EFFECTS OF PRESCRIBED BURNING ON HAZEL IN MINNESOTA

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Abstract. Single or repeated spring prescribed fires and single summer fires easily kill aerial stems of hazel (*Corylus* spp.). Although vigorous and abundant resprouting follows spring fires, resprouting is less vigorous after summer fire. Repeated summer fires destroy the ability of hazel to resprout by (1) exposing and destroying underground stem systems and (2) probably exhausting stored food reserves. A single fire may eliminate hazel if humus is sufficiently dry to be completely consumed. This drying may occur in the summer or fall, but rarely if ever in the spring.

Introduction

Survey notes on conditions in Itasca Park, Minnesota, prepared in the late 1870's by the General Land Office surveyor describe the location of timber in the area northeast of the present location of Douglas Lodge. Occasional observations about dense stands of brush (*Corylus cornuta* Marsh. and *C. americana* Walt.) are also recorded. Judging from present conditions in Itasca Park these dense stands of brush must have been fairly free of a pine overstory, although at least a scattering of trees must have been present nearby to serve as a seed source. A few years later, in 1886, a large forest fire burned northeastward from the present site of Douglas Lodge (Spurr 1954). The same areas once described as containing dense brush still have some brush, but today they also support dense stands of 70-year-old jack, red, and white pine (*Pinus banksiana* L., *P. resinosa* Ait., and *P. strobus* L. respectively).

The transformation from brush to a fully stocked stand of pine timber is a process not observed in Minnesota today. Nowhere, in fact, do we see evidence of hazel subsiding in numbers or massiveness. The observations of the General Land Office surveyor, the evidence of forest fire in the area a few years later, and the subsequent development of stands of pine timber stimulated my interest in prescribed burning as a method of controlling hazel brush, and as an aid to the regeneration of conifers.

A number of years' data are now at hand on the response of hazel to fire and the process by which nature must have reduced or temporarily eliminated hazel from upland forest sites. The purpose of this paper is to report on the response of hazel to prescribed burning. Some of the summer burns have prepared the mineral soil seedbeds suitable for the pines, but successful regeneration has not taken place because of the almost complete failure of red pine seed crops in proximity to the burning experiments, and the absence of a seed source in the jack pine cutover areas at the time they were burned.

Vegetative Reproduction of Hazel

Hazel is the most common upland shrub in Minnesota. It may grow in relatively pure stands, or as an understory to any of the pines, aspen, or other upland tree species in Minnesota (Fig. 1). *Corylus cornuta* tends to occupy mesic sites while *C. americana* occupies drier or more xeric sites, although many exceptions to this can be found. Hazel, because of shading and aggressive growth, has long been recognized as a major deterrent to the successful regeneration of upland conifers.

Fig. 1. Hazel growing beneath a stand of 90-year-old red pine on the Cutfoot Experimental Forest. Hazel may grow in pure stands or as an understory to every upland timber type in Minnesota.

Corylus cornuta (and presumably *C. americana* as well) reproduces by seedlings, sprouts, underground stems, and layers (Hsuing 1951). By far the most important means of complete colonization is vegetative reproduction from underground stems. Until hazel clones grow completely together they have a characteristic clump-like appearance centered about the parent seedling. Cheney (1928) found that most of the roots of hazel (presumably including underground stems) were in the upper foot of soil; Hsuing (1951) found that 92% of the roots and underground stems were in the upper 6 in. of soil. I have examined many underground stem systems of both *Corylus cornuta* and *C. americana* in relatively undisturbed forest conditions in Minnesota and have found nearly all of them in mor-humus, lying at or very close to the contact zone with mineral soil. The location of underground stems protects them from fire when the humus is moist, but makes them vulnerable when the humus is dry and combustible.

Prescribed Burning Experiments and Trials

The Lake States Forest Experiment Station maintains two major burning experiments in Minnesota. The oldest, near Six Mile Creek[2] on the Bena District of the Chippewa National Forest, began in April 1957. The second, on the Cutfoot Experimental Forest on the Chippewa National Forest, began in May 1960. Several improve-

[1] Located at the Northern Conifer Laboratory, Grand Rapids, Minnesota.

[2] Installed in cooperation with the Minnesota Conservation Department.

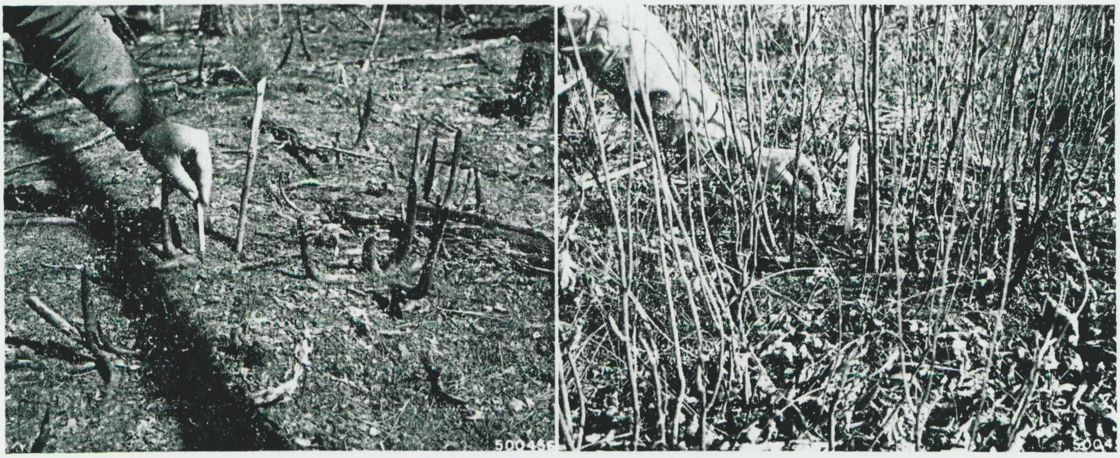

FIG. 2. Spring prescribed burning. Left: sufficient logging slash was present to consume most of the live aerial stems of hazel. Right: hazel sprouts at the same location after two growing seasons.

ments in design and measurement techniques were made in the Cutfoot experiment, and consequently it is drawn upon almost exclusively in this paper. The Six Mile Creek experiment, and several large-scale prescribed burning trials done later in northern Minnesota, corroborate in large measure the results of the Cutfoot experiment.

The seven treatments on the Cutfoot area, which has a red pine overstory with an understory of *C. cornuta* (Fig. 1), consist of: dormant-season burning done (1) annually, (2) biennially, and (3) periodically (6- to 7-year intervals); summer burning done (4) annually, (5) biennially, and (6) periodically; and (7) an unburned control. Each treatment is replicated four times, giving 28 compartments in the experiment. The compartments average a little less than 1 acre in size. All dormant-season burning thus far has been in the spring; weather permitting, it could have been done in the fall as well.

Each of the 28 compartments is subsampled to determine certain reactions to burning. For example, eight permanent milacre plots are mechanically located in each compartment to follow the responses of hazel. Humus moisture samples were collected immediately prior to burning at four mechanically predetermined places on the compartment. Humus weight was determined from eight random plots, each 1 foot square.

Because of the uncertainties of weather in Minnesota, especially in the summer, the scheduled burning at Cutfoot is done as soon as the compartments will burn reasonably completely. This may not be the most effective time to burn, however, and a number of auxiliary compartments are held in reserve to be burned after prolonged drying or during unusual burning conditions. One of these, compartment 30, was burned in the summer of 1961.

Spring Burning

The first prescribed burning was done at Six Mile Creek in April 1957. Results from this fire, and from others that followed at Six Mile Creek and Cutfoot, showed that all aerial stems of hazel are killed, regardless of how gentle the flames or frequent the burning. Prolific hazel sprouting follows spring burning, and the original stand of brush is replaced in stature and numbers of stems in only a few years. Even where enough logging slash is present to consume green stems, sprouting from underground stems follows (Fig. 2).

Repeated spring burns were then made at Six Mile Creek and on the Cutfoot area. The results after 4 years of different frequencies and seasons of burning and of the unburned controls for the Cutfoot experiment are given in Table I. On all spring burning treatments at Cutfoot there are at least twice as many sprouts per acre as in the original stand; in the plots burned two and four times there are more than three times as many stems. One year after a first burn, a reduction was noted in the size of stems as measured by the number of stems greater than 12 in. in height and by volume per acre in cubic feet. Nevertheless, the compartments burned once 4 years previously (6-7 years burning interval) are already well on their way to recovering the volume contained in the original stand.

Summer Burning

At Cutfoot the same number of burns have been completed in the summer as in the spring. The aerial stems of hazel are as easily killed by fire in the summer as in the spring. Four years after a single fire there are slightly more than 40,000 stems per acre on both the spring and summer burns, about twice the number contained in the original stand. Following two summer fires (at 2-year intervals) the number of stems begins to decline in sharp contrast to the trend shown by spring burning where the number of sprouts is still increasing. After four consecutive summer fires the number of sprouts per acre has declined to 9,500, about one-tenth the number in the companion spring-burning treatment.

Summer burning results in a reduction in the vigor of sprouting, although the comparison is confounded because summer burns have not had as much time for regrowth as have spring burns (last column, Table I). Nevertheless, the loss in vigor following summer fires, as measured by the number of stems greater than 12 in. or by cubic-foot volume per acre, is more than can be accounted for by differences in growing time. Four growing seasons following a single spring fire, for example, the Cutfoot experiment contains 29 cubic feet of brush per acre, whereas 3.5 growing seasons following a single summer fire there are 16 cubic feet per acre (Table I).

After four summer burns hazel is no longer present on 8 of the 25 milacre plots on which it was formerly found. By contrast, after four spring fires hazel is still

TABLE I. The response of hazel to different frequencies of spring and summer prescribed burning

Number and season of burns (burning frequency in parenthesis)	Number of stems per acre (1000's)		Volume per acre (cubic feet)	Growing seasons elapsed since last burn
	Total[1]	12 inches or more in height		
One (6-7 yr)				
Spring	40.4	38.7	29.5	4.0
Summer	41.9	38.4	16.2	3.5
Two (2 yr)				
Spring	74.4	63.6	13.2	2.0
Summer	34.2	18.3	1.6	1.4
Four (1 yr)				
Spring	95.0	31.5	1.8	1.0
Summer	9.5	0.8	0.1	0.5
Unburned	21.6	20.3	38.5	—

[1]Using analysis of variance on the total number of stems: One spring vs. one summer burn, difference is not significant; two spring vs. two summer burns and four spring vs. four summer burns, differences significant at .01 level. Two and four spring burns result in significant increase in stems over control (at .01 levels); two and four summer burns do not represent a significant decrease compared to control.

present on all 29 milacre plots on which it was originally found. It is likely that repeated summer fires will lead to the eventual destruction of all hazel clones, for the stems on the remaining plots are much reduced in numbers and vigor.

By most standards these summer fires have been gentle. Some compartments have been difficult to ignite. In 1961, summer burning on the main Cutfoot experiment was done in early June. These fires too were gentle, but a drouth was then in the offing which intensified until mid-July.

On June 21, the burning of auxiliary compartment 30 demonstrated fire effects on hazel not previously observed. The fire, backing into a gentle wind, consumed most or all of the humus and in many places exposed the underground stem systems of hazel clones (Fig. 3). Hazel was eliminated from four of the eight milacre measurement plots. Before burning, hazel averaged 12,300 stems per acre; 1¾ growing seasons later there were 3,800 stems per acre. Had fire occurred on any of several days in the next 3 weeks, it is likely that even more hazel would have been destroyed. The drouth in late June and early July probably approximated the conditions that were present when forest fires burned through the presettlement forests of Minnesota.

Three subsequent large-scale prescribed burns on jack pine cutover areas also demonstrate the effectiveness of summer fire, two near Willow River, Minn., and one near Cass Lake, Minn. These burns occurred 9 to 15 days after rain. Although no measurements have been made, observations of the exposed underground stem systems reveal that many hazel clones have been eliminated. Abundance and vigor of resprouting from the remaining clones were poor. Coincident with the destruction of hazel is the exposure of mineral soil seedbeds which seem so necessary to the natural regeneration of the various species of pine.

HUMUS MOISTURE CONTENT

Humus moisture contents are lower in the summer than in the spring (Table II). A summer fire therefore consumes more humus, as measured by depth and weight, and thus exposes more of the underground stem system of hazel to the heat of the fire. An additional factor in the greater effectiveness of summer burning is the probable loss of sprouting vigor caused by exhaustion of food reserves stored in the roots and underground stems of the plant. Summer fires repeated for a few years might well destroy hazel by exhaustion of food reserves alone. This has been demonstrated for hardwood shrubs and trees in the South by Hodgkins (1958), Lotti, Klawitter, and LeGrande (1960), and others.

Evidence from auxiliary compartment 30 suggests that hazel can be eliminated by a single fire if the humus moisture content is low enough. No moisture data are available, but presumably humus must be dry and friable down to mineral soil to be completely consumed. Canadian observations (Williams (1958) indicate that the moisture content should be in the neighborhood of 10 to 15% for complete humus consumption.

Humus (including the L, F, and H layers) in the Cutfoot experiment before burning averaged about 69,000 pounds per acre ovendry weight (Table II). Some 1¾ growing seasons after burning, the humus on compartment 30 averaged 31,000 pounds per acre (including 2 years' accumulation of fresh needle litter from the overstory red pine). No doubt some of the organic material remaining is charcoal residue. So much heat was liberated by this fire that some of the underground hazel stems or their supporting roots were burned off, and the above-

FIG. 3. Compartment 30, summer-burned on June 21, 1961. Left: a fire backing through pine litter and hazel. Right: 2 months following burning. Some of the aerial stems have collapsed, and many underground stem systems were exposed and destroyed by heat. A headfire or wildfire burning under these conditions would have been far more destructive to the overstory.

TABLE II. Average moisture content before burning, and depth and weight of humus 3 years after the first burn in relation to treatment, Cutfoot prescribed burning study[1]

Treatment	Average humus moisture content before burning (% of ovendry weight)		Depth of humus 3 yr after first burn (inches)		Weight of humus 3 yr after first burn (1,000 pounds per acre)	
	Spring	Summer	Spring	Summer	Spring	Summer
Three times burned	102	40	1.7	1.2	58.6	42.8
Twice burned	117	37	1.9	1.5	64.4	45.9
Unburned	—	—	2.8		69.0	

[1]Humus includes L, F, and H layers. Moisture content determined from samples collected immediately prior to each burn. Depth and weight statistics were collected 3 years after experiment began and include 1 year of fresh needle accumulation.
Several analyses of variance tests were made among the various treatments. Humus moisture content: spring vs. summer, difference significant at .01 level. Depth of humus: spring vs. summer, and summer vs. control, significant at .01 level; spring vs. control, at .05. Weight of humus; spring vs. summer, at .05; spring vs. control, not significant; and summer vs. control, at .01.

ground stems collapsed (Fig. 3). During periods of drouth in Minnesota, humus is a major source of fuel for either wild or prescribed fires—in some cases it is the most important source.

Occurrence of Burning Weather

Spring prescribed burning has been possible on all study areas every year since 1957. At least 2 or 3 suitable days were available every spring, and sometimes many more. (Suitable burning, as used in this paper, refers to conditions where the fires ignite readily and burn freely, and yet can be controlled without difficulty.) Spring burning is usually done from mid-April to mid-May. The most reliable burning weather occurs in the spring, but the ecological effects of spring fires are of transient importance.

Summer prescribed burning has been done for 3 years. If coniferous logging slash is present, prescribed burning can probably be done on one or more days every summer. If the surface fuel is pine litter, as in the Cutfoot experiment, prescribed burning can be done most summers although the humus may not dry sufficiently to destroy hazel. If only hazel and other hardwood fuels are available, prescribed burning cannot be done every year. The summer of 1961 had several days dry enough for prescribed burning in hardwoods; the summers of 1960 and 1962 had none.

Fall burning conditions are highly variable. They frequently have much in common with those in the spring, *e.g.* high humus moisture contents with burning made possible by the presence of cured surface vegetation. Occasionally, however, summer drying carries over to fall, and then humus and other heavy fuels will burn. Hazel can be destroyed under these conditions. Historically in the Lake States the most destructive fires in terms of life and property have occurred in late summer or fall. Where a seed source was present excellent stands of pine have also originated after these fires. Fall burns are usually made during the last week in September or the first 2 weeks in October, but little experimental work has been done during this season.

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