Table 2 indicates the ineffectiveness of burning alone as a strategy for controlling mountain laurel and enhancing oak

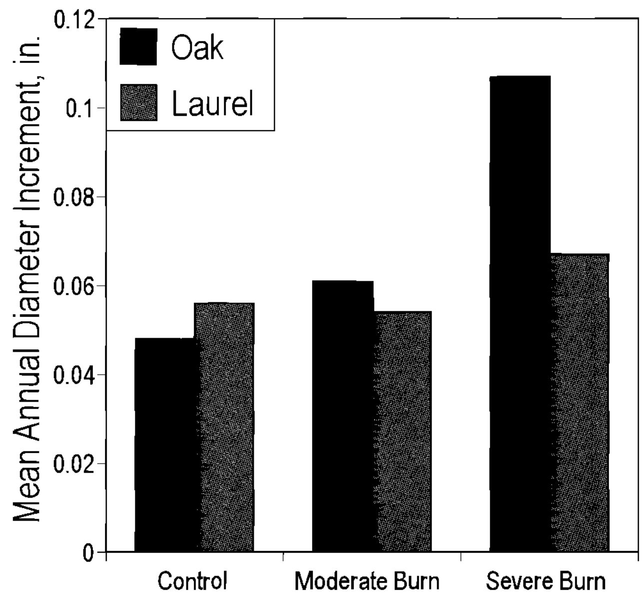

Figure 3. Mean annual diameter increment at root collar of oak and mountain laurel. Differences between oak and mountain laurel are significant for both burned treatments (Wilcoxon's signed rank test: control, $P < 0.05$; moderate burn, $P < 0.05$; severe burn, $P < 0.001$). Differences between treatments are significant for both oak and mountain laurel (Kruskal-Wallis test: oak, $P < 0.001$; laurel, $P < 0.05$).

reproduction. While stocking and dominance of oak on the quarter plots did show a small, nonsignificant improvement from the control to the moderately burned plots, both the size of the oaks and the proportion of the ground surface on which oak is free to grow are inadequate for successful regeneration of the stand. No oaks observed on the moderately burned plots exceeded Sander's (1972) 4.5 ft size criterion, indicating likely regeneration failure if the overstory were harvested now. Furthermore, the large fraction of plot quarters on which the largest oaks are only first or second year seedlings indicates oak may be having difficulty persisting on the moderately burned sites; many of these oaks were dead or absent on subsequent site visits. Chapman (1950) and Kittredge and Ashton (1992) observed that oak regeneration persisted well in the gaps between clumps of large mountain laurel. However, on the moderately burned sites, the large, clumped structure typical of the controls was replaced by an extremely dense, monolayer structure with few gaps. Thus, burning may have created an environment more hostile to oak establishment than that previously on the site. These results are consistent with those of Nyland et al. (1982), who considered that single burns are not likely to enhance oak recruitment significantly. Given the lack of apparent harm to the mountain laurel, we hypothesize that even repeated burns may not be sufficient to control understory densities and improve the competitive position of oak.

By contrast, on the open plots, the size and stocking of oak indicate that it will probably dominate the next stand, despite the fact that stocking was inadequate before overstory mortality. This result is surprising given the importance of large advanced regeneration to oak success under most circumstances (Sander 1972, Crow 1988, Smith and Ashton 1993). While much of the growth increase can be explained by increased light availability, it is possible that increased nutrient availability following fire is a contributing factor (Boerner et al. 1988, Gilliam 1988). Certainly, in a high light environment, oak should be able to allocate a greater fraction of its biomass to roots, and thus better take advantage of any nutrient pulse which occurs (Tilman 1988).

From a management standpoint, prescribed fire is not a sufficient condition for obtaining good advanced regeneration of oak. While fire can temporarily reduce the quantity and cover of competing species, if the conditions favoring development of a dense, shade-tolerant understory remain in place after the fire, then oak will find no advantage. However, fire may play an important supporting role in the context of harvests designed to reduce overstory density and allow oak establishment. Here, the surprising success of oak following overstory mortality in our study suggests that fire may enhance oak vigor above and beyond that expected in normal harvesting. However, it may be that less risky and expensive measures, such as deliberate crushing of mountain laurel with skidders, may provide a sufficient advantage to oak. A controlled comparison of fire with mechanical treatments for laurel control would help fill this knowledge gap.

Lorimer et al. (1994) assert that the mechanism by which fire enhances oak survival and growth is unclear, but point to the importance of competition in the understory. Based on these results, we suggest that the role of fire as a disturbance is to release total growing space (Oliver and Larson 1990) Where the overstory is still sufficiently dense to inhibit oak growth relative to that of its competitors, fire will not confer an advantage. If the effect of fire is primarily indirect (Lorimer et al. 1994), i.e., competition reduction and increased resource availability rather than some physiological bonus, then other types of disturbance may suffice. This view may help explain the mixed record of fire as a management tool in oak forests (Niering et al. 1970, Nyland et al. 1982, Wendel and Smith 1986, Boerner et al. 1988). It also emphasizes the important role of severe disturbances, both natural and human-induced, in determining the structure and diversity of oak ecosystems (Abrams 1992, Reice 1994).

Literature Cited

ABRAMS, M.D. 1992. Fire and the development of oak forests. Bioscience 42:346–353.

ABRAMS, M.D., AND G.J. NOWACKI. 1992. Historical variation in fire, oak recruitment and post-logging accelerated succession in central Pennsylvania. Bull. Torrey Bot. Club 119:19–28.

BOERNER, R.E.J., T.R. LORD, AND J.C. PETERSON. 1988. Prescribed burning in the oak-pine forest of the New Jersey Pine Barrens: Effects on growth and nutrient dynamics of two *Quercus* species. Am. Midl Nat. 120:108–119.

BUELL, M.F., H.F. BUELL, AND J.A. SMALL. 1954. Fire in the history of Mettler's Woods. Bull. Torrey Bot. Club 81:253–255.

CHAPMAN, G.L. 1950. The influence of mountain laurel undergrowth on environmental conditions and oak reproduction. Ph.D. diss., Yale Univ., New Haven, CT. 157 p.

CROW, T.R. 1988. Reproductive mode and mechanisms for self-replacement of Northern Red Oak (*Quercus rubra*)—a review. For. Sci 34:19–40.

DAY, G.M. 1953. The Indian as an ecological factor in the northeastern forest. Ecol. 34: 329–346.

DUCEY, M.J., W K. MOSER, AND P.M.S. ASHTON. 1996. Effect of fire intensity on understory composition and diversity in a *Kalmia*-dominated oak forest. Vegetatio 123:81–90.

GILLIAM, F.S. 1988. Interactions of fire with nutrients in the herbaceous layer of a nutrient-poor Coastal Plain forest. Bull. Torrey Bot. Club 115:265–271.

HANNAH, P.R. 1987. Regeneration methods for oaks. North. J. Appl. For 4:97–101.

HOST, G.E., K.S. PREGITZER, D.W. RAMM, J.B. HART, AND D.T. CLELAND 1987. Landform-mediated differences in successional pathways among upland forest ecosystems in northwestern Lower Michigan For. Sci. 33:445–457.

KITTREDGE, D.B., JR., AND P.M.S. ASHTON. 1990. Natural regeneration patterns in even-aged mixed-species stands in southern New England, U.S.A. North. J. Appl. For. 7:163–168.

LITTLE, S. 1974. Effects of fire on temperate forests: Northeastern United States. P. 225–250 in Fire and Ecosystems. Academic Press, New York.

LORIMER, C.G. 1984. Development of the red maple understory in northeastern oak forests. *For. Sci.* 30: 3–22.

LORIMER, C.G., J.W. CHAPMAN, AND W.D. LAMBERT. 1994. Tall understorey vegetation as a factor in the poor development of oak seedlings beneath mature stands. J. Ecol. 82:227–237.

NIERING, W.A., R.H. GOODWIN, AND S. TAYLOR. 1970. Prescribed burning in southern New England: introduction to long-range studies. Proc Annual Tall Timbers Fire Ecol. Conf. 10:267–286.

NYLAND, R.D., L.P. ABRAHAMSON, AND K.B. ADAMS. 1982. Use of prescribed fire for regenerating red and white oak in New York. P. 164–167 *in* Proc. Soc. Am. For., Soc. Am. For., Bethesda, MD.

OVERPECK, J.T., P.J. BARTLEIN, AND T. WEBB III. 1991. Potential magnitude of future vegetation change in eastern North America: Comparisons with the past. Sci. 254:692–695.

OVERPECK, J.T., D. RIND, AND R. GOUDBERG. 1990. Climate-induced changes in forest disturbance and vegetation. Nature 343:51–53.

OLIVER, C.D., AND B.C. LARSON. 1990. Forest Stand Dynamics. McGraw-Hill, New York.

Reice, S R 1994 Nonequilibrium determinants of biological community structure. Am. Sci. 82:424–435.
Russell, E.W.B. 1983. Indian-set fires in the forests of the northeastern United States. Ecol. 64:78–88.
Sander, I.L. 1972. Size of oak advance reproduction: Key to growth following harvest cutting. USDA For. Serv. Res. Pap. NC-79. 6 p.
SAS Institute. 1990. SAS/STAT User's Guide, Vol. 2. Ed. 4. SAS Inst., Cary, NC.
Smith, D.M., and P.M.S. Ashton. 1993. Early dominance of pioneer hardwood after clearcutting and removal of advanced regeneration. North. J. Appl. For. 10:14–19.
Thompson, D Q, and R H Smith 1970 The forest primeval in the Northeast—a great myth? Proc. Annual Tall Timbers Fire Ecol. Conf. 10:255–265.
Tilman, D. 1988. Dynamics and Structure of Plant Communities. Monogr. *in* Population Biology 26. Princeton University Press.
USDA 1981. Soil Survey of Windham County, Connecticut. USDA, Soil Conserv. Serv., coop. with Conn. Agric. Exp. Stn. and Storrs Agric. Exp. Sta.
Wendel, G.W., and H.C. Smith. 1986. Effects of a prescribed fire in a central Appalachian oak-hickory stand. USDA For. Serv. Res. Pap. NE-594.