Prescribed Burning in Southern New England: Introduction to Long-Range Studies

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IN 1967 LONG-RANGE studies were initiated in the Connecticut Arboretum on the vegetation dynamics of physically and chemically manipulated areas. One aspect of this research involves the controlled use of fire in representative vegetation types.

Since prescribed burning is a standard silvicultural practice in the Southeast, extending as far north as the Pine Barrens of New Jersey, it was considered of ecological interest to test the effects of such burns on representative vegetation types in southern New England. The aims of this research are to assess the role of controlled burning in modifying floristic composition, soil nutrient regime and microclimate. It is anticipated that the following questions will be answered in the course of this study. Is little blue-stem grassland perpetuated by fire and what effects do annual burns have on its productivity? By frequent controlled fires can one create open, park-like forests which have been reported to be typical of the Indian period? What effects will periodic removal of accumulated leaf litter have on tree reproduction and the establishment of herbaceous species, especially the rich assemblage of vernal perennials so typical of the eastern deciduous forests?

Historically, the oak forests of the Northeast have been subjected to natural fires for thousands of years. Such fires were of lightning or Indian origin, the latter set either accidentally or intentionally. That periodic Indian fires were a normal part of the forest history of southern New England is well documented (Morton, 1632; Hawes, 1923; Bromley, 1935; Byers, 1946; Day, 1953). Such fires cleared the underbrush, thereby facilitating hunting and movement through the forests. Burning also favored a grassy ground cover, probably *Agrostis hyemalis*, which served to attract deer. Such fires also favored the more fire-resistent oaks while the more fire-sensitive species were restricted to the moist lower slopes or swampy sites. This is the vegetation pattern Morton (1632) described in the early 1600's in southern New England. Although annual burning has been reported, the intervals between such fires may have been as long as 10 years, as indicated by tree ring studies on mature oak from Mettler's Woods, New Jersey (Buell *et al.*, 1954). In southern New England the advent of forest fire protection at the turn of the century initiated a new era. Forests previously subjected to fire were protected; leaf litter accumulated; and, when started, a fire caused severe damage to the forests.

In this project, nine study areas have been established. Six are located within the Connecticut Arboretum at Connecticut College, two within the Pachaug State Forest, and one within the Nehantic State Forest. All of these lie within 18 miles of New London and 20 miles of the coast.

Within the Eastern Highlands of Connecticut, the underlying bedrock is composed primarily of granite and gneisses of complex origin. Over most of the region sandy loam soils have developed from the ground moraine. Locally, where temporary glacial lakes occurred, the soils are of coarser sandy texture. The regional forest vegetation is characterized by sprout oak or central hardwoods forests. The dominant trees include various oaks: red (*Quercus rubra*), white (Q. *alba*), black (Q. *velutina*), and scarlet (Q. *coccinea*). Frequent associates are hickory (*Carya tomentosa, C. ovata,* *C. glabra*), black birch (*Betula lenta*), and red maple (*Acer rubrum*). Hemlock (*Tsuga canadensis*), and beech (*Fagus grandifolia*) though associated with the hardwoods, are restricted to those sites without a recent fire history. Cutting and fire have been widespread throughout the region. In 1840, 70 percent of southern New England had been cleared for agriculture. At present, about 63 percent of the State has returned to forest (Thomson, 1958).

The purpose of this paper is to describe certain of the initial results obtained during the first 3 years of the project.

DESCRIPTION OF STUDY AREAS

Three old fields and three forest study areas were permanently established in 1967. All the fields and two of the forest communities were located within the Arboretum; one forest stand in the Pachaug State Forest. The Arboretum study areas were all of post-agricultural origin and underlain by sandy loam soils. In contrast, the Pachaug stand, presumably never cleared for agriculture, is the most xeric site and is underlain by coarser sandy soils. Its inclusion permits an evaluation of the differential effects of light burns on white and pitch pine—both present in the stand, and may provide further insights as to how to improve site conditions for better stocking of white pine. In 1968 a red pine plantation was added to the study in order to evaluate the role of fire as a possible factor in arresting red pine root rot caused by *Fomes annosus,* that so frequently strikes these plantations after they reach 30 to 40 years of age. In 1969-70 two additional forest areas were added—a lower-slope post-agricultural hardwoods stand in the Arboretum and a relatively mature post-agricultural forest in the Nehantic State Forest. The latter has not yet been burned. Descriptions that follow will be restricted to areas initially established. Each of the nine experimental areas consists of two experimental plots—a burn and a contiguous control.

Andropogon Grasslands

These post-agricultural lands have been abandoned from pasture since the late 1920's and are still relatively open, due to periodic, unintentional fires, the most recent having occurred in 1965 on the Avery Tract, and in 1966 on the Matthies Tract. At least one of these areas was used by the military during World War II, resulting in a slight modification of the micro-relief. During the past decade, removal of black cherry (*Prunus serotina*) by basal-bark herbicide techniques arrested early forest development. In 1967 the remaining cherry were removed and the stumps sprayed with herbicide. Little bluestem (*Andropogon scoparius*) forms a relatively continuous grassland, except where the cherry formerly occurred. Here the little bluestem is replaced by patches of redtop (*Agrostis alba*), goldenrod (*Solidago rugosa*) and sedge (*Carex pensylvanica*), and woody reproduction, especially cherry. The distinctive forbs occurring between the clumps of little bluestem are aster (*Aster linariifolius*), wild indigo (*Baptisia tinctoria*) and sheep sorrel (*Rumex Acetosella*), their occurrence ranging from frequent to rare in the three study areas. Occasional patches of the hair-cap moss (*Polytrichum*) and lichens also occur between the grass tussocks. Coverage of woody species varies from 5 to 25 percent. It is restricted primarily to shrub clones of huckleberry (*Gaylussacia baccata*), bayberry (*Myrica pensylvanica*), sweetfern (*Comptonia peregrina*), and sumac (*Rhus copallina*) and occasional cherry saplings or sprouts less than 3 feet high.

Forest

The two forested areas designated as the oak-cherry and oak-birch stands are located on easterly facing slopes in the Arboretum along the Thames River. The oak-cherry stand has developed in an old pasture, adjacent to a stone fence lined with large, open-grown black oaks which served as a ready seed source. It is now a young black oak forest with a conspicuous understory of black cherry. The larger trees of sprout origin, 8 to 12 inches dbh, range from 20 to 35 years of age. Shrub and herb strata are practically absent. Poison ivy (*Rhus radicans*) and a few scattered low-bush blueberry (*Vaccinium vacillans*) clones contribute less than one percent cover. The low sub-shrub, spotted wintergreen (*Chimaphila maculata*), though the most conspicuous ground cover, also represents less than

FIG. 1. The oak-black birch stand burned in 1968 and 1970 (Avery Tract, Burn Plot L). Most of the smaller trees on the ground are black birch killed during the first burn. Photo, December 1970.

one percent coverage. Oak leaf litter, reaching 7 cm in depth, overlies the mineral soil.

The oak-birch forest on the Avery Tract (Fig. 1) is dominated by black, red, and white oaks, in this order of abundance. Black birch is an important associate. The oaks are 6 to 12 inches dbh with scattered large specimens up to 18 inches. The birch is mostly less than 6 inches dbh. In the understory flowering dogwood and transgressives of hickory are frequent; beech is rare. The dominant shrub, greenbrier, covers 20 percent of the burn plot and twice this area in the control. This species, which is typical of open, post-agricultural sites, is decreasing in importance with closure of the tree canopy. Herbs contribute less than 1 percent coverage. Those present, in order of frequency, include spotted wintergreen, goldenrod (*Solidago caesia*) and sedges. The oak leaf litter is continuous and ranges from 2 to 7 cm in depth. Scattered red cedar snags and stumps indicate more open site conditions in the past. Increment borings indicate that this stand has developed over the past 40 years.

The oak-pine woodland in the Pachaug State Forest represents one of the more mature white oak stands that develops on these excessively drained sandy soils. Oaks, primarily white, form the dominant aspect, with trees up to 10 inches dbh. Increment borings indicate the larger trees to be 40 to 50 years old. White pine and pitch pine are both conspicuous associates, the former most frequent as saplings and transgressives less than 1 to 2 inches dbh. Scattered seedlings of both species occur. The shrub layer is poorly developed, with localized clones of huckleberry, bayberry, bearberry (*Arctostaphylos Uva-ursi*) and low-bush blueberry. Accumulation of leaf litter within the blueberry clones appears to be smothering this species. Ground cover is sparse. Locally, ground pine (*Lycopodium*) forms a relatively continuous cover. This mixed stand was understocked with white pine, but situated adjacent to a stand of large white pine, which might serve as a future seed source. It was thought that a good seed year combined with favorable seed-bed conditions following prescribed burning might favor further pine establishment. Subjecting pine transgressives in such a stand to prescribed burning would also permit an analysis of the sensitivity of a conifer considered relatively intolerant of fire.

METHODS

Burn and contiguous control plots were established in each experimental area and were as nearly comparable in size as site conditions would permit. In most cases plots were a minimum of 0.1 hectares. Comparable data were taken in the burn and control plots. All preburn data were taken during the summer of 1967. Permanent transects were laid out across the plots with pipes marking the two ends of the line. Transects 2.5 to 5 m apart and ranging from 10 to 50 m in length were established in each plot. A series of 0.5 $\times$ 2 m quadrats, in which density and cover of herbaceous vegetation and tree and shrub reproduction were analyzed, were laid out on alternate sides of the transects. To obtain productivity data in the fields herbaceous vegetation was harvested at the end of the growing season by clipping up to 15 comparable quadrats.

In forest plots tree and shrub density was analyzed in 10 × 10 m quadrats. The dbh of all trees over 1 inch in diameter were taken. Tree heights and increment borings were taken of representative trees in each stand. In certain Arboretum plots all woody vegetation was actually mapped in order precisely to assess future changes. Herbaceous cover and tree and shrub reproduction were recorded from 0.5 × 2 m quadrats. Plots, quadrats and transects were permanently marked with pipes and located with respect to drill marks in nearby boulders so that they may be relocated, even if pipes are vandalized.

To determine the micro-climatic effects of burning, Taylor min-max mercury thermometers were set up in two pairs of experimental plots, one in the forest and one in the old field. One plot of each pair was burned; the other served as an unburned control. The thermometers were protected from direct sun by shields (Baum, 1949; Cantlon, 1953). They were placed at 5 cm, 20 cm, and 1 m above the soil surface. To record soil temperatures a Palmer min-max soil thermometer was positioned 4 cm below the soil surface at each station, taking care not to disturb the vegetation and litter. Daily high-low temperature readings were taken from April, 1967 to March, 1968. Following the initial burn in March, 1968, readings at the four stations were recorded through November, daily at first and then three times weekly.

Temperatures experienced within the plots during experimental burns were measured by the following methods: (1) steel bars 12 × ⅜ × ⅛ inches marked by Tempilaq melting at temperatures ranging from 125° to 1,000°F laid out along the transect lines on the surface and below the surface of the leaf litter in the forest plots and on the ground and within the tussocks in the old field plots; (2) strips of aluminum foil marked with Tempilaq and laid out in similar manner; (3) an iron-constantan thermocouple connected to a potentiometer reading directly in degrees C and placed in the leaf litter or tussocks (Fig. 2) or inserted in the cambial layer at the base of selected trees. Cambial temperatures were determined by inserting the thermocouple into cambium and covering the incision with a thin layer of putty.

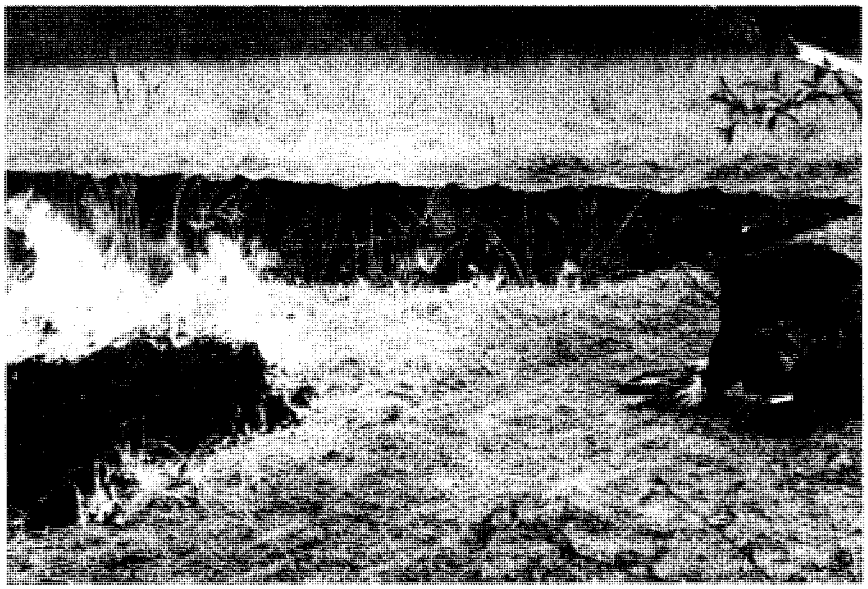

FIG. 2. Recording fire temperature in a clump of little bluestem during the 1970 spring burn (Matthies Tract, Plot A). The thermocouple reading exceeded 750°F for 5 seconds. Control Plot B in background. Photo, May 1970.

In the fall of 1967, prior to burning, replicated soil samples were taken at 0 to 2 inch and 2 to 6 inch depths from burn and control plots. Each sample was derived from 20 soil tube cores made in a randomized pattern along the transects. Analyses for pH, readily dispersible silt and clay fractions, organic matter, cation exchange capacity, total nitrogen, available phosphorus and potassium, and exchangeable calcium and magnesium were carried out by S. A. Wilde and Associates of Madison, Wisconsin. Ten samples were also analyzed for the micro-elements, manganese, boron, zinc and molybdenum. The results of these soil analyses will be reported in a subsequent paper.

EFFECTS OF BURNING

ANDROPOGON GRASSLANDS

The most striking change in the grasslands resulting from the

FIG. 3. Little bluestem field showing control (left) and burned plot (right), following two spring burns, 1968 and 1969. Note the taller, more vigorous aspect of the burned area (Matthies Plots E and F). Photo, Autumn 1969.

initial and subsequent burns has been to produce more floriferous, vigorous and taller stands of *Andropogon* compared to the controls (Fig. 3).

Table 1 summarizes the productivity data following three annual burns. The results indicate that productivity of *Andropogon* increased with burning on one site (Matthies Tract) (Fig. 3), and maintained a relatively stable production on the other more xeric site (Avery Tract) (Fig. 4), as compared to a progressive decrease in dry weight production in the controls. Flower production also dramatically increased with burning. On the Matthies Tract, 245 flower stalks per square meter were recorded in the control, compared to 385 in the burn; on the Avery Tract, comparable figures were 143 in the control, 399 in the burn. Although the *Andropogon* in the control plots was somewhat taller than in the burns in early June, by the end of the growing season maximum height was attained in the burns. Stems in the burned plots were up to 50 cm

TABLE 1. BIOMASS PRODUCTION OF *Andropogon scoparius* FROM THE MATTHIES AND AVERY TRACTS IN THE CONNECTICUT ARBORETUM. DATA ARE GIVEN AS GRAMS DRY WEIGHT PER SQUARE METER (AVERAGE OF QUADRATS SAMPLED), AND AS GRAMS DRY WEIGHT PER ONE PERCENT COVER (c).

	MATTHIES TRACT				AVERY TRACT			
	Burn		Control		Burn		Control	
	Gms./m²	Gms./1%c.	Gms./m²	Gms./1%c.	Gms./m²	Gms./1%c.	Gms./m²	Gms./1%c.
1967 (pre-burn)	244	3.6	343	4.7	278	3.9	251	3.9
1968	283	5.0	304	4.0	245	3.6	216	3.5
1969	365	5.5	260	3.8	275	3.8	219	3.0
1970	290	4.5	189	3.3	—	—	—	—

FIG. 4. Pre- and post-burn aspects in the little bluestem grassland. Note the denser, more floriferous grass cover following three annual burns (right). Red cedar, a relatively fire sensitive species has been uninjured (Avery Tract Plot H). Photos, 1967 (left) and 1970 (right).

taller than the controls (140 cm maximum height on burned plots as compared to an average of 90 cm on unburned plots).

Following the initial burn, *Andropogon* increased 12 percent in cover, whereas forb cover declined 11 percent. Sheep sorrel, initially one of the more frequent herbs, has decreased, as has moss and lichen cover. Following the initial burn, *Andropogon* seedlings were frequent on bare soil between the grass tussocks. They were rare in the control plots. By late summer, burned compared to unburned plots exhibited a far more aesthetically attractive impression—an eastern counterpart of the western mid-grass prairie. In the Northeast such post-agricultural landscapes appear to be perpetuated by the xeric nature of the site and periodic fires. On Long Island the Hempstead Plains, once covered with extensive stands of *Andropogon* grassland, were believed to be perpetuated by fire until destroyed by urban development (Harper, 1912).

Associated changes in microclimate following the initial burn, compared to the contiguous control, are shown in Figure 5. At 5 cm above the soil surface, maximum temperatures in unburned grassland were consistently higher by 5 to 10°F from April to mid-June than in the burn. Thereafter, there was little difference until late July when the maximum temperatures again occurred in the control. The occurrence of cooler temperature, near the ground in the burn, may be explained on the basis of the increased air circulation and re-radiated heat from between the erect open clumps of *Andropogon,* compared to the matted grass cover in the control. Minimum temperatures were consistently lower in the control plots. At 4 cm below the surface, the burned field was approximately 5°F warmer, with the highest temperature of 90°F reached in July. Weekly minimum temperatures taken at this level revealed only minor differences between burn and control plots.

Forest Stands

The general effect of the initial burns was (1) a reduction in surface leaf litter and organic debris with minimal destruction of the duff, (2) stem kill of certain smaller trees and shrubs, and (3) root-

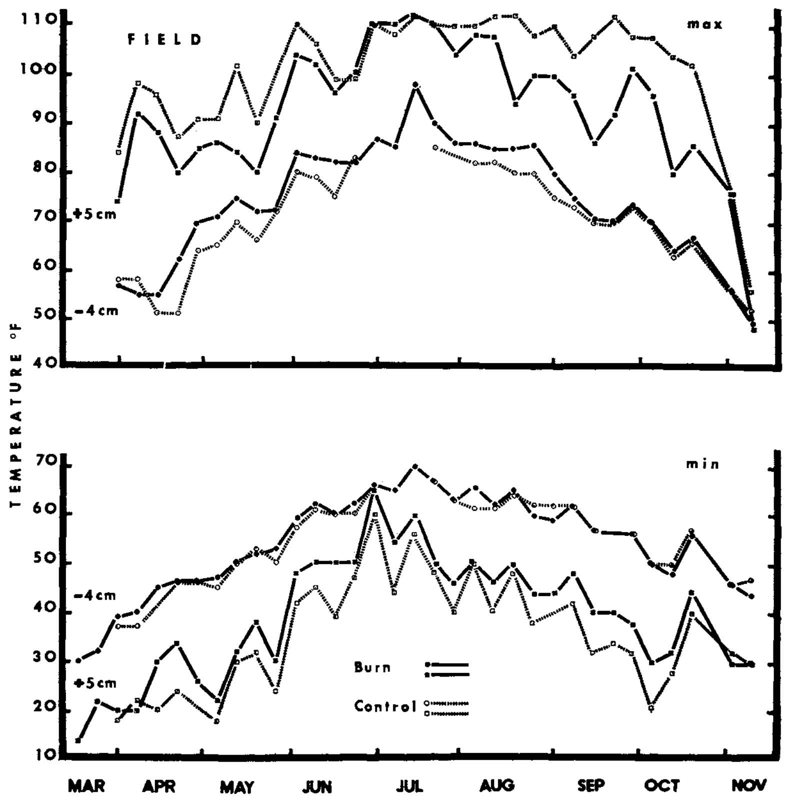

FIG. 5. Average weekly maximum and minimum temperature regime in *Andropogon scoparius* control and burned plots at 5 cm above and 4 cm below the soil surface following the spring burn, March 27, 1968, Matthies Tract, Connecticut Arboretum.

kill limited to the smaller size classes of the more fire-sensitive tree species.

Figure 6 summarizes the floristic shift among tree species in the oak-birch and oak-cherry stands following the initial burns. Figure 7 shows the oak-birch stand immediately after this burn. Black birch exhibited 88 percent tree mortality in the 1 to 2 inch size class 5 months after the fire. A year later, this figure had risen to 100 percent, and a few trees up to 6 inches in diameter had also died. Root-kill was insignificant among other species. Stem-kill of hickory and black and white oak in the 1 to 2 inch size class has exceeded 50 per-

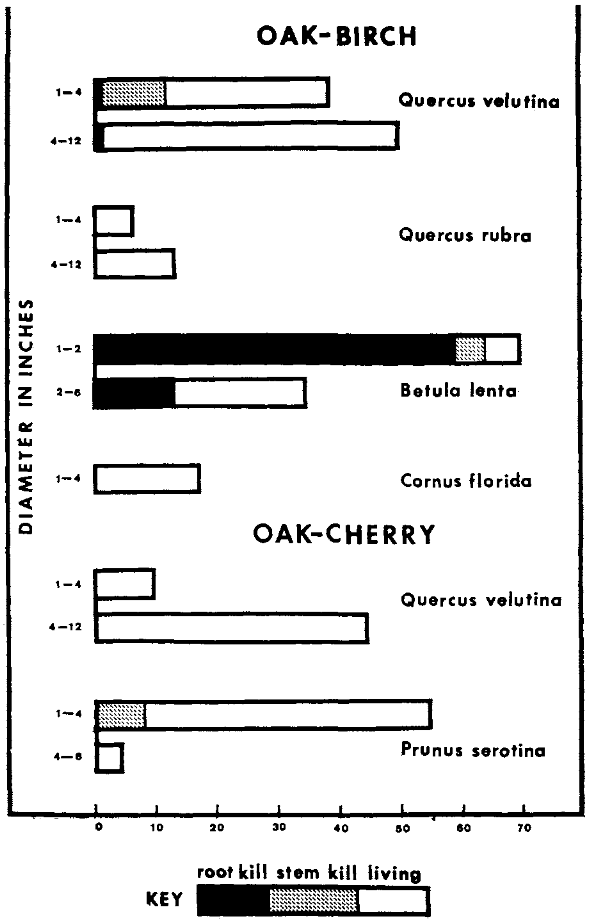

FIG. 6. Tree mortality (number of stems per 0.1 hectare) in post-agricultural oak-black birch and oak-cherry stands, five months following the initial spring burn, March 27, 1968, within the Connecticut Arboretum.

cent. In the black oak-cherry stand following a second burn, stem-kill has been restricted to understory black cherry and oak transgressives less than 4 inches dbh. The general effect of burning in both of these stands has been to reduce the density of smaller stems within the understory, with no major observable damage to larger trees up to 12 inches in diameter. Occasional smaller oaks exhibit basal bark injury.

FIG. 7. The oak-birch stand two weeks after the initial burn (Avery Tract, Plot L). Surface litter was consumed, but considerable duff left unburned. Surface litter fire temperatures reached 600°F as measured by Tempilaq-marked bars. Photo, 1968.

Shrub cover and especially greenbrier has been drastically reduced by the combination of fire and subsequent rabbit browse.

Although ground cover species were initially sparse, burning has favored spotted wintergreen (*Chimaphila maculata*), an evergreen ericad of high aesthetic value. It has increased six-fold following the initial burn in the oak-cherry stand. Although this increase was primarily vegetative, seedling reproduction was observed. With the removal of 2 to 7 cm of leaf litter overlying a 2 cm layer of duff, woody seedling reproduction also showed a marked increase. Eighteen different species were recorded in the burn, compared to only seven in the control. Greenbrier was most common in both areas; but such shade-tolerant species as flowering dogwood and shrubby viburnums were especially favored in the burn plots. These findings are in accord with the idea that leaf litter serves as a physical deterrent to seedling reproduction.

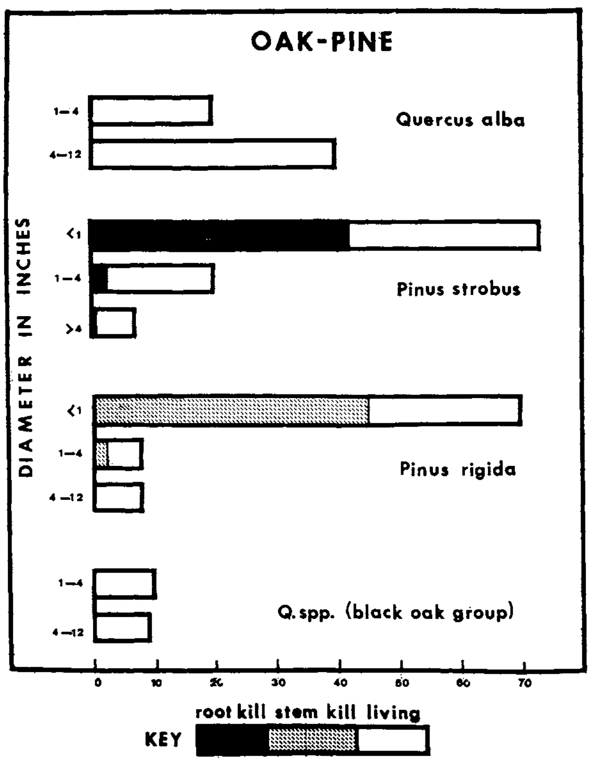

FIG. 8. Tree mortality (number of stems per 0.1 hectare) in the white oak-pine stand with associated white and pitch pine transgressives, five months after the initial spring burn, April 28, 1968, within the Pachaug State Forest.

Figure 8 summarizes the floristic shift among tree species in the oak-pine stand. Initially burned in 1968, root-kill of white pine was limited to seedlings and transgressives less than 6 feet in height and mostly less than 1 inch dbh. In contrast, pitch pine exhibited only stem-kill, followed by a high percentage of resurge. On the basis of these data, one might suggest the hypothesis that the greater importance of white pine in colonial forests might have been correlated with periodic light burns that provided favorable site conditions for its establishment, while not destroying many of the transgressives already present, as would normally occur in the case of intense wildfires.

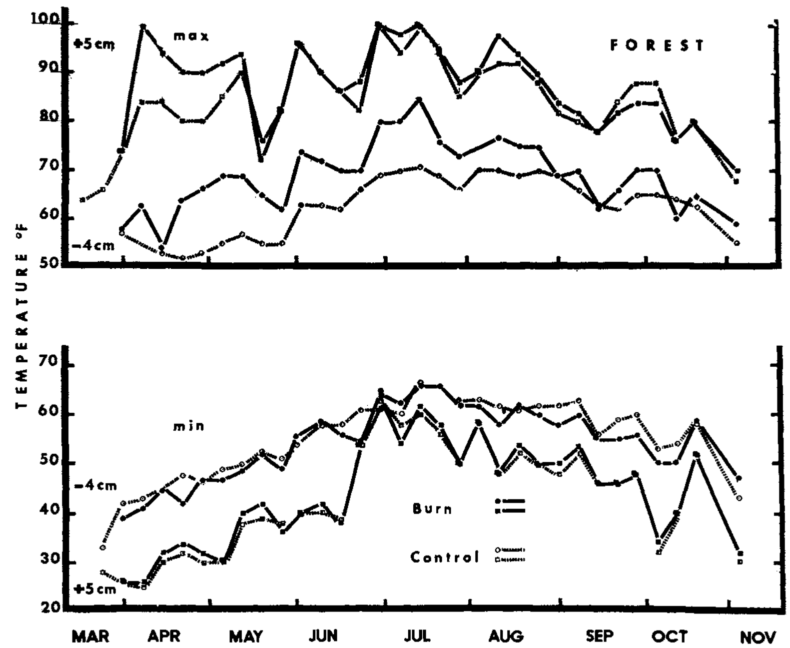

FIG. 9. Average weekly maximum and minimum temperature regime in the oak-birch stand at 5 cm above and 4 cm below the soil surface following the spring burn, March 27, 1968, Avery Tract, Connecticut Arboretum.

Following the initial burn in the red pine plantation the cover of woody undergrowth was reduced from 29 to 10 percent. Although vigorous resurge appeared following the burn, by late summer heavy rabbit and deer browse greatly reduced the sprout growth. Black haw (*Viburnum cassinoides*) was so severely browsed that it was difficult to identify. Other species experiencing moderate to heavy browse included red maple, black cherry, shadbush (*Amelanchier* sp.) and low and high-bush blueberry. Gill and coral fungi were abundant in the burn as compared to the contiguous control area, where gill fungi were rare and coral fungi were not recorded. Improved soil moisture resulting from the partial removal of the heavy pine litter may account for this striking response. Soil moisture studies are being planned to test this hypothesis.

Microclimatic changes subsequent to the initial burn in one of the forest stands (oak-birch) were followed for several months (Fig. 9). Major temperature differences in the burn occurred at 5 cm above and 4 cm below the soil surface. The absolute temperature during the week of April 8, one week after the burn, ranged from 26° to 100°F in the burn plot compared to 25° to 80°F in the control. The average weekly maximum temperatures at the 5 cm level within the burn were from 3° to 10°F higher, until the tree canopy closed in mid May. Thereafter, the differences were insignificant.

At 4 cm below the soil surface, the April 3 temperature range was 41° to 58°F in the burn and 44° to 47°F in the control. Maximum temperatures below the soil surface averaged 8° to 13°F higher in burn than control plots, a pattern that continued until August. However, by September average differences of 1° to 5°F were recorded. During rainy periods soil temperature differences between the two areas tended to disappear. No significant temperature differences between burn and control were recorded at the 1 meter level.

Fire Temperatures

An attempt has been made to ascertain the temperatures reached during the burns in grass tussocks, leaf litter and within the cambium at the base of selected trees. The Tempilaq-marked foil measures the approximate flash temperatures. The Tempilaq-marked steel bars on the other hand, owing to their greater thermal capacity, may give a better indication of the damaging effect of the fire. In the fields flash temperatures have been measured up to 1000°F, whereas temperatures on Tempilaq-marked bars have only reached 225°F. In the forest stands flash temperatures have reached 850°F, while maximum readings of 650°F, were obtained with the steel bars in initial burns, where organic accumulations were large, and 350°F in second burns. In the red pine plantation, the hottest burn, steel bar temperatures exceeded 650°F.

Cambial temperatures have been recorded in two black birch trees during a light burn in 1970. The cambium of a black birch 2.4 inches dbh reached a maximum of 154°F, and another 8.1 inches dbh reached 79°F. Flash temperatures of 750° to 850°F and steel bar temperatures

FIG. 10. Controlled burning in the 30-year-old red pine plantation, Pachaug State Forest. Note flames streaking up the tree trunks. Temperature measurements in the cambium at the base of a pine 10.3 inches dbh reached 125°F. Leaf litter temperatures exceeded 650°F, as measured by Tempilaq-marked bars. No mortality of these trees has been recorded. Photo, May 5, 1969.

of 300°F were recorded at the base of these trees. Neither tree appeared affected 4 months later. In the very hot red pine plantation burn (Fig. 10) the cambium of a pine 10.3 inches dbh reached 125°F, whereas the Tempilaq-marked bar gave a reading in excess of 650°F, the maximum such temperature recorded in any burn. It is hoped to obtain further cambial and fire temperature data during future burns and to correlate fire intensity with stem kill.

SUMMARY

This study has attempted to analyze the effects of prescribed burning on *Andropogon* grasslands and certain forest types typical of southern New England. Observations at the end of 3 years indicate the following.

1. There was an increased productivity of *Andropogon* as a result of burning. Although initial growth in height was greater in the control, by the end of the growing season the maximum height of the little bluestem was up to 50 cm taller in the burned plots. Burning also resulted in greater flower-stalk production.

2. In forest stands root-kill was restricted primarily to fire-sensitive species such as black birch in the 4 inch size class. Stem-kill was also limited primarily to the 1 to 4 inch size class. Larger trees appeared undamaged except for occasional basal bark injury. Shrub cover, such as greenbrier, was greatly reduced by the fire and subsequent rabbit browse. In the oak-pine stand root-kill of white pine was restricted primarily to saplings less than 1 inch dbh, indicating a tolerance of this species to light burning. In the red pine plantation an intense initial burn resulted in no observable damage to the pine, which was in the 4 to 12 inch dbh size range.

3. Microclimatic changes in the fields revealed higher maximum temperatures at 5 cm above the ground in the control as compared to the burned plots. However, at 4 cm below the soil surface the burned plots were warmer than the controls. At 5 cm above the soil surface the forest maximum temperatures were reached in the burned plots prior to closure of the tree canopy. Subsurface temperatures were also higher than on the adjacent control plots. No significant differences were recorded at the 1 meter level.

4. During burns flash temperatures reached 1000°F in the fields, compared to 850°F in the forest stands. However, the amount of heat developed, as indicated by Tempilaq-marked steel bars, was greater in the forest stands (650°F in initial burn; 350°F in second burn) than in the grasslands (225°F). Maximum temperatures attained by the cambium at the base of a few selected trees during these burns, have ranged between 79° and 154°F.

ACKNOWLEDGEMENTS

This investigation has been supported by Grant GB 5632 from the National Science Foundation. Mr. John Emery, Miss Carol Price and the following students at Connecticut College—Priscilla Christman, Ferdinand Gerber, Susan Godfrey, Linda Manno, Lynne Melville, Ellen Ross, Susan Rossire and Pamela Warga—have participated in various ways in the gathering of data. Mr. John Stengel and Mr. Craig Vine of the Connecticut Arboretum staff have assisted in the establishment and maintenance of the experimental plots.

The authors wish to acknowledge the continuing interest and cooperation of the Connecticut Park and Forest Commission, and especially of Mr. Harry McKusick, State Forester, and Mr. Robert Garrepy, Ranger at the Pachaug State Forest. The use of the State forest fire fighting equipment and the assistance of the Commission's staff in burning the experimental plots has been indispensible.

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