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FOREST RESEARCH BRANCH

Progress Report

Project A-602

A preliminary study of the physical characteristics and moisture content of clearcut lodgepole pine and white spruce slash in Alberta

by

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INTRODUCTION

Logging slash is a highly flammable fuel type, representing a high fire hazard. The degree of hazard depends on species, quantity, age, continuity and arrangement, and moisture content.

In Alberta, logging slash must be lopped and scattered, or treated in a manner deemed satisfactory to reduce the hazard to within safe limits. This policy is universal throughout the Province, regardless of the type of forest cover, method of logging, degree of utilization, or prevailing weather conditions. It is based on the theory that when tree tops are brought into contact with the ground they can absorb and retain moisture more readily, thereby increasing the rate of decay and deterioration. While this hypothesis is generally accepted, there is an urgent need to investigate the effect of other factors, such as quantity, condition, and arrangement of slash. It is possible that any one or all of these have a greater effect on slash hazard than proximity to the surface moisture. The important question to be answered is this: Does lopping and scattering, or any other slash treatment, reduce the fire hazard sufficiently to warrant the work necessary? If so, which treatment does the most for the least cost, and what factors influence the desired end result of reduced hazard?

The purpose of this project is to study the physical characteristics and moisture content of lodgepole pine and white spruce slash on clearcuts. Emphasis will be placed on an objective comparison of slash conditions and moisture content in lopped and unlopped slash. It is hoped

that the results of this study will provide a basis for an extensive and practical evaluation of slash flammability for the two species at various ages after clearcutting.

LOCATION AND DESCRIPTION OF STUDY AREAS

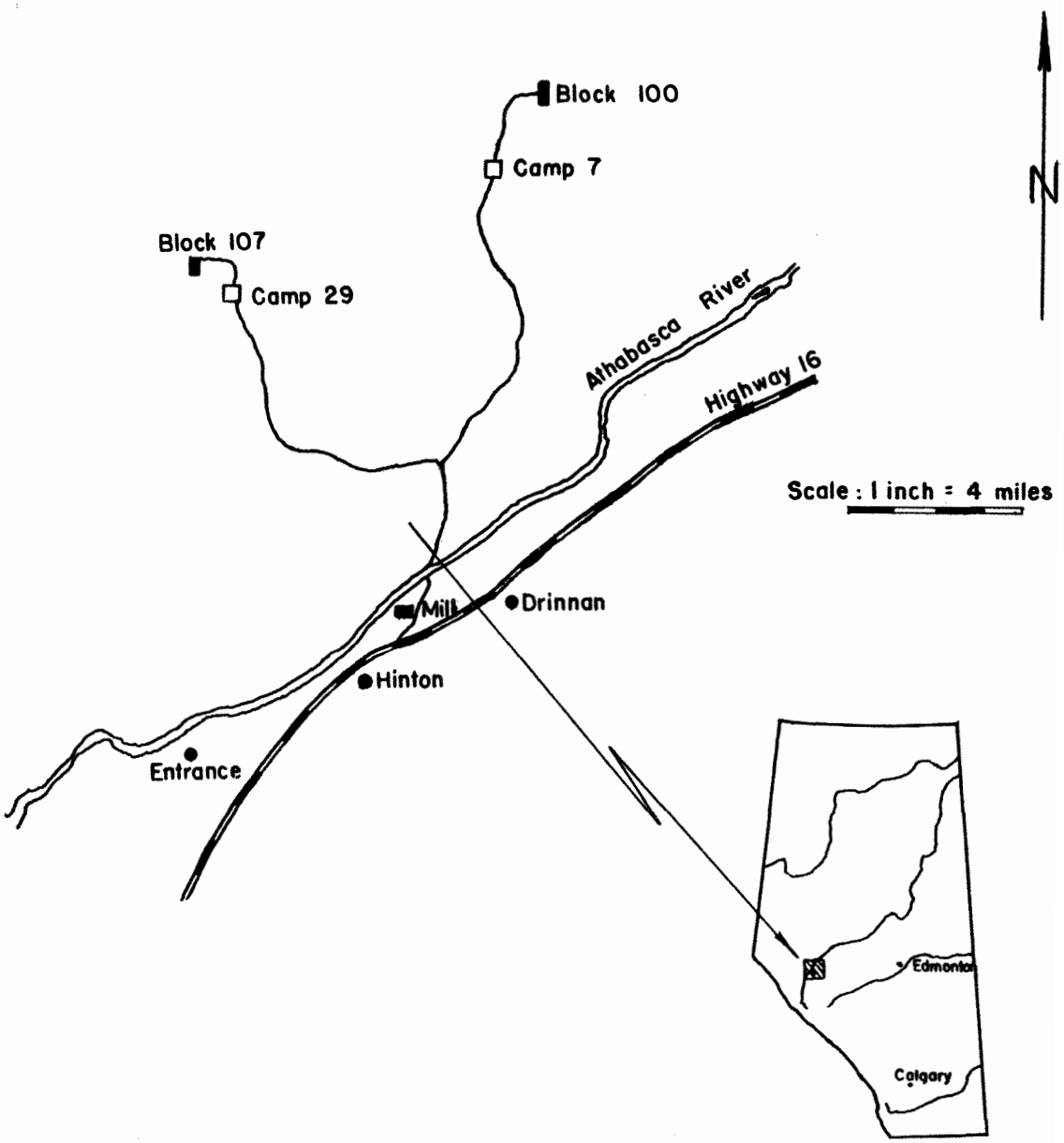
The study areas are located near Hinton (53° 24' N., 117° 37' W.), Alberta in the transition zone between the Upper and Lower Foothills Sections of the Boreal Forest Region (Rowe 1959). The forests are chiefly coniferous, dominated by pure lodgepole pine (Pinus contorta var. latifolia) of fire origin on the drier sites, white spruce (Picea glauca), black spruce (P. mariana), and aspen (Populus tremuloides).

Two 40-acre study areas, representing typical lodgepole pine (Camp 29, Block 107) and white spruce-alpine fir (Camp 7, Block 100) stands were selected in co-operation with officials of the North Western Pulp and Power Ltd. The lodgepole pine stand is on level ground, while the white spruce-alpine fir area is on a five per cent northerly exposure. Both sites were clearcut in summer of 1963 as part of the logging operations carried out by the North Western Pulp and Power Ltd. Refer to Figure 1 for study area location.

Following clearcutting, three one-fifth acre sample plots were laid out adjacent to each of the two clearcut blocks to determine several stand characteristics (Table 1).

The lodgepole pine clearcut supported an even-aged, 75-year old stand of fire origin. Dominant height is 67 feet, with a range of diameters

Fig. 1. Location of Study Area in Alberta



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from 1 to 13 inches. It is characterized by a relatively low density of minor vegetation, giving it a park-like appearance. Moss is the predominant surface fuel, accounting for 85 per cent of the cover. Shrubs, herbs and grasses occur mainly in openings of the crown canopy, while needles and twigs are scattered throughout.

TABLE 1. Summary of Stand Characteristics

	Lodgepole Pine Camp 29, Block 107				White spruce-alpine fir Camp 7, Block 100			
	Pl	Sw	Snags and Chicots *	Total	Sw	Fa	Snags and Chicots *	Total
No. of stems/acre	362	97	170	629	168	168	110	446
B.A.(Sq.ft.)/acre	144.0	11.3	27.1	182.4	122.2	70.7	58.3	251.2
Per Cent of B.A.	79	8	13	100.0	49	28	23	100.0
Average Dbh	8.3	3.8	4.7	6.6	9.5	8.1	8.3	8.7

The white spruce-alpine fir mixture is an uneven-aged stand, with a diameter range of 1 to 32 inches. Maximum tree height is 100 feet. Mosses are abundant and deep. Shrubs, herbs, and grasses cover up to 40 per cent of the ground surface, while needles and twigs are scarce. A prominent feature of the forest floor is the heavy accumulation of snags and chicots*.

Immediately following clearcutting of the lodgepole pine block, it was surveyed and divided into four treatment areas. Refer to Figure 2 for experimental layout. Each treatment area is approximately 9 acres (400' x 1000'), running across the length of the block. The corners of

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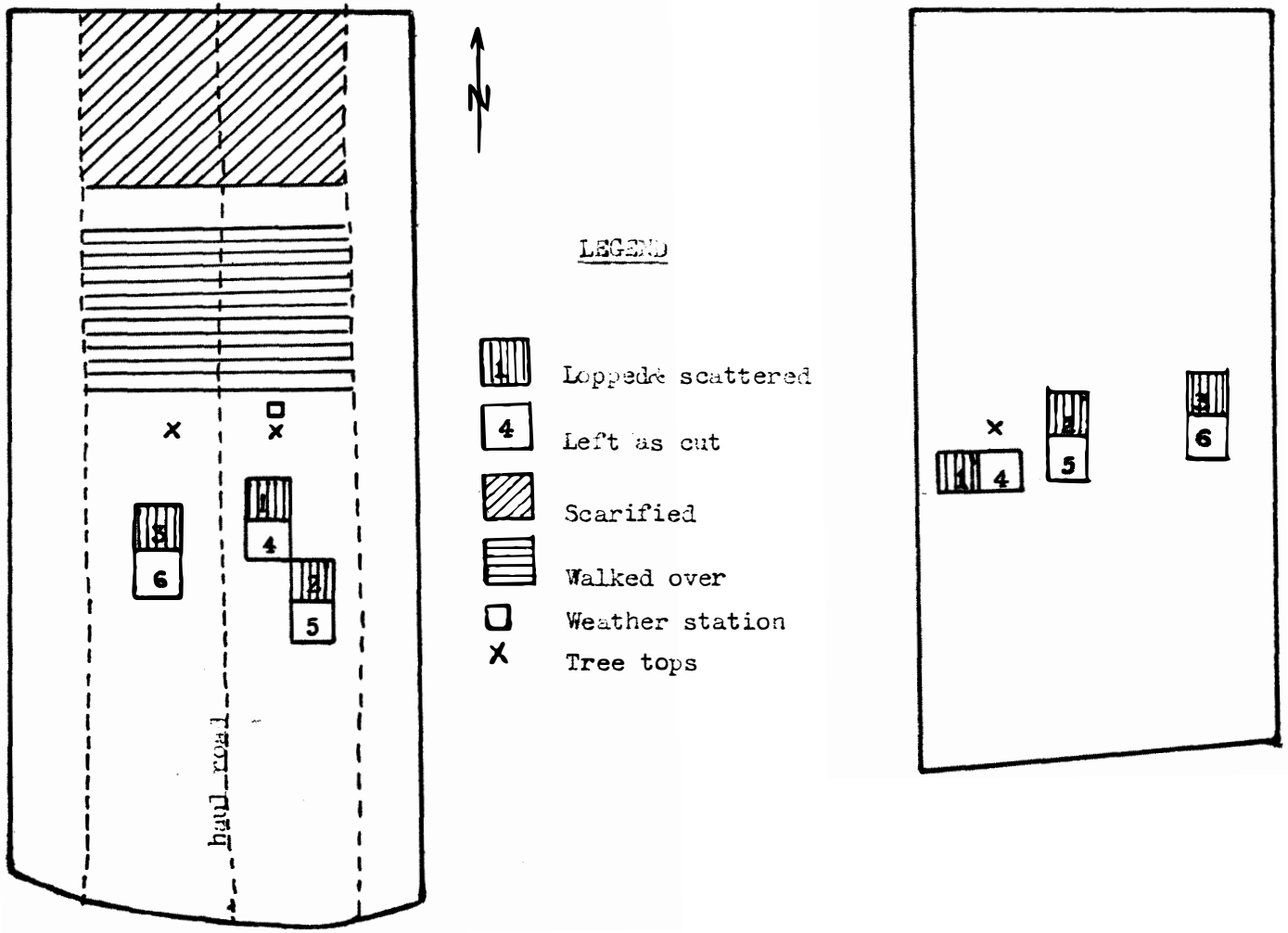
* Chicots - A dead tree with less than one-half of the stem standing.

FIGURE 2. EXPERIMENTAL LAYOUT OF FIELD SITES



Camp 29, Block 107
Lodgepole pine

Camp 7, Block 100
White spruce-alpine fir

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each treatment area are marked by aluminum corner stakes and marker tape. Each area is separated by a 100-foot corridor to safeguard against disturbance by bulldozers carrying out the slash treatments. Four treatments were applied during the 1963 field season. These are: (1) scarification, (2) "walking over" with a bulldozer, (3) lopping and scattering, and (4) left as cut (control). Owing to limitations in personnel and time, lopping and scattering was limited to three 100-foot square plots. Each of these plots was measured and their corners marked with white, wooden corner posts. To facilitate the sampling procedure, similar plots supporting slash left as cut were established immediately adjacent to the lopped and scattered ones. This arrangement also facilitated visual observation and comparison of slash characteristics of the two treatments.

Scarification and "walking over" were done by the North Western Pulp and Power Ltd., using a D-8 Caterpillar equipped with a special scarification blade. "Walking over", can be described as a method of slash treatment aimed at packing down the slash to increase its proximity to the surface moisture. Approximately five acres were treated in this fashion.

A similar treatment procedure was followed on the white spruce-alpine fir cutover (Refer to Fig. 2). Three pairs of 100-foot square slash plots, lopped and scarified and left as cut, were established after clear-cutting and marked by white wooden corner posts. Owing to unfavourable ground conditions, scarification and "walking over" could not be done during the 1963 field season, but will be applied prior to the 1964 field season. The location and size of these treatments will depend on the location of

haul roads, and the condition of the ground at the time the treatments are applied.

OBSERVATION AND SAMPLING PROCEDURE

Forest Fire Weather

Forest fire weather readings are available from the North Western Pulp and Power Ltd. and the Alberta Forest Ranger School (Table 2). These, however, are of limited value in research work, owing to great climatic fluctuations over short distances. Weather readings were found to be meaningful only if taken at the field sites. A weather station, consisting of a hygrothermograph and a recording rain-gauge, was erected on the lodgepole pine cutover. Readings were taken at the time of fuel sampling, and the charts changed weekly. A similar weather station will be erected on the white spruce-alpine fir clearcut in 1964.

Table 2. Fire Weather Data

	May	June	July	August	September
a) Precipitation					
Hinton Ranger Station	1.57	0.15	2.43	-	0.53 (1-18th)
North Western Pulp & Power Ltd.	1.12	0.28	2.59 (9-31st)	3.24	1.18 (1-18th)
Lodgepole pine clearcut (Camp 29, Block 107)	-	-	2.28	1.22	0.20 (1-14th)
b) Temperature					
Mean Maximum					
Hinton Ranger Station	59.0	68.1	72.1	71.2	69.2
North Western Pulp & Power Ltd.	60.6	68.0	72.5 (9-31st)	72.4	69.3 (1-13th)
Lodgepole pine clearcut (Camp 29, Block 107)	-	-	64.6	65.2	69.8

	May	June	July	August	September
Temperature					
Mean Minimum					
Hinton Ranger Station	31.9	38.1	45.5	44.8	43.9
North Western Pulp & Power Ltd.	32.1	38.4	45.8 (9-31st)	45.4	44.9 (1-11th)
Lodgepole pine clearcut (Camp 29, Block 107)	-	-	42.5	44.4	47.4
(c) Relative Humidity					
Lodgepole pine clearcut (Camp 29, Block 107)			(9-31st)		(1-11th)
Mean average 2-hr. min.	-	-	46.4	49.5	45.5
No. of days 21 to 30%	-	-	1	2	0
No. of days 31 to 40%	-	-	7	12	5
No. of days 41 to 55%	-	-	13	7	6
No. of days 56 to 75%	-	-	1	9	1
No. of days 76% and over	-	-	0	1	0
No. of days	-	-	22	31	12

Sampling Procedure

A slash moisture sampling routine was started immediately following clearcutting. Emphasis was placed on comparing the moisture content between slash lopped and scattered and left as cut. Needles and three fuel size classes (0.00-0.50", 0.51-2.00", and 2.01-4.0" diameter) were sampled. Beginning on July 9, samples were taken from six lodgepole pine and six white spruce tops. These tops were gathered systematically from the cutover

area and set out side by side for ease and convenience of sampling. Every other top was lopped. Sampling was carried out at weekly intervals, at the same time each afternoon. A schedule of the samples taken at the lodgepole pine clearcut is as follows:

Table 3. Sampling procedure - tree tops

Species & treatment	Needles	FUEL SIZE 0.00-0.50 in.	0.51-2.00 in.	2.01-4.00 in.
Lodgepole pine				
lopped	1	1	1	1
unlopped	1	1	1	1
White spruce				
lopped	1	1	1	1
unlopped	1	1	1	1
Total	4	4	4	4

Each sample is a composite from three tree tops. The sampling method is destructive, but open to least criticism when comparing moisture content in lopped and unlopped slash. Samples up to 2-inch diameter were obtained by cutting representative cross-sectional pieces from twigs and branches, while only the surface $\frac{1}{2}$ inch was sampled on slash pieces over 2-inch diameter. A brace and bit was used to bore into the bole and the borings collected for oven-drying.

A similar sampling routine was started on July 25 on the 100-foot

square slash plots. One composite sample (approximately 25 gms. green weight) was taken at random from each plot of each size class. All samples were taken between 6 and 18 inches above the ground surface to minimize variation owing to height above ground.

Table 4. Sampling Procedure - Lodgepole pine slash plots

Slash Size \ Treatment	Lopped		Unlopped	
	Plot 1	Plot 2	Plot 4	Plot 5
needles	1	1	1	1
up to 0.50"	1	1	1	1
0.51-2.00"	1	1	1	1
2.01-4.00"	1	1	1	1
Totals	4	4	4	4

On August 6 another six lodgepole pine tops were selected and laid out near Plots 3 and 6. Three of the tops were lopped. A sampling procedure similar to the first sets of tree tops was carried out until the end of the field season.

All samples were taken to the field laboratory for weighing and oven-drying. Two propane drying-ovens were used for this purpose. The length of the drying schedule was dependent on the type and size of fuel. Normally, the samples were dry after 24-36 hours at 100° C.

In addition to the sampling procedure described, samples were taken of moss, both in open and under the forest canopy, and needles just

turning brown. Weekly observations were made of the per cent of needles turning brown and the per cent that had fallen off. The type and per cent cover of minor vegetation was recorded before and after cutting.

Two sets of six fuel moisture sticks were set out in the clearcut and under the adjacent forest canopy. Two sticks were set out at the 1 and 2 foot elevations, and on the ground surface. The sticks were weighed at the time of the weekly sampling routine.

An attempt was made to determine the weight and size distribution of slash on the ground. Six 4' x 4' fuel samples were selected systematically near the 100-foot square sample plots. Each sample was cut vertically through the fuel bed at the perimeter of the 4' x 4' plots, transferred to a tarpaulin, separated into four size-classes, namely (1) 0.00-0.50", (2) 0.51-2.00", (3) 2.01-4.00", and (4) 4 inches and over in diameter, and weighed. Following weighing of the various size-classes, a representative sample was taken from each size class and taken to the field laboratory for oven-drying and moisture content determination. This method is rather time-consuming and a large number of samples is required for a reliable measure of slash weight and size distribution. However, it is planned to test this method for one more year.

Slash depth was measured on each of the three pairs of lopped and unlopped slash. Thirty-six measurements were taken at 20-foot intervals on each 100-foot square plot. The readings were averaged and analyzed for differences within and between treatments. The cubic foot volume for each plot was calculated by adding the volumes of the 20-foot grid squares.

The observation and sampling procedure just described was also carried out at the white spruce-alpine fir clearcut, starting on August 19. Owing to time limitations, sampling to determine slash weight and size distribution could not be completed, but will be continued in 1964. Fuel moisture sampling was done on six white spruce and six alpine fir tops and the three pairs of 100-foot square slash plots.

ANALYSIS OF DATA

Moisture contents and oven-dry weights of all samples were computed. The students t-test was used to determine the significance of differences of slash moisture between species, treatment, and size. Graphs were drawn to illustrate the march of fuel moisture throughout the field season. Analysis of variance was applied to test for variations between sampling methods.

The moisture contents of fuel moisture sticks were calculated and the significance of the differences between clearcut and under canopy determined by applying the students t-test. The data from the six 4' x 4' square slash samples were summed and averaged for each size class. Slash volume per acre was calculated, using the unit-area method.

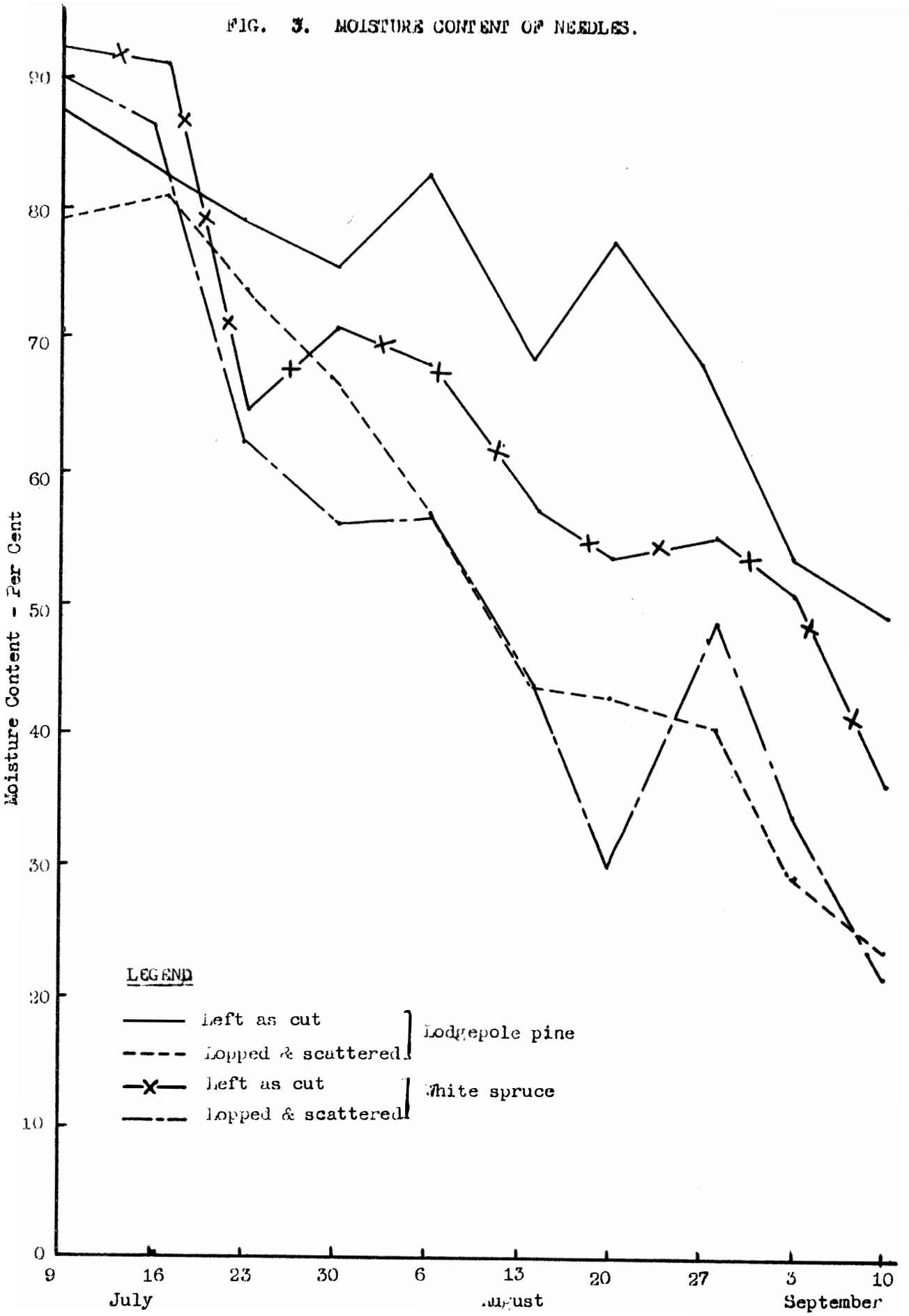
RESULTS

Fuel Moisture

a) Needles

The loss of moisture in lopped and unlopped lodgepole pine and white spruce tops is shown in Figure 3. Lopping was done immediately before

FIG. 3. MOISTURE CONTENT OF NEEDLES.



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sampling started on July 9. Based on 10 weekly samples, the mean difference in moisture content of needles of lopped and unlopped lodgepole pine tops was 18.0 per cent; 11.1 per cent for white spruce. Approximately $2\frac{1}{2}$ months after cutting, 99 per cent of the lopped lodgepole pine needles were brown compared to 75 per cent of the unlopped slash. However, only a few needles had dropped off the branches and twigs by the end of the field season. In comparison, about 95 per cent of the white spruce needles on lopped branches and 80 per cent on unlopped branches had fallen off by the end of the field season. The lag in the march of moisture between lopped and unlopped lodgepole pine slash is 3 to 4 weeks; for white spruce 2-3 weeks. White spruce needles have nearly all fallen off $2\frac{1}{2}$ months after cutting. Needles turn brown when their moisture content reaches about 35 per cent.

The above observations were substantiated by samples taken on the slash plots. Over 90 per cent of the lodgepole pine needles were brown $2\frac{1}{2}$ months after cutting, but still attached to the branches. White spruce needles, on the other hand, had nearly all fallen off $2\frac{1}{2}$ months after cutting.

An analysis of variance was carried out for the four sets of samples (two from tree tops, two from slash plots). The F-values for the lopped and unlopped slash were 0.33 and 1.72. The null hypothesis was accepted, indicating that the samples were from a normal population and could be grouped for future analysis. The significance of the differences between paired

samples of lopped and unlopped slash was tested by Student's t-test (Table 5).

Table 5. Mean Variation in needle M.C.% between lopped and unlopped slash.

Treatment	Mean diff.	df	t	Significance (1% level)
Lodgepole Pine				
Lopped vs unlopped (6 tree tops)	-18.0	9	5.12	Highly Significant
Lopped vs unlopped (12 tree tops)	-21.3	9	7.92	Highly Significant
Lopped vs unlopped (Plot 1 vs Plot 4)	-11.4	7	6.83	Highly Significant
Lopped vs unlopped (Plot 2 vs Plot 5)	-22.1	7	4.17	Highly Significant
Lopped vs unlopped (tree tops and slash plots)	-18.4	19	8.64	Highly Significant
White Spruce				
Lopped vs unlopped (6 tree tops)	-11.1	9	4.99	Highly Significant

b) Fine Fuels - up to 2-inch diameter

Two size-classes - 0.00-0.50", and 0.51-2.00" - were sampled separately and their moisture contents determined (Figure 4). The mean differences in moisture content for both species and size-classes are given in Table 6.

For branchwood less than 2 inches in diameter, the differences are significant for lodgepole pine, but not for white spruce. Fuels in these size-classes have a lower average moisture content than needles. The mean difference in the green moisture content of lodgepole pine needles and twigs and branches is about 15 per cent; for white spruce about 20 per cent. Since

FIG. 4. MOISTURE CONTENT OF FINE SLASH
(up to 2-inch dia.)

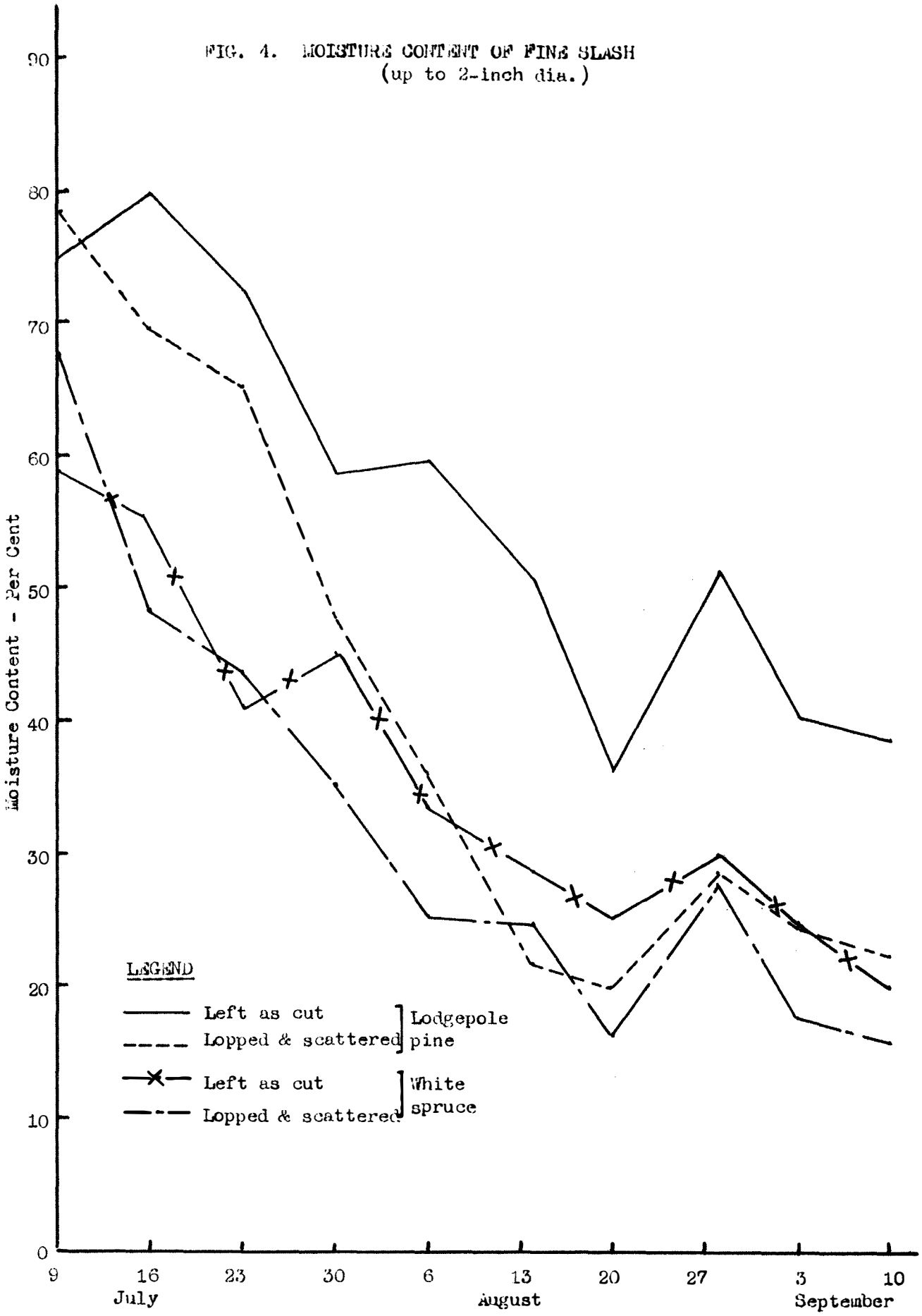

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Table 6. Mean Variation in M.C.% between lopped and unlopped slash up to 2 inch diameter.

Size-class	Treatment	Mean diff.	df	t	Significance (1% level)
Lodgepole Pine					
0.0-0.50	Lopped tops vs unlopped tops	-14.3	9	2.99	Significant
0.51-2.00	Lopped tops vs unlopped tops	-15.0	9	5.95	Highly significant
White Spruce					
0.00-0.50	Lopped tops vs unlopped tops	-5.56	9	2.76	Not significant
0.51-2.00	Lopped tops vs unlopped tops	-2.47	9	1.01	Not significant

the rate of drying appears to be similar, fine twigs and branches reach a highly flammable state earlier than the foliage. The effect of this on the total fire hazard may be considerable, for fine twigs and branches constitute 30-40 per cent by weight of all lodgepole pine and white spruce slash under 4 inches in diameter.

c) Large Fuels - 2 inches and over.

Fuels over two inches in diameter are normally part of the bole. Only the largest branches of a few mature trees reach this size. Theoretically, in pulpwood operations, all tops should be 4 inches or less in diameter. In practice, however, there is a substantial amount of larger material on the forest floor, mainly the result of decay, mortality, but also utilization practises.

Sampling of bole moisture consisted of taking ½ to 3/4-inch deep borings with a brace and bit. Usually, the lopped boles were resting on the ground surface, whereas the unlopped boles were suspended above ground. Each sample consisted of three borings, one on top of the bole and two at the sides. No borings were made into the portion of the bole in contact with the ground.

Table 7. Mean Variation in M.C.% between lopped and unlopped slash over 2-inches in diameter.

Species	Treatment	Mean diff.	df	t	Significance(1% level)
Lodgepole Pine	Lopped vs unlopped	+4.9	9	1.76	Not significant
White Spruce	Lopped vs unlopped	+7.9	8	2.30	Not significant

Unlike needles and fine slash the lopped boles have a higher mean moisture content than unlopped boles. This is probably due to the proximity of the lopped boles to the surface moisture. However, the mean differences are not significant statistically.

All of the results are from samples taken at the lodgepole pine clearcut. Although a similar sampling procedure was initiated on the white spruce-alpine fir clearcut, there are insufficient samples for a statistical analysis. However, the trends of moisture loss appear to be similar.

Fuel Moisture Indicator Sticks

In an attempt to compare the variation in moisture content owing to height of fuel above the ground surface, standard round ½-inch fuel moisture

sticks were laid out on wire frames. For variations in moisture content refer to Figure 5. Mean moisture contents of the indicator sticks are given in Table 8 below:

Table 8. Mean M.C.% of moisture indicator sticks

Location	On ground surface	1' elevation	2' elevation
In clearcut	30.7	19.0	15.8
Under canopy	55.1	26.7	26.1
Difference	24.4	7.7	10.3

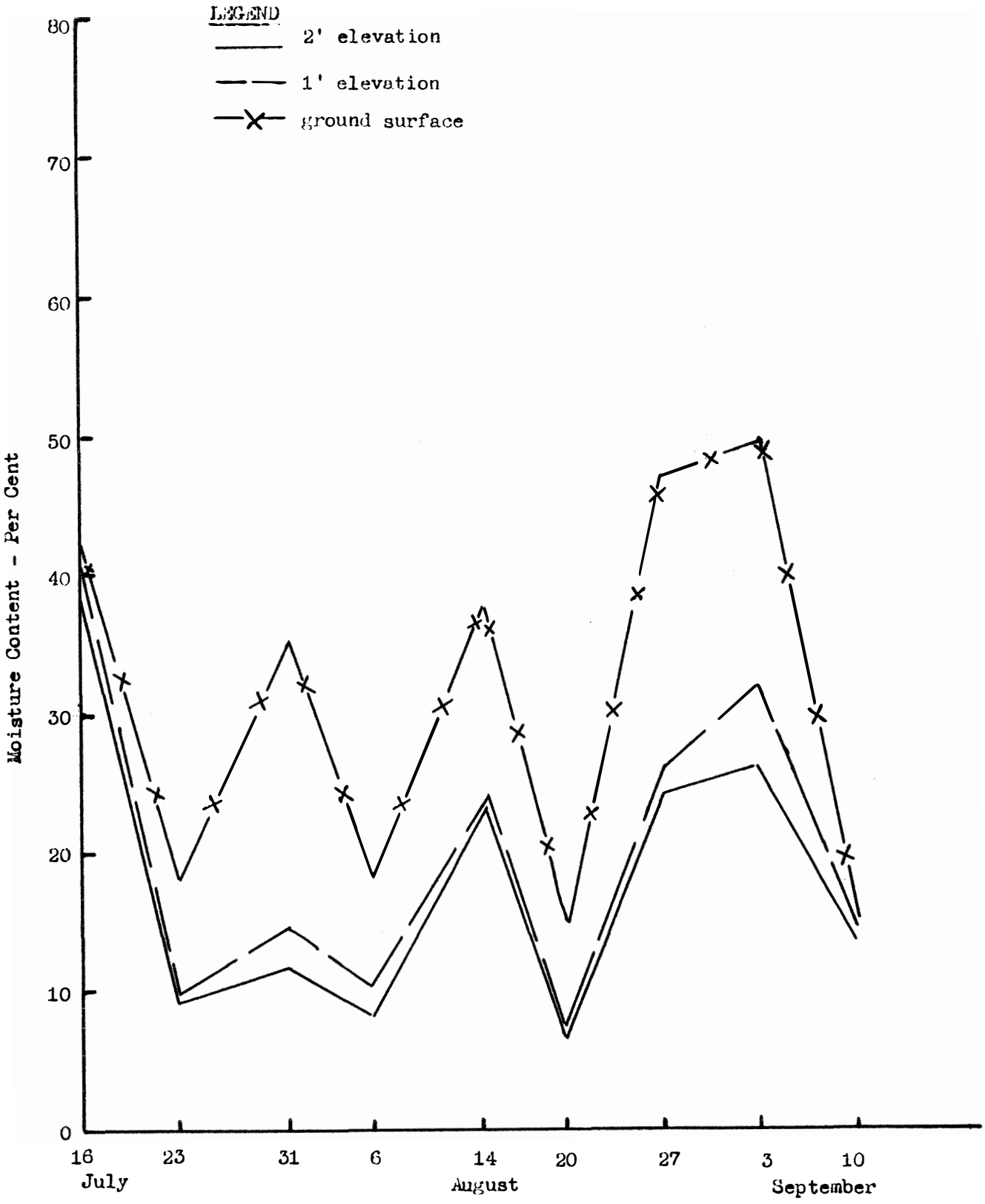
Slash Depth and Volume

Thirty-six depth measurements were taken at 20-foot intervals on each 100-foot square slash plot. These measurements are given in Table 9.

Table 9. Average slash depth in feet.

Lodgepole Pine				White Spruce - alpine fir			
Lopped		Unlopped		Lopped		Unlopped	
Plot 1	1.08	Plot 4	0.87	Plot 1	1.16	Plot 4	1.26
Plot 2	0.92	Plot 5	0.97	Plot 2	1.18	Plot 5	1.56
Plot 3	0.71	Plot 6	0.75	Plot 3	0.95	Plot 6	1.14
Averages	0.90		0.86		1.10		1.32

Fig. 5. MOISTURE CONTENT % OF INDICATOR STICKS ON CLEARCUTS.



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The students t-test revealed no significant differences in slash depth between lopped and unlopped slash for either species.

Slash volume was calculated by adding the volumes of the 20-foot grid squares. The formula used is:

$$V = \frac{A}{27 \times 4} (Zh_1 + 2Zh_2 + 3Zh_3 + 4Zh_4) \text{ cu. yds.}$$

where V = volume in cubic yards

A = area of each section

Zh_1 = sum of corner heights used once

Zh_2 = sum of corner heights used twice

Zh_3 = sum of corner heights used three times

Zh_4 = sum of corner heights used four times.

Table 10. Slash volume per acre (cubic yards)

Lodgepole Pine				White Spruce			
Lopped		Unlopped		Lopped		Unlopped	
Plot 1	1704	Plot 4	1334	Plot 1	1870	Plot 4	1967
Plot 2	1617	Plot 5	1563	Plot 2	1930	Plot 5	2685
Plot 3	1220	Plot 6	1263	Plot 3	1765	Plot 6	1815
Averages	1513		1387		1855		2156

Slash weight

Total oven-dry weight of each of the six 4' x 4' square lodgepole pine samples ranged from 10.2 to 45.9 tons per acre. The average of all samples

was 28.0 tons per acre. These figures include all surface fuels, except moss and duff. The per cent distribution of slash in the 0.00-0.50", 0.51-2.00", 2.01-4.00", and 4.01" and over in diameter was 35, 17, 20, and 28.

CONCLUSIONS

The march of fuel moisture in clearcut lopped and unlopped lodgepole pine and white spruce slash was followed from the time of cutting to the end of the field season. Slash depth, volume, and weight were measured and computed. Preliminary results, based on one summer's research, are as follows:

1. The mean difference in the moisture content between lopped and unlopped lodgepole pine needles is 18.4 per cent. The corresponding figure for white spruce is 11.1 per cent. During the first field season after clearcutting, lopped and scattered slash loses moisture more rapidly than slash left as cut.
2. The mean differences in moisture content between fine (0.00-2.00") lopped and unlopped lodgepole pine slash are significant at the 1 per cent level; for white spruce the differences are not significant.
3. For coarse (2.01-4.00") lodgepole pine and white spruce slash, the differences between lopped and unlopped slash are not significant at the 1 per cent level.
4. Most lodgepole pine needles turn brown within $2\frac{1}{2}$ months after cutting, but do not fall off the branches. White spruce needles turn brown about two months after cutting and have nearly all fallen off the branches by this time.

5. The lag in moisture between lopped and unlopped lodgepole pine during the 1963 field season was 3 to 4 weeks, for white spruce 2 to 3 weeks.

6. The mean differences between the moisture contents of indicator sticks were statistically significant at the 1 per cent level at the 1 and 2-foot elevations and on the ground surface. The differences between the 1 and 2-foot elevations were not significant.

7. The differences in slash depth between lopped and unlopped lodgepole pine and white spruce slash were not significant at the 1 per cent level.

8. Average weight of lodgepole pine slash was 28 tons per acre.

Lopped and scattered lodgepole pine and white spruce slash loses moisture faster than slash left as cut. The time lag in rate of drying varies between 3 and 6 weeks. Since moisture content is a good indicator of flammability, lopped lodgepole pine and white spruce slash reach a high hazard earlier than slash left as cut. Investigations carried out in 1963 indicate that a high degree of flammability is reached about 2-3 months after clearcutting. Lodgepole pine represents a particularly high hazard as it retains its needles after the first year. White spruce loses moisture at a somewhat faster rate than lodgepole pine, with the result that it reaches a high hazard sooner. However, since white spruce loses most of its needles 2½ months after cutting, the high hazard lasts for a relatively short time.

FUTURE WORK

The moisture sampling routine will be continued in 1964. Weekly samples will be taken on both the lodgepole pine and white spruce-alpine fir cutovers. Slash depth will be measured on all slash plots, including areas scarified and "walked over" with a bulldozer. Four-foot square samples of slash will be weighed to more fully evaluate this method of slash measurement.

An effort will be made to determine the proportion of slash in contact with the surface moisture and the effect of this on fuel moisture and rate of decay. Observations will be made throughout the field season of the per cent of needles dropping off. The per cent of green vegetation will be noted.