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ABSTRACT – On four oak savanna restoration compartments with a total area of 100 acres, annual burns (1965-1972) reduced the percent of milacre plots stocked with hazel to 39 compared with 65 on unburned areas. Four growing seasons after one and three fires the hazel distribution was not significantly different from the control. Annual burns increased the density of hazel stems in clones to 19.5 per .0001 acre compared to 11.0 on controls. Stem density four years after 1 and 3 burns averaged 10.0 and 8.0 per .0001 acre. The o.d. weight of live hazel stems per .0001 on annual burn areas was 16 percent of that on controls. Four years after 1 or 3 fires stem weight was not significantly different from the control. Stem height on annual burn areas averaged 17 inches compared with 33 inches on the controls. Maximum stem heights on annual burns averaged 24 inches compared with 42 inches on controls. Four growing seasons after 1 or 3 fires average and maximum stem heights were not significantly different from controls.

Figure 1 and Figure 3 mentioned in this paper appear on the cover of this *Journal.*

The exclusion of fire and grazing in mixed oak stands of Central Minnesota allows a dense understory of American hazel *(Corylus americana,* Walt.) to develop (Figure 1). This dense shrub understory replaces the more open grass, forb and shrub ground cover typical of the natural oak savanna as described by Curtis (1959). Starting in 1964, prescribed burns have been applied systematically on a portion of the Cedar Creek Natural History Area (CCNHA) in Anoka County, Minnesota, to restore and maintain natural babitats and to provide students with fire experience (Irving, 1970). This study describes the effect of fire on the American hazel in some of the burned compartments. During the summer of 1972 field data on the clonal distribution pattern, aerial stem density and height of American hazel were collected by sampling four burn compartments and four adjacent unburned control areas. This paper reports, analyzes and interprets the results of this study.

Size and Location of Study Area

The CCNHA, or simply Cedar Creek as it is informally known, has a total area of about 4,500 acres (1820 ha), is located about 30 miles (48 kilometers) north of the Minneapolis-St. Paul metropolitan area in Anoka and Isanti counties, and is administered by the University of Minnesota and the Minnesota Academy of Science (Marshall, 1968). The area selected for natural habitat restoration and research by burning is in the southeast portion of the area and includes mixed oak upland stands, old fields, and marshes (Irving, 1970). On this physiographic unit the Anoka sand plain upland soils are fine sands of the Sartell and Zimmerman series, and topography is generally level except for some stabilized dune areas which provide short slopes of 6 to 15 percent (Grigal, *et al.* 1974).

Record of Previous Burning

Of the four compartments selected for study, two had been burned seven and eight times, respectively, during the preceding eight years, one had been burned once in 1969, and one had been burned three times between 1966 and 1969. The compartments burned once and three times had four growing seasons of recovery before field data were collected in the summer of 1972. Eight control plots were established in unburned stands, two adjacent to each of the burned compartments. The area, average over-story basal area and fire history of each of these compartments are presented in Table 1.

Seventeen of the 19 burns on these compartments were conducted during the spring season with the earliest burn on April 11 and the latest May 17. The compartment with three burns experienced two relatively low intensity and incomplete fires in August, 1966, and September, 1967. Then, in April, 1969, fire was applied with satisfactory intensity and continuity. The April and May fires were ignited in late afternoon, usually after 5:00 p.m. (CST), and from three to ten days after measurable precipitation. Air temperatures at the start of the burns ranged from 56 ^{0}F to 91 ^{0}F (13-33 ^{0}C) and relative humidities from 26 percent to 72 percent. Wind velocities ranged form 0 to 20 miles per hour (0 to 8.9 cm/sec) and usually averaged from 5 to 10 miles per hour (2.2 to 4.5 cm/sec). Strip head-firing was the normal ignition pattern. Rate of spread and fuel consumption were measured on some 1965 burns on the CCNHA. Strip head fires had rates of forward spread of 7.3 to 13.6 chains per hour (8 to 15 ft/min; or 4.1 to 7.6 cm/sec), and fuel consumption ranged from 917 to 6,500 pounds per acre (.02 to .15 pounds per square foot or .04 to .31 grams per square centimeter) (Wick, 1966).

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Table 1.
Area, stocking and fire history of study compartments.

Treatment	Area Acres	Area ha	1972 Basal Area sq.ft./ac.	1972 Basal Area m^2/ha	Fire History Month/Day/Year of Burns
7 burns in 8 years	27	11	70	16.1	5/4/65; 4/25/66; 4/11/67; 4/26/68; 5/12/69; 4/12/71; 5/16/72
8 burns in 8 years	25	18	42	9.2	5/4/65; 4/13/66; 5/5/67; 4/26/68; 5/12/69; 5/4/70; 5/3/71; 4/25/72
3 burns, 4 seasons rest	10	4	64	14.7	8/30/66; 9/6/67; 4/23/69
1 burn, 4 seasons rest	27	11	61	14	5/14/69
Control			60	13.8	No recent fires

Early spring burns, conducted when surface fuels were cured, produced flame heights of from a few inches to three feet in leaf litter and grass surface fuels. Depth of flame front ranged from less than a foot in sparse grass to several feet in heavy oak leaf litter. The duration of flame contact with hazel stems was usually less than one minute (enough to kill cambium tissue) but exceeded 10 minutes near concentrations of woody fuels such as dead branches from wind-damaged oaks. Late spring burns with green herbaceous material present burned with lower intensities and slower rates of spread and produced more smoke.

Hazel Distribution and Measurement

To estimate the proportion of the area in each compartment which was stocked with American hazel, a random sample of 218 one-quarter milacre (.00025 ac., or .0001 hectare) circular plots were located. On each sample plot the presence or absence of hazel was recorded, and when one or more hazel stems were present, the height of the tallest stem was measured. The results are presented in Figure 2.

Statistical analysis of the two annual burn compartments using the students "T" test found no significant differences between the two compartments when comparing either the percentage of plots stocked with hazel or the average maximum height of hazel stems. The same test indicated no significant difference between the two four year rest compartments and the controls when comparing hazel stocking or average maximum height of hazel stems.

Annual burn plot data were then pooled and compared to the pooled data from the four year rest and the control compartments. Between these, significant differences were found in both the hazel stocking measurements and the average maximum stem height measurements. The observed differences in variance between the snnual burns and the other compartments are related to the variation in age distribution of hazel stems. The annual burn compartments have even-aged one year old stands of hazel. As the time since the last burn increases, the even-aged stand of stems is augmented by younger and shorter stems.

The series of annual burns apparently reduced the number of hazel clones and the height of the tallest stems. However, four growing seasons after one or three burns the height of the hazel stems on burned plots was not significantly different from that found on unburned controls.

Hazel Density, Average Height and Weight

To examine the influence of fire history on the relative density of stems in hazel clones, ten systematically located sample points were selected in each of the four burn compartments, and eight points were located in adjacent unburned areas. In the hazel clone nearest each of these sample points a .0001 acre (.405 sq. meters) circular plot was established. The sampling unit was, therefore, the hazel clone, and the portion of each selected clone that fit into a .0001 acre plot (radius - 1.18 feet or 35.97 centimeters) was measured. Each live hazel stem was clipped at the ground line, and its length was measured to the nearest two inches. Clipped material was bagged, dried at 105 ^{0} F (40.6 ^{0} C) for 24 hours, and weighed. Overstory competititon at each plot was estimated by measuring basal area using a 10 factor prism. The results of this phase of the study are presented in Table 2.

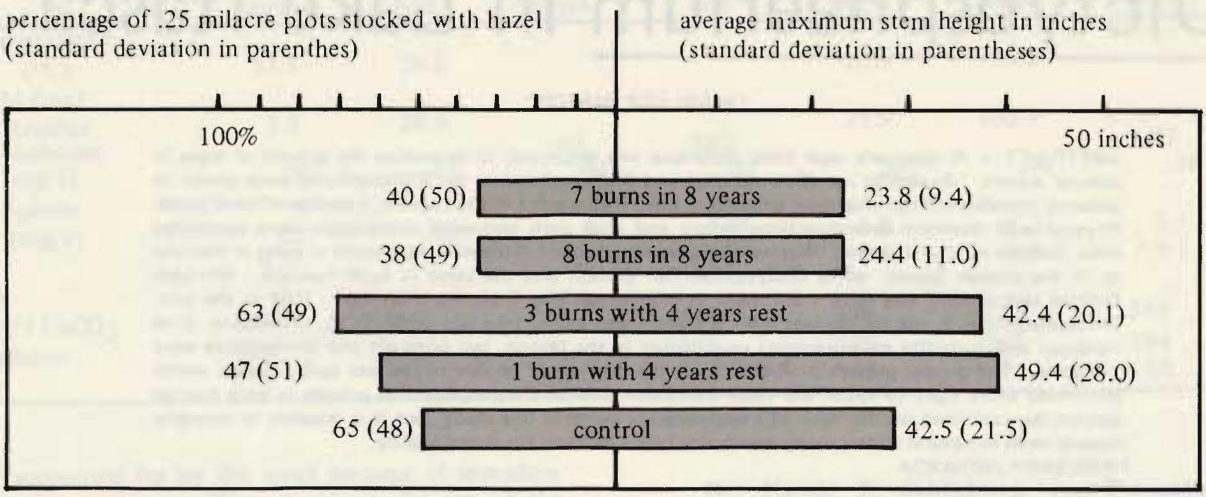
The density, average height, and average weight of hazel stems in sample clones four growing seasons after a fire are not significantly different from those on unburned controls.

Table 2. Density and weight of hazel stems by frequency of burning.

Treatment	Overstory Basal Area sq. ft./ac	Number of Stems per .0001 Acre	Average Height of Aerial Stems Inches	Average Weight per Plot in Grams
a. 7 burns in 8 years	70 (46)*	19.2 (4.6)*	16 (6.1)*	16.3 (3.6)*
b. 8 burns in 8 years	42 (68)	19.9 (8.4)	18 (6.1)	30.6 (16.4)
c. 3 burns, 4 rests	64 (39)	8.0 (2.7)	34 (14)	117 (92.2)
d. 1 burn, 4 rests	61 (51)	10.0 (6.2)	30 (9.4)	92.1 (49.4)
e. Control	60 (44)	11.0 (4.6)	33 (14.2)	150.4 (85.3)

* Standard deviations in parentheses.

FIGURE 2 – COMPARISON OF HAZEL DISTRIBUTION AND MAXIMUM STEM HEIGHT BY FREQUENCY OF BURNING



However, a series of annual burns approximately doubled the number of stems per sample clone and reduced the average height to about one half that of unburned clones (Figures 1 and 3).

The older, and therefore larger, stems in the clones on unburned control plots and on the four year rest plots account for the approximately four times greater dry weight on these plots compared to the annual burn plots.

Observed Effects of Fire

The reduction in hazel distribution after a series of annual burns suggests that fire has eliminated some clones, reduced the height of some, and probably retarded the establishment of others. Tappeiner (1971) suggested that "periodic" fire may stop spread by killing seedlings of beaked hazel (*Corylus cornuta,* Marsh.). A similar increase in density of aerial stems and reduction in height following annual spring fires was reported for beaked hazel by Buckman (1964) who reported that hazel recovery was nearly complete four years after a burn. A preliminary attempt by Sando (1967) on the CCNHA to compare 1966 height growth of hazel on compartments burned one, two and three times found that height growth after three successive annual fires averaged 30.5 inches (77.5 cm) and was significantly less than that found after one fire.

The results of this study suggest that a series of annual burns reduced the height of stems and the proportion of the area dominated by the hazel understory. Field observations suggest that grasses and forbs are increased while the shrub layer is reduced by annual burns. The effect of one fire or a series of fires appears to be temporary and a regular schedule of burning will be needed for oak savanna restoration and maintenance. An interval of several years between fires might increase available fuel, fire intensity, and oak overstory mortality, but the hazel understory will probably recover between fires.

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