DEVELOPMENT OF A JACK PINE SLASH BURNING INDEX IN ONTARIO

by

B. J. Stocks

FOREST RESEARCH LABORATORY
ONTARIO REGION
SAULT STE. MARIE, ONTARIO
INTERNAL REPORT O-29

CANADIAN FORESTRY SERVICE
DEPARTMENT OF FISHERIES AND FORESTRY
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Not for publication

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INTRODUCTION

The Canadian Forest Fire Weather Index (Anon., 1970) is now in widespread use in most areas of Canada. The Fire Weather Index (FWI) is national in scope and is a numerical rating of fire intensity in a standard fuel type, i.e., upland pine sites where the main research into the development of the FWI was carried out.

By definition the FWI is dependent on weather only and is related to the ease of ignition of wildfires. Given that ignition occurs, it is a relative measure of expected fire behavior and daily fire control requirements. The FWI is independent of differences in fuel loading and fuel characteristics, and this point, in conjunction with the fact that the developmental research was undertaken in upland pine fuel types, would seem to indicate that a given FWI value probably does not represent the same fire behavior in different fuel types (although as a means of integrating weather variables to arrive at a single, representative index value the FWI is probably quite adequate).

Because fuel types vary widely in many parts of Canada and because a given FWI value may mean one thing in terms of fuel dryness and fire behavior in a particular fuel type and something entirely different in another, it is necessary to develop burning indexes for use in conjunction with the FWI. By measuring fire intensity during controlled burns and relating intensity, rate of spread, and fuel consumption to the FWI and its component indexes, it will be possible to develop burning index tables for major fuel types for use in conjunction with the FWI. Thus, the fire control officer in the field could calculate a daily FWI for his district, and, through the use of burning index tables, estimate fire intensity in any of the major fuel types within his district, should a fire occur on that day.

In Ontario, as well as in Alberta (Quintilio, 1970) and British Columbia, work is presently underway (by Canadian Forestry Service fire researchers) on the development of burning indexes for major forest fuel types. Jack pine slash is the first fuel type being investigated in Ontario and 10 experimental burns were carried out in the summer of 1970 with at least 20 additional burns scheduled for the 1971 field season. It is hoped that, at the end of this period, a sufficient number of fires will have been conducted (under a broad range of weather conditions) to facilitate the development of a jack pine slash burning index.

DESCRIPTION OF AREA

The experimental burns were conducted in Garrison Township in northeastern Ontario, located 20 miles east of Matheson and 15 miles south of Lake Abitibi. The burning sites were situated on flat, well-drained sandy soils with a typically podzolic profile.

The two areas in which the 1970 burns were carried out were relatively similar in stand composition before logging. The first area was predominantly even-aged jack pine (*Pinus banksiana* Lamb.) (90%), with a small number of black spruce (*Picea mariana* (Mill.) BSP) (10%). The area was 90% stocked, with the trees averaging 80 years in age and 60 feet in height. In the second area in which plots were located, even-aged jack pine constituted 70% of the stand with black spruce (20%) and white birch (*Betula papyrifera* Marsh.) (10%) also present. This area was 80% stocked, with the trees also averaging 80 years old and 60 feet high.

METHODS

Of the 10 1-acre plots that were burned in 1970, eight were located in a large 2000-acre jack pine cutover, logged for pulp in the winter of 1969. The remaining two plots were located 4 miles away in a jack pine clearcut 100 acres in size, cut over in 1967. Firelines 8 feet wide were cleared by hand for the initial eight burns, with a bulldozer being used to clear 16-foot firelines around the final two plots. Each slash plot was 1 acre in area (2 x 5 chains) and plot orientation was in either a north-south or east-west direction, as winds generally blew from south or the west. In both areas jack pine slash still retained a large percentage of needles, but the black spruce slash was needleless.

Slash weight was measured before and after each burn by using the line intersect method (Van Wagner, 1968). The total length of line sampled was 3 chains, in the form of a 2- x 1-chain cross intersecting at the center of the plot. The diameter of any piece of slash crossed by the 3-chain line was tallied, with slash fuels under 1 inch in diameter measured to the nearest 1/8 inch and those larger than 1 inch to the nearest 1/10 inch. Duff weight and depth were determined from random samples taken on each block and depth of burn was measured by using 27 steel pins positioned in the ground before burning so that a file mark on the side of each pin was level with the top of the moss or duff layer. The 27 pins were located on a 1/2-chain grid pattern throughout each plot.

The 10 burns were conducted during three different periods of the fire season: late June, late July, and early September. Weather measurements (wind, relative humidity, rainfall, and temperature) were taken at the burning sites during the periods when burning was being carried out and for a week or so before the initial burn in each of the three time periods. The FWI and its component indexes were calculated daily, by using data from the burning site weather station during and slightly before each burning period and by using weather information from the nearest Department of Lands and Forests station (20 miles west of the sites) in the interim.

Moisture content samples were taken for all fuel sizes immediately before each burn was ignited.

Of the 10 burns, six were ignited across the 2-chain width of the plot, while the other four blocks were ignited along their 5-chain width, because of changing winds and the desirability of having the fires burn with the wind. In a few instances wind shifts during a burn caused a fire to change direction and this created problems in determining rate of spread. Wires attached with string to 27 stakes on a 1/2-chain grid pattern throughout each plot were used to measure each fire's rate of spread. Each wire was run from a stake over a sawhorse and weighted to fall when the fire reached the stake and burned through the string. Fire progress was also recorded on slide film in most cases.

Fire intensities for each burn were calculated by using Byram's (1959) formula:

Fire intensity = heat of combustion x rate of spread x fuel consumed

(BTU/sec/ft) (BTU/lb) (ft/sec) (lb/sq ft)

Heats of combustion were obtained by reducing the gross value 9100 BTU/lb to values of 7700, 7800, 7900, and 8000 BTU/lb for the low, moderate, high, and extreme classes of the FWI, respectively. These reduced values take into account heat-yield losses due to the separation and vaporization of bound water, and incomplete combustion of the slash fuels.

From a protection standpoint, in addition to the constructed firelines, approximately six Provincial personnel were on hand to water down surrounding areas before and during the burn and to extinguish any small spot fires that resulted from the burn.

RESULTS

Fire behavior data (intensity, rate of spread, fuel consumption, and heat of combustion) for each of the 10 fires is given in Table 1, along with the FWI and its component indexes on each of the 10 burning days. The fires are arranged in order of increasing FWI rather than by date to facilitate interpretation of the table. Four burns took place in the HIGH range (values 11 to 22) of the FWI, five in the MODERATE range (values 4 to 10), and one in the VERY LOW class (FWI = 0).

Whereas each of the nine other 1-acre burns was carried out as a separate entity, the block burned in the VERY LOW class was part of a 2000-acre controlled burn conducted for site preparation by the provincial government. This plot did not burn until late at night when negligible wind and high humidity made the FWI effectively 0. All other blocks were ignited at approximately 2 PM.

Linear correlation analyses were run between the FWI and its component indexes and various fire behavior parameters such as intensity, fuel consumption (slash and duff), rate of spread, and depth of duff burned. Both total fuel consumption and depth of duff burned were significantly correlated (at the 1% level) with the Fine Fuel Moisture Code (FFMC), the Initial Spread Index (ISI), and the FWI. The ISI and FWI values also correlated well (significant at the 5% level) with fire intensity and rate of spread. Correlations between the Duff Moisture Code (DMC), Drought Code (DC) and Adjusted Duff Moisture Code (ADMC) and the four measured fire parameters were generally poor and not significant.

Figure 1 shows a plot of fire intensity over FWI for nine of the 1970 burns. Fire #3 was excluded as its very low intensity value had a very strong influence on the slope of the curve, because of the small number of fires plotted. An exponential curve has been fitted to the data.

Table 1 shows pre-burn slash weight/acre varies from 16.24 to 24.70 T, the average weight being 20.29 T/acre, or 0.93 lb/sq ft. Table 2 gives a breakdown of this average weight by fuel size classes.

Average duff weight on the 10 burned plots was 25.70 T/acre or 1.18 lb/sq ft. Average duff depth measured was 2.91 inches. Total available fuel averaged 45.99 T/acre or 2.11 lb/sq ft.

Table 3 shows slash and duff consumption for the five burns conducted in the MODERATE range of the FWI and the four burns carried out in the HIGH range. No percent-consumption figures are shown for these burns as it is impossible to determine exactly how much fuel is consumed in each class because of movement of fuel downward from one class to another during burning. Even when fuel pieces are sampled in exactly the same order before and after burning, one is unable to determine consumption accurately as smaller fuel pieces may drop two or more classes. In this study, however, the amount of "dropping" from the 4.1-in. + class to 3.0- to 4.0-in. class was determined. This allowed calculation of percent-consumption figures for two fuel classes: > 4 in. and ≤ 4 in. The results, along with duff-consumption figures, are shown in Table 4. The amount consumed, by percentage and weight, is larger under HIGH than MODERATE conditions.

CONCLUSIONS

The analysis of the 10 jack pine slash fires carred out in 1970 indicates an increase in values of fire behavior parameters such as intensity, rate of spread, fuel consumption, and depth of burn with an increase in fuel dryness, i.e., the FWI and its component indexes. The fact that this relationship is strongest with the FFMC, ISI, and FWI indicates that perhaps the moisture content of larger or deeper fuels (indicated by the DMC, DC, and ADMC) is not yet low enough, at FWI values of 18 or less, to contribute significantly to fire behavior.

It is hoped that, in the 1971 field season, burns can be conducted under broader FWI conditions than was the case this past year. More burns in the HIGH and EXTREME categories are essential in order to accurately extend the exponential curve shown in Figure 1 and, ultimately, to develop a burning index for jack pine slash.

This internal publication may be considered as a progress report on burning index development work in Ontario to date. Further reports will be forthcoming as data are obtained and analyzed.

ACKNOWLEDGEMENTS

The author acknowledges the consultation, advice, and assistance of J. D. Walker in the conducting of these experimental fires.

The capable and continuing assistance of the Ontario Department of Lands and Forests in general and the Matheson Division staff (Swastika District) in particular is also greatly appreciated.

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Van Wagner, C. E. 1968. The line intersect method in forest fuel sampling. Forest Sci. 14: 20-26.

Table 1. Fire behavior data for 10 controlled burns in jP slash (1970)

Fire #	Date	Wind (mph)	Temp.	RH	Rain (in.)	FFMC	DMC	DC	ISI	ADMC	FWI
3	June 25	0	52	75	0.12	57	20	83	0	25	0
9	Sept. 2	5	72	32	--	84	8	192	3	14	4
10	Sept. 9	4	76	42	--	87	9	170	4	16	6
1	June 21	7	78	30	--	86	18	62	4	21	7
8	July 29	4	86	39	--	87	22	172	4	33	9
2	June 22	9	69	53	--	87	20	69	6	23	10
4	July 21	10	67	35	--	90	12	127	9	19	13
5	July 22	4	87	41	--	92	16	136	8	24	13
6	July 23	4	85	38	--	92	20	145	8	29	14
7	July 24	7	83	46	--	92	23	153	10	34	18

(continued)

Table 1. Fire behavior data for 10 controlled burns in jP slash (1970) (concluded)

Fire #	Date	H/C* (BTU/lb)	Fuel consumption (lb/sq ft)	R/S** (ft/sec)	Intensity (BTU/sec/ft)	Slash wt (T/ac)	Duff wt (T/ac)	Total fuel wt (T/ac)	Depth of duff burn (in.)
3	June 25	7700	0.072	0.02	11	18.56	25.70	44.26	0.10
9	Sept. 2	7800	0.266	0.25	519	20.00	26.57	46.57	0.37
10	Sept. 9	7800	0.296	0.25	577	24.62	23.74	48.36	0.40
1	June 21	7800	0.331	0.30	775	16.24	26.35	42.59	0.68
8	July 29	7800	0.385	0.26	781	19.88	28.75	48.63	0.72
2	June 22	7800	0.333	0.32	831	17.34	23.09	40.43	0.66
4	July 21	7900	0.380	0.27	811	24.67	24.18	48.85	0.73
5	July 22	7900	0.362	0.28	801	20.24	28.31	48.55	0.54
6	July 23	7900	0.475	0.34	1276	24.70	22.65	47.35	0.81
7	July 24	7900	0.469	1.05	3890	16.66	27.66	44.32	1.20

* H/C Heat of combustion.

** R/S Rate of spread.

Table 2. Pre-burn slash weights by fuel classes for 1970 jack pine slash burn sites

Fuel diameter	Weight (lb/sq ft)	Weight (T/ac)	% (by wt)
< 1/8"	.053	1.16	5.7
3/16" - 1/2"	.093	2.03	10.0
5/16" - 1.0"	.046	1.00	4.9
1.1" - 2.0"	.067	1.47	7.2
2.1" - 3.0"	.156	3.39	16.7
3.1" - 4.0"	.230	5.01	24.7
4.1" +	.286	6.23	30.8
Total	.931	20.29	100.0

Table 3. Slash and duff consumption by fuel classes under MODERATE and HIGH danger conditions for 1970 jack pine slash fires

Fuel class (in.)	MODERATE Pre-burn weight (lb/sq ft)	MODERATE Post-burn weight (lb/sq ft)	HIGH Pre-burn weight (lb/sq ft)	HIGH Post-burn weight (lb/sq ft)
< 1/8	.061	.011	.048	.009
3/16 - 1/2	.092	.026	.098	.017
5/16 - 1.0	.051	.028	.045	.020
1.1 - 2.0	.063	.049	.067	.075
2.1 - 3.0	.120	.124	.197	.190
3.1 - 4.0	.210	.203	.268	.216
4.1 +	.283	.238	.285	.232
slash total	.880	.679	1.008	.759
duff	1.180	1.068	1.180	1.003
TOTAL	2.060	1.747	2.188	1.762

Table 4. **Percent duff and slash consumption under MODERATE and HIGH hazard conditions**

Fuel	MODERATE weight (lb/sq ft)	MODERATE %	HIGH weight (lb/sq ft)	HIGH %
slash ≤ 4 in. diam.	.156	26.1	.196	27.1
slash > 4 in. diam.	.045	15.9	.053	18.6
slash total	.201		.249	
duff	.112	9.5	.177	15.0
total fuel consumption	.313		.426	

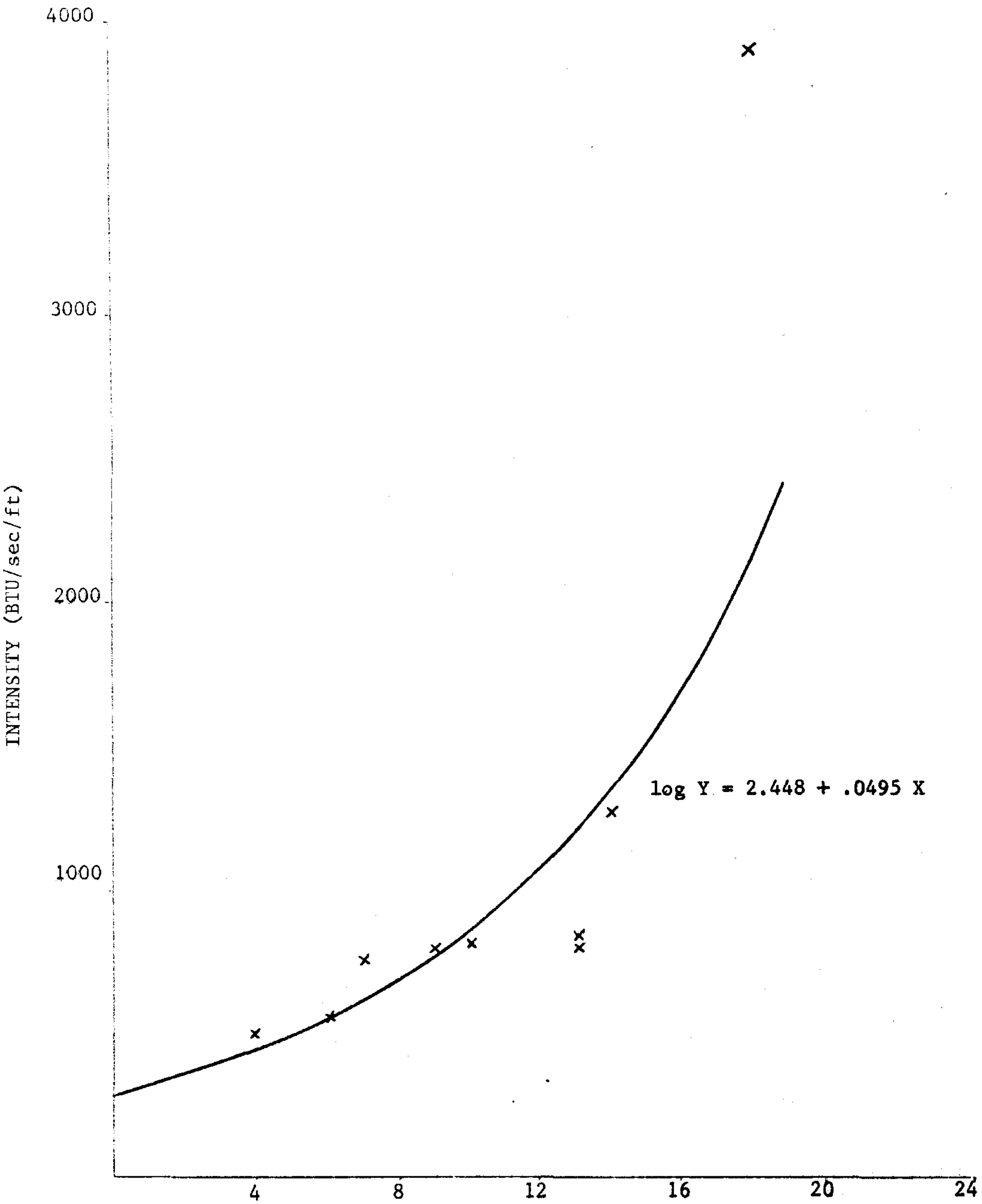

Figure 1. Curve of fire intensity over FWI for 9 jack pine slash fires carried out in 1970.

ENVIRONMENT CANADA

ENVIRONMENT CANADA

CANADA

MEMORANDUM

FILE NO.
Dossier No

/À Recipients of
Internal Report O-29

DATE September 24, 1971

Great Lakes Forest Research Centre
P.O. Box 490
Sault Ste. Marie, Ontario

OM/De Director, GLFRC

BJECT/Sujet

Errata - Internal Report O-29

Since publishing the above mentioned report an error has been discovered which effects Tables 1, 3 and 4 and Fig. 1.

Attached, hereto, please find copies of corrected pages for:

(i) the "concluded" section of Table 1
(ii) Table 3
(iii) Table 4
(iv) Fig. 1

Would you please make appropriate insertions in your copy (copies) of this report. We are sorry for the inconvenience that this may have caused.

G. W. Green
for
Director
Great Lakes Forest Research Centre

GWG/cc

Attach.

2013 REV.7/70 (H.Q. 3L)

Table 1. Fire behavior data for 10 controlled burns in jP slash (1970) (concluded)

Fire #	Date	H/C* (BTU/ lb)	Fuel consumption (lb/sq ft)	R/S** (ft/ sec)	Intensity (BTU/ sec/ft)	Slash wt (T/ac)	Duff wt (T/ac)	Total fuel wt (T/ac)	Depth of duff burn (in.)
3	June 25	7700	0.078	0.02	12	18.56	25.70	44.26	0.10
9	Sept. 2	7800	0.384	0.25	749	20.00	26.57	46.57	0.37
10	Sept. 9	7800	0.424	0.25	827	24.62	23.74	48.36	0.40
1	June 21	7800	0.555	0.30	1299	16.24	26.35	42.59	0.68
8	July 29	7800	0.615	0.26	1247	19.88	28.75	48.63	0.72
2	June 22	7800	0.538	0.32	1343	17.34	23.09	40.43	0.66
4	July 21	7900	0.659	0.27	1406	24.67	24.18	48.85	0.73
5	July 22	7900	0.490	0.28	1084	20.24	28.31	48.55	0.54
6	July 23	7900	0.735	0.34	1974	24.70	22.65	47.35	0.81
7	July 24	7900	0.871	1.05	7225	16.66	27.66	44.32	1.20

* H/C Heat of combustion.

** R/S Rate of spread.

Table 3. Slash and duff consumption by fuel classes under MODERATE and HIGH danger conditions for 1970 jack pine slash fires

Fuel class (in.)	MODERATE Pre-burn weight (lb/sq ft)	MODERATE Post-burn weight (lb/sq ft)	HIGH Pre-burn weight (lb/sq ft)	HIGH Post-burn weight (lb/sq ft)
< 1/8	.061	.011	.048	.009
3/16 - 1/2	.092	.026	.098	.017
5/16 - 1.0	.051	.028	.045	.020
1.1 - 2.0	.063	.049	.067	.075
2.1 - 3.0	.120	.124	.197	.190
3.1 - 4.0	.210	.203	.268	.216
4.1 +	.283	.238	.285	.232
slash total	.880	.679	1.008	.759
duff	1.180	.881	1.180	.735
TOTAL	2.060	1.560	2.188	1.494

Table 4. Percent duff and slash consumption under MODERATE and HIGH hazard conditions

Fuel	MODERATE weight (lb/sq ft)	MODERATE %	HIGH weight (lb/sq ft)	HIGH %
slash $\leq$ 4 in. diam.	.156	26.1	.196	27.1
slash > 4 in. diam.	.045	15.9	.053	18.6
slash total	.201		.249	
duff	.299	25.3	.445	37.7
total fuel consumption	.500		.694	

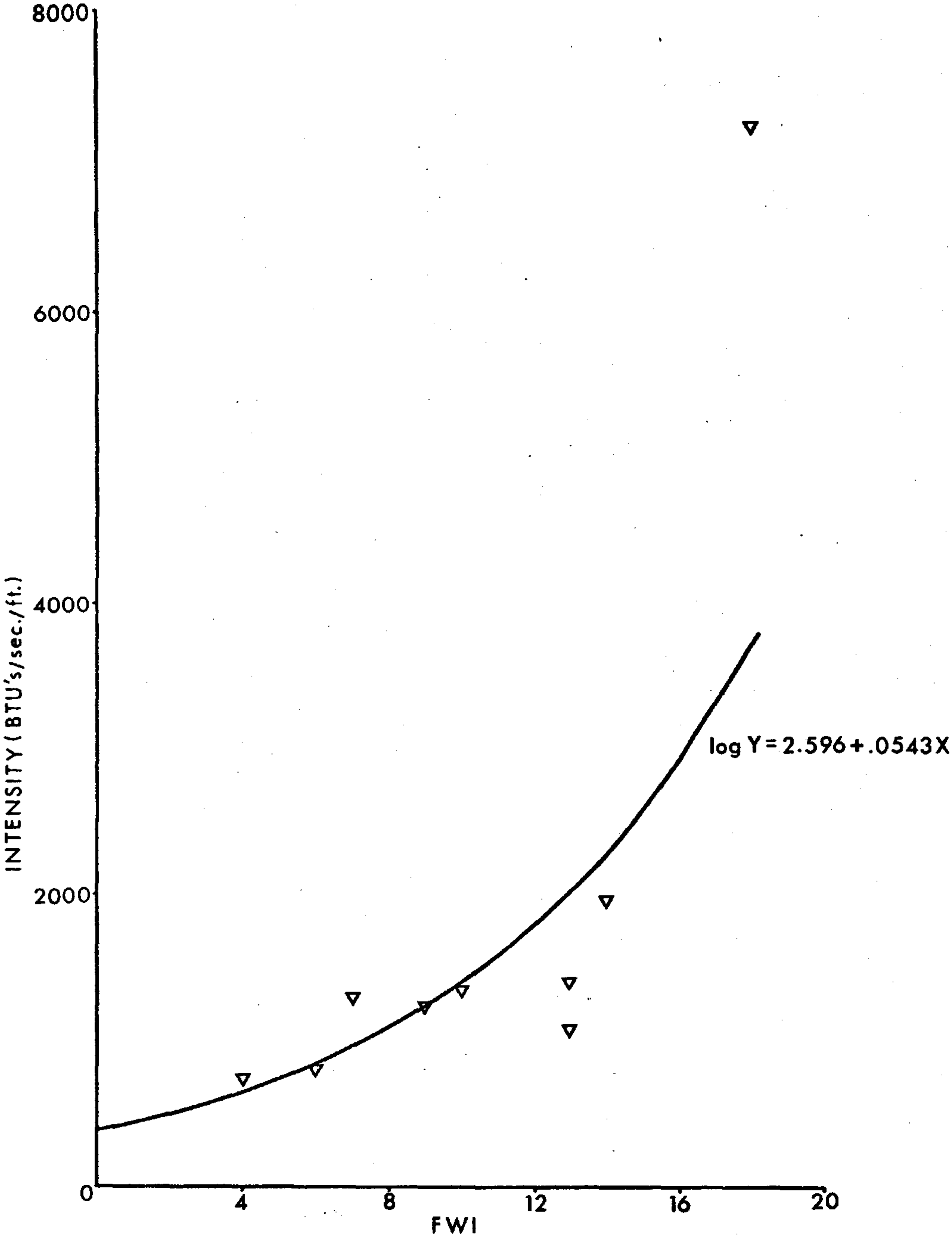

Figure 1. Curve of fire intensity over FWI for 9 jack pine slash fires carried out in 1970.