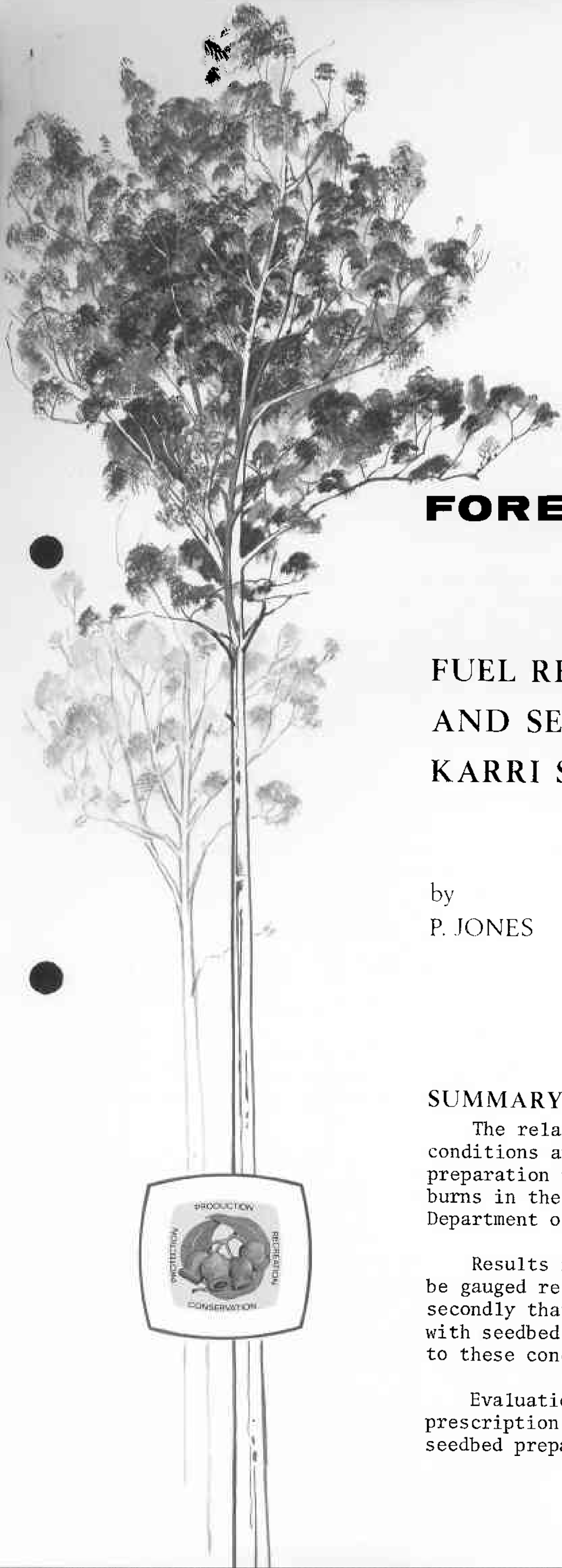

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FUEL REMOVAL, FUEL CONDITIONS AND SEEDBED PREPARATION IN KARRI SLASH DISPOSAL BURNS

by
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SUMMARY

The relationship between fuel removal and fuel conditions and between fuel removal and seedbed preparation was investigated during 14 slash disposal burns in the 1975-76 burning programme of the Forests Department of Western Australia.

Results indicate firstly that fuel removal cannot be gauged reliably by fuel moisture content alone, and secondly that fuel removal does not necessarily correlate with seedbed preparation. The various factors relevant to these conclusions are discussed.

Evaluation of the Department's slash burning prescription shows that it provides adequately for seedbed preparation.

INTRODUCTION

Slash (regeneration) burning has been undertaken by the Forests Department since the earliest days of forest management in the karri (Eucalyptus diversicolor F. Muell.) forests of Western Australia.

The objectives of slash burns are:

(1) to prepare seedbed suitable for karri regeneration;
(2) to induce seedfall from seed trees (if present);
(3) to dispose of logging residue so that fire hazard within the regenerating forest is minimised and access for future management operations is improved.

Until recently, slash burns have been organised by only a few officers, and their choice of techniques has been based on personal experience and judgement. The burns have been confined to small areas and have been intermittent, timed to coincide with the periodic karri seed supply.

However, the recent expansion of trade cutting from pure karri stands to mixed karri-marri (E. calophylla R. Br.) forest has prompted a great increase in the scale of the Department's slash burning programme. With areas in excess of 3000 ha to be burnt annually, more precise control of the operation is needed so that optimum results are obtained at minimum cost and difficulty.

Both ashbed and exposed mineral soil are suitable for the establishment and development of karri seedlings, and burning is the best way of preparing these seedbeds within cutover forest areas. Since the volume of logging slash consumed and the area of seedbed prepared by a burn appeared to be related to the intensity of the fire, this study of slash burns in cutover karri forest was designed to investigate the relationship firstly between fire intensity and fuel conditions, and secondly between fire intensity and seedbed preparation.

METHOD

Fourteen separate burns were selected for study, 8 in the "spring" (December 1975 to January 1976) burning programme and 6 in the autumn of 1976 (Table 1); they included burns in all three southern divisions (Pemberton, Walpole and Manjimup), in pure karri stands as well as in mixed karri-marri and some karri-marri-tingle (E. guilfoylei Maiden) forest areas.

The study areas were cull-felled and scrub-rolled before burning. Although strip lighting was used in all burns, there were variations in the light-up times and the lighting techniques. It was assumed that these differences were not significant, however, and therefore would not influence burn intensity markedly.

Fire intensity

Fire intensity, which is difficult to measure accurately, can be calculated fairly reliably using Byram's (1959) formula:

$$I = Hwr$$

where H = calorific value of the fuel
w = quantity of fuel consumed
r = rate of consumption.

The calorific value of the fuel consumed in the different burns is assumed to be constant; the quantity consumed and the

TABLE 1

Slash burns assessed

Walpole		Pemberton		Manjimup
Spring	Autumn	Spring	Autumn	Autumn
Frankland 8 Frankland 6 Dawson 3 Walpole 1 Swarbrick 4 Keystone 2 Keystone 4	Weld 14	Boorara 2	Poole 4 Poole 12 Weld 5 Weld 2	Gray 1

rate of consumption are the variables to be considered.

Because slash burns may be stationary and may continue to burn for several days, the rate of fuel consumption cannot be measured easily. It would be most accurately gauged by means of a continuously recording weighbridge, but since this type of equipment was neither available nor practicable in the circumstances, intensity was calculated by measuring instead the quantity of fuel consumed.

Slash fuel quantities were assessed both before and after each burn using the line intersect method (van Wagner, 1968): a line of known length is laid over the slash area and the diameter of every piece of woody material at its point of intersection with the line is recorded. From these measurements, quantity (in $t \cdot ha^{-1}$) is calculated using the formula:

$$W = \frac{e\Pi^2 \, \Sigma d^2}{8L}$$

where W = weight
e = wood density
d = piece diameter
L = line length.

Permanent sampling lines 100 m in length were used, the number for each burn (a minimum of 5 and a maximum of 10) depending on the size of the burn area. They were placed to give an even distribution (Fig. 1).

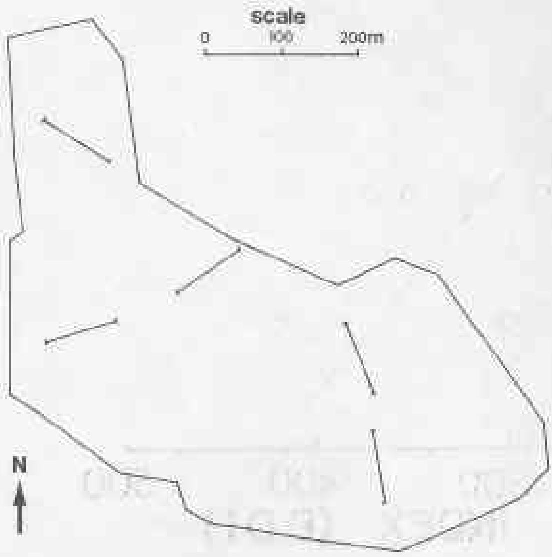

FIGURE 1: Distribution of fuel assessment lines in Frankland 8.

Only fuel over 25 mm in diameter was recorded, in 25 mm classes up to 300 mm and individually over 300 mm. The quantities of fuel consumed ($<$ 300 mm, $>$300 mm and total) were then expressed as percentages of the total available fuel.

Fuel moisture content

Three categories of fuel may be defined:

(1) Exposed fine fuel - those leaves and twigs at the top of the slash heap.

(2) Sheltered fine fuel - those leaves and twigs at the bottom of the slash heap.

(3) Heavy woody material - pieces over 100 mm in diameter.

Fine Fuel - The moisture content of sheltered fine fuel may be as much as 5% higher than that of exposed fine fuel (Forests Department, unpublished reports); the reverse is rare but can occur immediately after light rain. However, because sheltered fuel is generally the wetter it must be considered the limiting factor, and for this reason the moisture content of sheltered fuel was used as the value for fine fuel moisture content.

In general, moisture content was determined by destructive sampling: leaf material was collected in tins and oven dried, and moisture loss was expressed as a percentage of oven dry weight. In some cases, however, moisture content was measured using a direct reading Marconi moisture meter previously calibrated against the destructive samples.

Heavy Fuel - The moisture content of heavy fuel was gauged indirectly using as an indicator the drought index developed by Keetch and Byram (1968), which is generally known as the Byram drought index (BDI). The BDI used for each burn was that calculated on the day of the burn at the headquarters of the division in which the burn occurred.

To test the accuracy of BDI as an indicator of heavy fuel moisture content, the following trials were carried out at the Forests Department's Manjimup research station. Logs 100 mm and 200 mm in diameter were cut from tops of the previous winter's cutting and de-barked. A section cut from each was left exposed in a clearing, weighed, and then oven dried to calculate its moisture content, which was assumed to be representative of the whole log.

Using this value as a base point, the moisture content of the whole logs was calculated at intervals throughout the summer by weighing the logs.

These values were averaged and plotted against the BDI, and linear regression equations and correlation coefficients were calculated to determine the strength of the relationship between the BDI and log moisture content.

Seedbed classification

Seedbed may be classified into four categories:

(1) Ashbed - the soil structure is altered by intense heating, ash remains from the burnt material, and the soil is sterilised.

(2) Exposed top soil - the mineral soil is exposed by the burning away of litter, but heat has not been sufficient to alter the soil structure, to leave ash deposits, or to sterilise the soil.

(3) Disturbed ground - the topsoil is

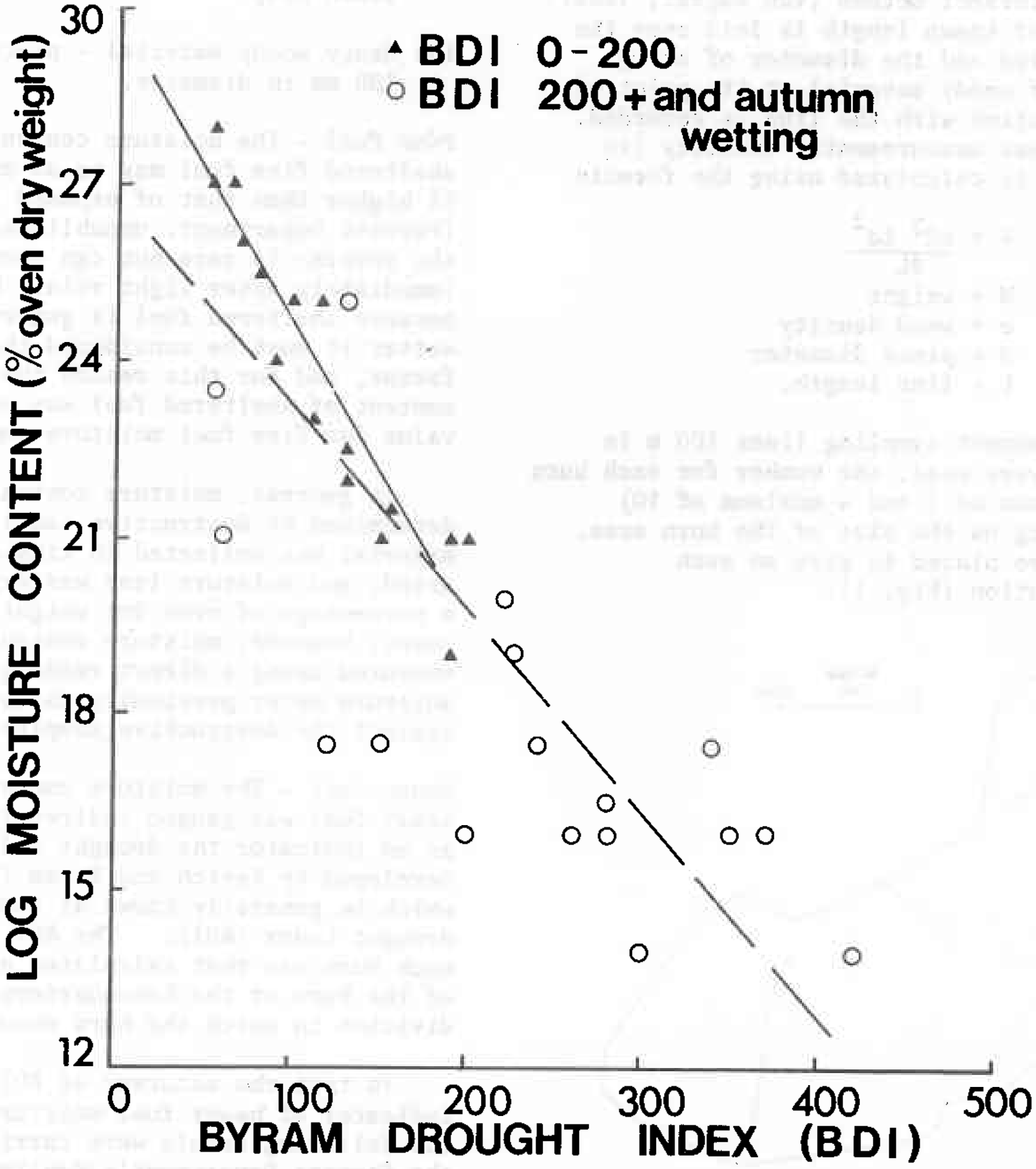

FIGURE 2: Graph of average log moisture content for 100 mm and 200 mm diameter logs against Byram drought index (BDI).

exposed and disturbed when the litter layer is removed by logging or scrub rolling.

(4) Non-productive - the soil is either unavailable (for example, covered by a log) or unsuitable for seedling growth (for example, mechanically compacted).

In order to classify the seedbeds prepared by the burns, point samples were taken every 2 m along the fuel assessment lines and along a transect placed at random across the burn. Seedbed categories were recorded, and each category was then expressed as a percentage of the total number of samples.

RESULTS

Figure 2 shows the moisture content values of the 100 mm and 200 mm logs plotted against the BDI.

The linear regression equations and correlation coefficients are as follows:

(1) for the whole season

$Y = -0.034x + 26.8$
$r = -0.85^{***}$
$r^2 = 0.72$

(2) for BDI from 0 to 200

$Y = -0.051x + 29.7$
$r = -0.94^{***}$
$r^2 = 0.88$
where Y = log moisture content
x = BDI
r = correlation coefficient.

The calculations indicate that the factors affecting BDI build-up are also closely related to fluctuations in average log moisture content.

Tables 2 and 3 give details of the spring and autumn burns respectively, including initial fuel quantities, percentage fuel removed, fuel moisture

TABLE 2

Spring burn details

Burn	Initial fuel ($t \cdot ha^{-1}$)	Fuel removed (%)			BDI	Fine fuel moisture content (%)	Seedbed (%)	
		< 300 mm	> 300 mm	Total			Ashbed	Total
Swarbrick 4	415	51	32	36	258	8	23	79
Dawson 3	630	44	32	35	315	16	30	81
Frankland 6	400	61	48	49	248	13	31	80
Frankland 8	578	54	39	43	217	8	33	84
Walpole 1	399	64	29	39	217	8	28	87
Keystone 4	606	50	59	57	184	11	14	81
Keystone 2	322	45	8	22	161	14	21	76
Boorara 2	728	55	28	31	103	14	27	82

TABLE 3

Autumn burn details

Burn	Initial fuel ($t \cdot ha^{-1}$)	Fuel removed (%)			BDI	Fine fuel moisture content (%)	Seedbed (%)	
		< 300 mm	> 300 mm	Total			Ashbed	Total
Weld 14	395	49	34	34	481	11	40	94
Poole 4	410	54	34	40	430	16	37	89
Weld 5	321	54	34	42	412	15	32	90
Poole 12	377	50	54	53	410	8	41	80
Weld 2	433	64	32	37	394	10	23	87
Gray 1	715	72	47	53	320	14	27	83

content values and percentage seedbed prepared.

Fine fuel moisture content and fuel removal. The data do not indicate any relationship between these two variables.

BDI and fuel removal. When the percentage values of total fuel removed were plotted against the BDI, their relationship was found to be weak ($r^2 = 0.02$). However, the two lowest BDI values clearly correlate with the lowest values for total fuel removed (Keystone 2 and Boorara 2).

Fuel removal and seedbed preparation. In all burns, percentage values for total seedbed preparation were very high, indicating complete removal of the fine fuels to expose the top soil. It is therefore not possible to infer from the results any relationship between fuel removal and seedbed preparation.

In contrast, however, ashbed formation varied markedly. The percentage of ashbed formed was plotted against the total percentage of fuel removed (Fig. 3) and against the percentage of fuel over 300 mm in diameter removed (Fig. 4).

With the exception of one anomalous point, ashbed formation in spring burns shows a weak but positive correlation with increasing fuel removal for both of these fuel classes. In the autumn burn data, however, no such correlation is apparent.

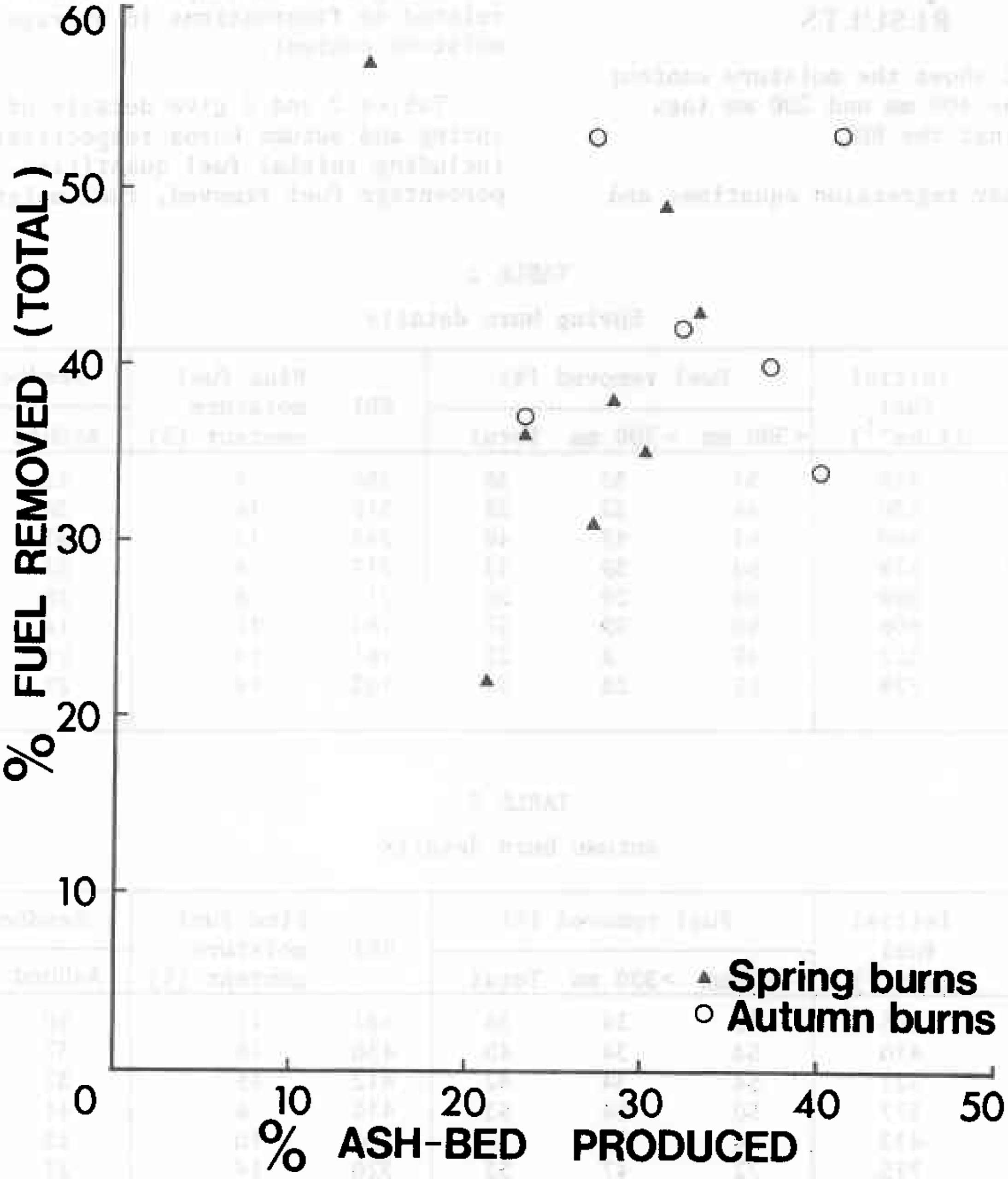

FIGURE 3: Graph of percentage fuel removed (total) against percentage ashbed formed in spring and autumn burns.

DISCUSSION

As the BDI accounted for 72% of the variation in the average moisture content of the sample logs, it may be considered an accurate indicator of the drying trend of large diameter woody material. However, the moisture content of sample logs is not necessarily an accurate measure of fuel moisture content in the field; because the samples were short pieces with cuts at both ends and because their bark had been removed, it is possible that they dried more rapidly than would otherwise be expected. The BDI is therefore valid for ranking burns in terms of heavy fuel drying but not of actual fuel moisture content.

The lack of correlation between the fuel moisture content of both fine and heavy fuels and fuel removal may perhaps be accounted for by one or a combination of the following points.

(1) Fons (1961) and McArthur (1967) have shown that increased fuel moisture content decreases the rate of spread of a fire. This, however, does not necessarily imply a significant reduction in the quantity of fuel consumed by the fire. Pompe and Vines (1966) used a flow calorimeter to demonstrate that the moisture content of fuel does not alter the amount of heat released by a fire but rather the rate at which it is released. Applying different moisture regimes to similar amounts of fuel, they found that complete consumption

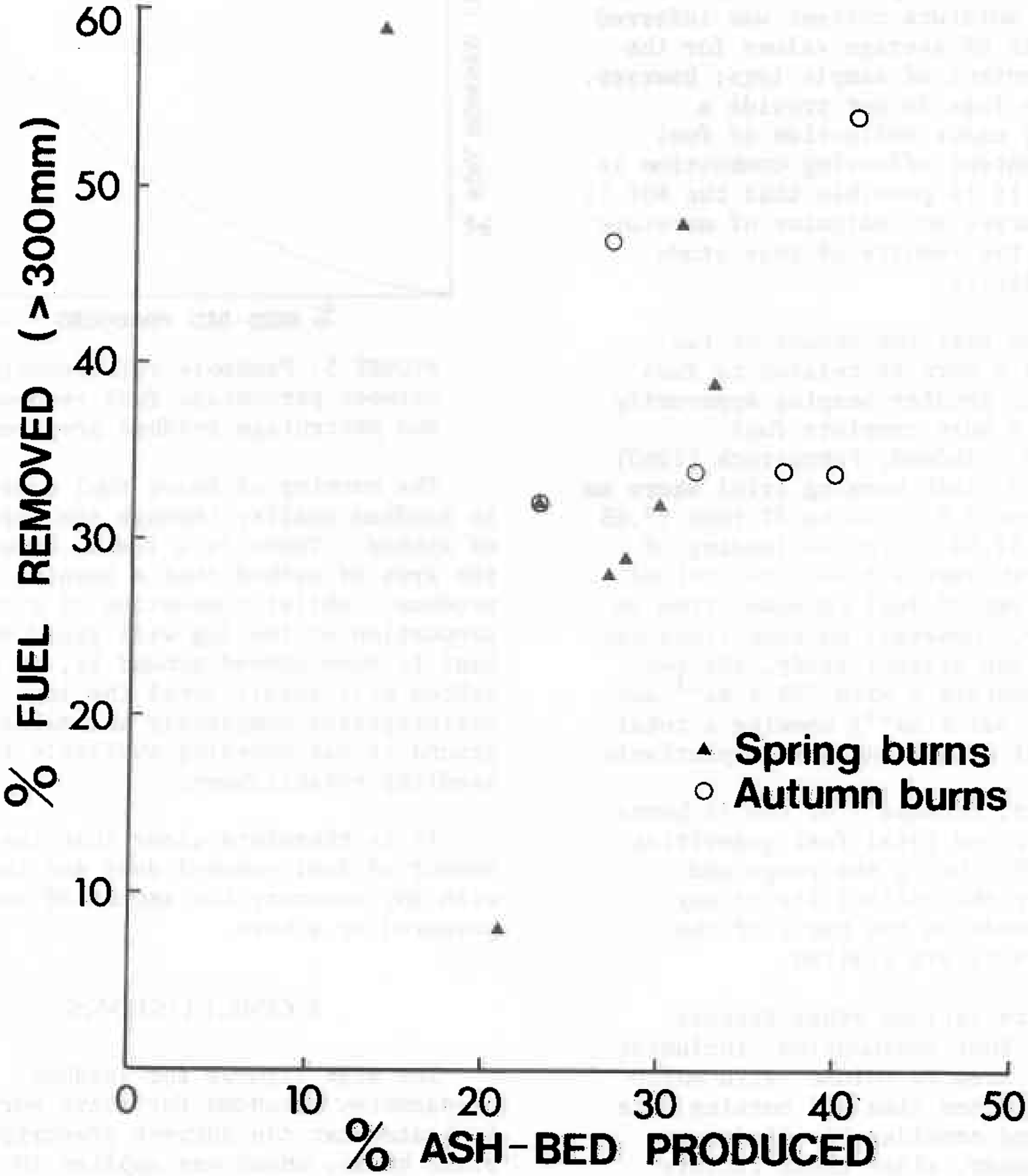

FIGURE 4: Graph of percentage fuel removed (> 300 mm diameter) against percentage ashbed formed in spring and autumn burns.

resulted in an overall similarity in heat output but a difference in the time required for complete evaporation and for heating of the fuel to ignition temperature.

(2) Furthermore, Brackebusch (1975) concluded from the results of a log-drying study conducted over a period of 19 years that except after long periods of drying, water in the inner sections of a log seldom escapes; moisture gains and losses, which usually involve the log's outer shell only, are consequently presented in false perspective if, as in the present study, change in weight of the whole log, which includes a constant water load, is used as a measure.

(3) The relationship between the BDI and heavy fuel moisture content was inferred on the basis of average values for the moisture content of sample logs; however, since these logs do not provide a necessarily exact reflection of fuel moisture content affecting combustion in the field, it is possible that the BDI is not so accurate an indicator of moisture content as the results of this study seem to indicate.

(4) It seems that the amount of fuel consumed in a burn is related to fuel arrangement, greater heaping apparently resulting in more complete fuel consumption. Indeed, Fahnestock (1960) reports on a slash burning trial where an increase from 7.5 to 20 to 32 tons (7.65 to 20.4 to 32.64 t) in the loading of conifer slash over a fixed area raised the percentage of fuel consumed from 56 to 72 to 79. However, no such trend was evident in the present study, the two extremes (Boorara 2 with 728 t·ha^{-1} and Weld 5 with 321 t·ha^{-1}) showing a total fuel removal of 31% and 42% respectively.

Moreover, because 7 of the 14 burns studied involved total fuel quantities close to 400 t·ha^{-1}, the range and consequently the reliability of any comparison made on the basis of the study's results are limited.

There are various other factors relevant to fuel consumption, including the surface area to volume ratio which affects residence time and burning rate of a fuel bed considerably (Anderson, 1969). However, since these factors were not investigated during the study, the view presented here is incomplete.

Whilst the preparation of optimum seedbed is dependent on fire, the relationship between the two is not linear. Figure 5 illustrates the probable relationship, which results because most of the ground is covered by fine fuels. Although they represent only a small part of the total fuel weight, their complete consumption during a burn gives maximum ground exposure; this occurs even though total fuel consumption may be low.

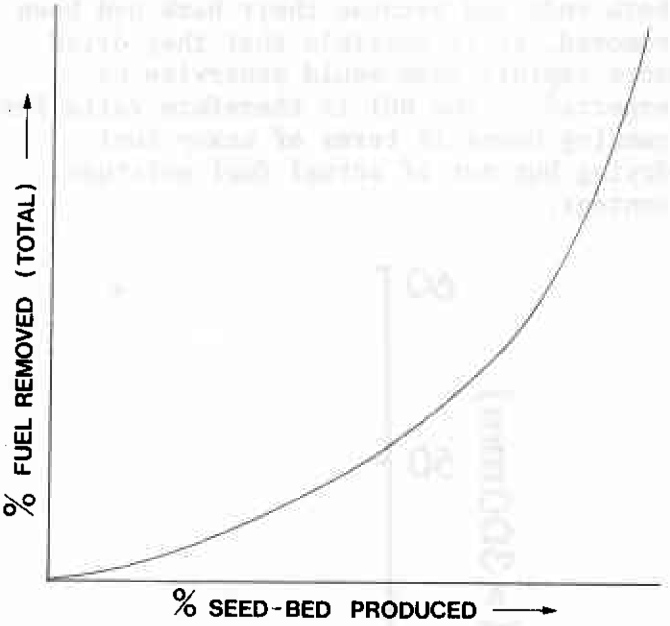

FIGURE 5: Probable relationship between percentage fuel removed (total) and percentage seedbed prepared.

The burning of heavy fuel contributes to seedbed quality through the formation of ashbed. There is a limit, however, to the area of ashbed that a burning log can produce: whilst combustion of a certain proportion of the log will yield enough heat to form ashbed around it, no more ashbed will result until the log disintegrates completely and makes the ground it was covering available for seedling establishment.

It is therefore clear that the total amount of fuel removed does not indicate with any accuracy the amount of seedbed prepared by a burn.

CONCLUSIONS

The high figures for seedbed preparation recorded for every burn studied indicate that the current prescription for slash burns, which was applied in all study areas and which requires conditions where the moisture content of fine sheltered fuels is less than 18% and the BDI is greater than 150, can provide for the preparation of adequate seedbeds in the karri forest.

However, slash burns cannot be evaluated in terms of seedbed preparation alone. Burn intensity must be modified to ensure that the fire is both controllable and safe for lighting and suppression crews; the optimum burn is that which is most intense within the prescribed conditions but which can also be safely controlled.

Investigations aimed at identifying the minimum conditions required for a successful burn will concentrate in particular on the relationship between heavy fuel moisture content and the BDI.

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