

EARLY EFFECTS OF A PRESCRIBED  
FIRE IN SPRUCE-FIR SLASH ON SOME  
SOIL PROPERTIES

by

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## TABLE OF CONTENTS

	PAGE
INTRODUCTION .....	1
STUDY AREA AND METHODS .....	2
RESULTS AND DISCUSSION .....	4
Effects on Chemical Properties .....	5
Effects on Soil Temperature .....	5
REFERENCES .....	12

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INTRODUCTION

Regeneration of overmature spruce-fir stands after clear-cutting is a problem in the lease area of North Western Pulp and Power Ltd. at Hinton, Alberta. The soil in this forest type has a thick layer of unincorporated organic material and a continuous moss cover. These layers, accumulated through the centuries in undisturbed dense stands, are very poor substrates for spruce-seed germination and seedling growth. They also insulate the soil and keep the soil temperature low, thereby retarding organic breakdown and other biological activities. The result is site degradation, which may be reversed with prescribed fire.

The effect of slash burning on soil properties is not uniform because fire intensity and the edaphic properties of the site greatly influence the degree of changes in the soil. Decreased porosity of the mineral soil surface (Beaton, 1959) and lowered nitrogen contents (Austin and Baisinger, 1955; Knight, 1966) after fires may degrade site quality. However, in soils with thick surface organic horizons, fires consume only a part of the duff and leave the mineral soil intact. Higher soil-temperatures after fire may restore the

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nitrogen status of the soil to that before burning or even to a higher level, and the amounts of "available" phosphorus and exchangeable Ca and K are increased as a result of burning (Lutz, 1960). Because planted stock has grown more vigorously on recently burned than on unburned areas (Allan, 1961), it is believed that burning improves soil quality. But beneficial fire effects may only be temporary. Uggla (1967) in Sweden found that nine growing seasons after a burn on thin humus, height-increment curves of spruce planted in the burned and unburned areas crossed and after 21 growing seasons, the current height increment was 65% greater on the unburned soil.

In the summer of 1967, a prescribed burn was carried out by the Department of Forestry and Rural Development in co-operation with the Alberta Forest Service and North Western Pulp and Power Ltd. This paper describes the early effects of that fire on some soil chemical properties and on soil temperature.

#### STUDY AREA AND METHODS

The study area is on a broad plateau (4800 ft above sea level) in the High Foothills Section of the Boreal Forest Region (Rowe, 1959) in west central Alberta, about 15 miles north of Hinton. Regional climate of the area is cool with mean temperatures of 11, 36, 58, and 38°F in January, April, July, and October, respectively. Mean annual precipitation is 22 inches, with 80 inches of snowfall. Mean precipitation between April 1 and September 30 is 16 inches (Longley, 1968).

The area was covered with a decadent spruce-fir stand more than 300 years old with a thick feather moss layer.

The soil is a moderately well-drained to imperfectly drained Orthic Gray Wooded developed on a mixture of glacial till. The soil profile has the following description:

Horizon	Thickness in inches	Description
L F H	5	Very dark grayish brown, mostly partly decomposed moss and conifer litter, pH 5.2.
Ae	6	Gray to pale brown, sandy loam, weak platy, pH 5.2.
Bt	14	Yellow brown, sandy clay loam, weak blocky, pH 5.4.
BC	at 22	Brownish gray, loose or slightly compacted sandy loam, pH 5.4.

The stand in the burning block was clear-cut in the winter of 1966-67. After the removal of merchantable timber, 45.6 tons of logging slash per acre remained (Kiil, 1969). Burning was carried out on August 10, 1968 with the Spread and Buildup Index (Anonymous, 1966) 7 and 18 respectively. About 27 tons of organic matter per acre was consumed by the fire which burned with a maximum intensity of 800 BTU/sec per foot (Kiil, 1969).

Five randomly selected, 1-sq-ft samples of the forest floor (LFH layer) were collected from the burning block one day before and after the fire. The samples were oven-dried at 70°C, weighed, ground and thoroughly mixed before being chemically analyzed. Soil pH was determined in H<sub>2</sub>O by the paste method; organic matter was estimated by the Walkley-Black procedure as described by

Jackson (1958); and total nitrogen was determined by Prince's modification of the Kjeldahl method (Jackson, 1958). Total phosphorus was extracted with HF digestion, and "available" phosphorus with 0.5 M  $\text{NaHCO}_3$ . Phosphorus of both extractions was determined with the ascorbic acid-reduced molybdophosphoric blue-color method. Cation exchange capacity was obtained by  $\text{NH}_4\text{Ac}$  leaching and by titration of the distilled  $\text{NH}_4$  with 0.5 N  $\text{H}_2\text{SO}_4$ ; exchangeable and water-soluble Ca, Mg, and K were determined by atomic absorption spectrophotometry. Exchangeable  $\text{NH}_4$  was obtained by leaching the soil with 1 N NaCl, distilling, and titrating with 0.05 N  $\text{H}_2\text{SO}_4$ .

Soil-temperature measurements were made with two series of Colman units with thermistors installed at 10, 30, and 60 cm (4, 12, and 24 inches) depth in the standing timber, in the unburned clear-cut, and in the burned clear-cut. Thickness of the LFH layer at the observation points were 3 and 8 inches in the standing timber, and 3 and 7 inches in the unburned clearcut and in the burned area. Measurements were taken at weekly intervals from May 22 to September 25 in 1968 between 10 AM and 2 PM. The time lapse between individual measurements on the same day was not longer than 30 min.

Data from the soil temperature studies were statistically analyzed by "Analysis of Variance". Differences between means were tested for significance by Duncan's "Multiple Range Test". Mean values of chemical properties before and after burning were compared with "Student Test".

## RESULTS AND DISCUSSION

Fire affected the soil by leaving an ash residue derived from the burning slash and by oxidizing a part of the surface organic layer. The extent of these effects depended on the fuel concentration. Only a portion of the

layer in areas with light slash concentrations was consumed, while the fire penetrated into the F layer in the vicinity of heavy fuel.

#### Effects on Chemical Properties

As shown in Table 1, the burning increased the pH in the surface organic layer. Amounts of organic matter and total nitrogen decreased, but the wide C/N ratio was not changed, because about the same percentage of carbon and nitrogen was lost. Average concentrations of total and "available" phosphorus were higher after the fire than before, but the differences were not statistically significant. As shown in Table 2, with the exception of exchangeable K, exchange properties did not change significantly. Water-soluble Ca and K increased in concentration and total amount while Mg remained unchanged (Table 3). The combined amount of exchangeable and water-soluble Ca and K in the forest floor increased by 207 and 102 lb per acre, respectively. Eighty percent of the Ca increase was in the exchangeable form, while 85% of the gain in potassium was water-soluble.

#### Effects on Soil Temperature

For the whole soil profile, the number of days with soil temperatures between 6 and 8°C (42.8 and 46.4°F) was significantly greater in the burned clear-cut than either in the unburned clear-cut or in the standing-timber area. Differences between the standing-timber area and the unburned clear-cut were insignificant (Table 4). The effect of depth on soil temperature varied with site treatment. In the burned area, temperatures at 10 cm depth were significantly higher than at 60 cm. In the area with standing timber, temperatures at 10 cm

Table 1. Some chemical properties of the forest floor before and after burning

Condition	pH	Organic Matter %	Total Nitrogen %	C/N Ratio	Total phosphorus ppm	Available phosphorus ppm
Before burn	5.28 $\pm$ 0.40*	77.3 $\pm$ 3.0*	1.34 $\pm$ 0.01*	33.7 $\pm$ 2.0	1394 $\pm$ 100	196 $\pm$ 23
After burn	6.18 $\pm$ 0.20*	56.4 $\pm$ 6.0*	1.06 $\pm$ 0.04*	30.7 $\pm$ 3.0	1554 $\pm$ 210	267 $\pm$ 63

Numbers represent means with standard error.

\*Significantly different at the 95% probability level.



Table 2. Cation exchange capacity and exchangeable  $\text{NH}_4$ , Ca, Mg and K of the forest floor before and after burning

Condition	Cation exchange capacity	Exchangeable cations			
		NH <sub>4</sub>	Ca	Mg	K
meq/100g					
Before burning	76 ± 6	1.12 ± 0.12	47 ± 3	8.3 ± 0.4	1.0 ± 0.1*
After burning	82 ± 6	0.94 ± 0.12	58 ± 5	9.3 ± 0.8	1.7 ± 0.2*

Numbers represent means with standard error.

\*Significantly different at the 95% probability level.

Table 3. Water soluble Ca, Mg, and K of the forest floor before and after burning

Condition	Concentration in ppm			Amount in lb/acre			Dry weight of the forest floor (tons/acre)
	Ca	Mg	K	Ca	Mg	K	
Before Burning	2176 $\pm$ 88*	368 $\pm$ 38	777 $\pm$ 59*	164 $\pm$ 28	28.5 $\pm$ 5.6	61 $\pm$ 6 **	38 $\pm$ 4
After Burning	2638 $\pm$ 94*	354 $\pm$ 48	2073 $\pm$ 422*	206 $\pm$ 25	25.8 $\pm$ 2.8	147 $\pm$ 15**	38 $\pm$ 4

Numbers represent means with standard error.

\* Significantly different at the 95% probability level.

\*\* Significantly different at the 99% probability level.

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Table 4. The influence of site treatment on the number of days with different temperature values between May 22 and September 25, 1968

Soil temperature (°C)	<u>Burned clear-cut</u>			<u>Unburned clear-cut</u>			<u>Standing timber</u>		
	10	30	60	Soil 10	Depth 30	in cm 60	10	30	60
0 - 1.99	14	22	40	21	23	33	17	33	36
2 - 3.99	12	23	9	28	20	37	16	35	35
4 - 5.99	28	16	29	70	74	56	31	58	54
6 - 6.99	28	23	48	4	3	0	55	0	0
7 - 7.99	42	42	0	0	0	0	7	0	0
8 - 8.99	2	0	0	0	0	0	0	0	0

were significantly higher than at 30 or 60 cm. There was no significant difference owing to depth in the unburned clear-cut (Fig. 1).

Soil temperatures at 10 cm depth began to rise rapidly in late May or early June, from near freezing point. The warming trend continued until about July 10, when the temperature curve levelled off. The duration of relatively high temperature regimes was about 10 weeks with 7.3, 5.1, and 6.6°C (45.1, 41.2, and 43.9°F) mean temperatures in the burned clear-cut, unburned clear-cut, and standing-timber areas respectively. Rapid warming at 30 and 60 cm depth began in early June and continued until August 7. Mean temperatures at this time were 7.2, 5.1, and 5.1°C (45.0, 41.0, and 41.0°F) in the burned clear-cut, unburned clear-cut, and standing-timber areas, respectively. Rapid cooling at all depths began on September 11.

The 20% loss in nitrogen content may be recovered as indicated by Lutz (1960), owing to the improved soil temperatures. The increase in the available amounts of Ca and K and the higher soil temperatures after prescribed burning can be regarded as improvements of site conditions for tree growth. Little is known about the temperature requirements of white spruce and alpine fir. However, water and mineral uptake and tree growth increase with higher temperatures. If the fire lengthened the time of favorable soil temperatures, accelerated physiological processes should increase the rate of seedling growth. As a result of faster growth, seedlings could reach the mineral soil sooner and become less susceptible to drought.

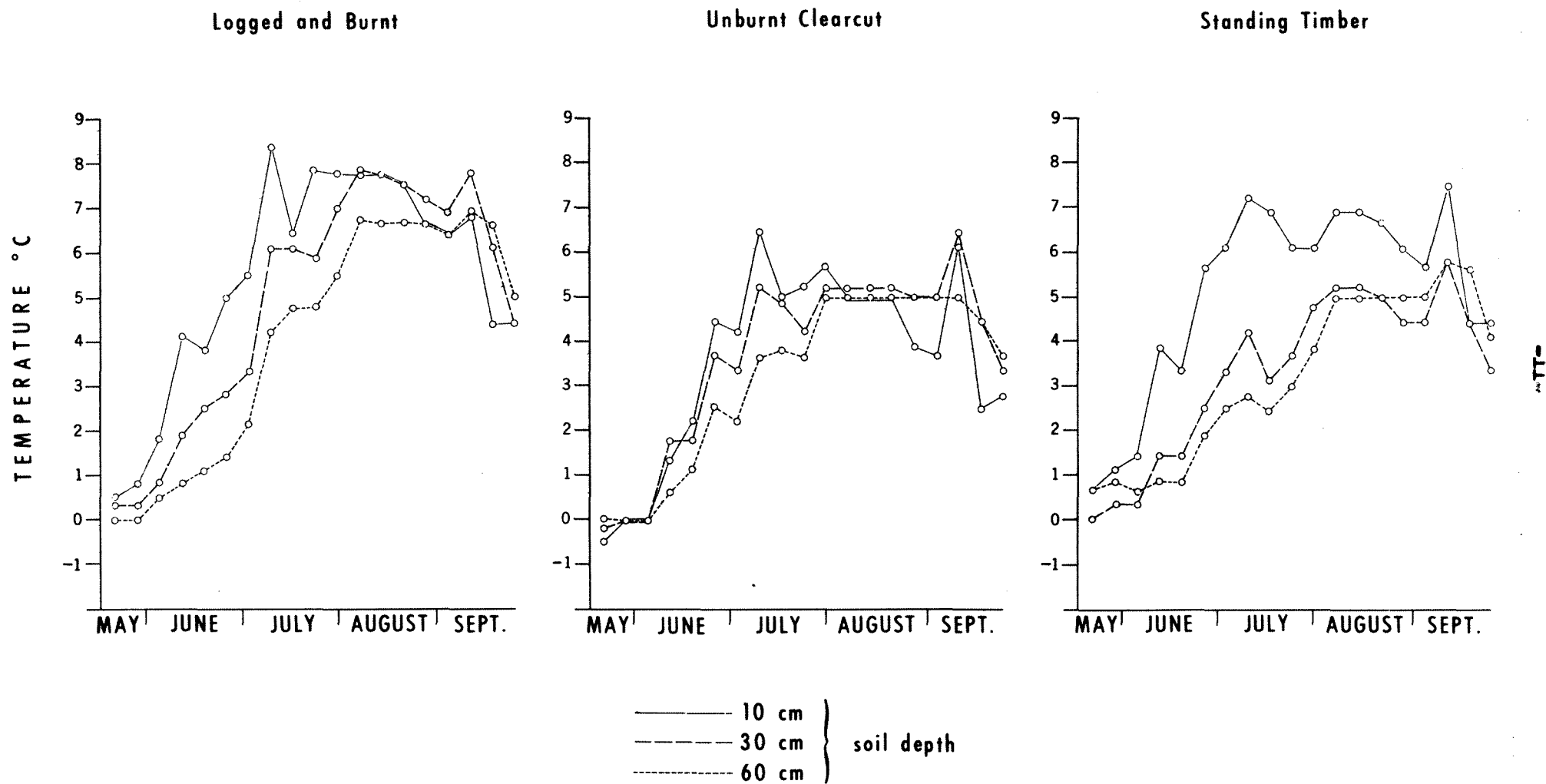


Figure 1. Soil temperature regimes at 10, 30, and 60 cm depth in the logged and burned area, in the unburned clear-cut, and in the standing timber, in 1968.

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