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PRESCRIBED BURNING TO MANIPULATE THE UNDERSTOREY COMPOSITION OF JARRAH FOREST - A LARGE SCALE TRIAL

(Hakea burn)

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Summary

A 2200 ha block of jarrah forest was burnt during dry conditions in March 1980 as part of a research program to examine whether fire could be used for widespread modification of the forest understorey. The aim of the treatment was to reduce the likely impact of the jarrah dieback disease by diminishing the abundance of an important susceptible host species, (Banksia grandis), and by establishing thickets of native legumes.

The fire burnt at low to moderate intensity and reduced the basal area of B. grandis by about 50% across much of the study area. Long term reduction in the density of this species would only be achieved by further removal of seed producing individuals and control of regeneration from seedlings and surviving rootstocks. The distribution of legume regeneration related closely to the presence of the species before burning, and high fire intensities were not essential for satisfactory establishment of thickets. Jarrah trees greater than 10 cm diameter recovered readily from crown scorch but logs burning adjacent to trees were a major cause of stem damage.

Further research should aim to determine whether this level of understorey manipulation will provide tangible benefits for dieback control.

Introduction

Most of the jarrah (*Eucalyptus marginata* Donn ex Sm.) forest in the south-west of Western Australia is subject to regular prescribed burning intended to prevent litter and scrub fuels from accumulating above a level considered acceptable for fire control. Fires are generally prescribed every 5-7 years according to the rate of fuel accumulation with the aim of keeping fine fuel loads below about 8 t/ha. Heavier fuels make wildfire suppression impossible under adverse weather conditions and increase the likelihood of serious commercial damage to the forest during uncontrolled fires. Fuel reduction burning is mostly done in spring when fuels are moist and the local Soil Dryness Index[1] (Mount 1972) is below about 500. The region has a long dry summer and the peak SDI often exceeds 1700 in March or April before autumn rains commence. The intensity (Byram 1959) of prescribed fires is deliberately kept low in order to minimise damage to the trees and seldom exceeds 350 kW/m (Christensen and Kimber 1975).

[1] The Soil Dryness Index used in W.A. is calculated in units of 0.1mm of rainfall.

Large areas of forest have the potential to be seriously degraded by jarrah dieback, a disease caused by the soil borne fungus Phytophthora cinnamomi Rands. (Podger 1972). Intensification and spread of the disease is aided by a susceptible understorey, such as the dense thickets of Banksia grandis Willd. which occur on some sites in the higher rainfall zone of the forest (Shea 1975). In contrast, conditions in the surface soil beneath an understorey of native legumes, particularly Acacia pulchella R.Br., have been demonstrated to be generally unfavourable to the fungus (Shea 1975, Shea and Malajczuk 1977). Native legumes may also be significant in overall forest nutrition through fixation of nitrogen (Shea and Kitt 1976).

Shea et al (1979) proposed that fires could be prescribed to reduce the abundance of B.grandis and simultaneously regenerate legumes, thus reducing the likely impact of dieback should infection occur. To be effective, such fires would have to be prescribed under dry conditions in summer or early autumn, and should generate substantially higher intensities than those associated with spring burning. This combination of season and intensity is necessary for several reasons. Firstly, B.grandis has thick bark, a well developed rootstock habit, and reshoots readily after fire. Banksia mortality relates directly to fire intensity, with fires of less than 350 kW/m having little effect on the population after 2 years. (Burrows 1985). Burrows (1985) considers that fires of sufficient intensity to kill a substantial proportion of the larger individuals can only be obtained by allowing fuels to accumulate well above 8t/ha, or by burning lighter fuels at high levels of fire danger (Sneeuwjagt and Peet 1976). Secondly, burning during dry conditions favours regeneration of many of the common native legume, which re-establish from seed stored in the upper few centimetres of the soil (Peet 1971, Shea et al 1979). Hardseededness (Gill 1981) is common amongst this group and many will only germinate in substantial numbers after the soil has been heated or disturbed mechanically. Species of _Acacia_, _Bossiaea and Kennedya_ typically exhibit this behaviour. Burning under dry conditions promotes complete consumption of litter fuels down to mineral earth and heat penetration into the soil thus providing a favourable environment for seed germination (Christensen _et al_ 1981). In addition, autumn germinants are assured of substantial winter rainfall, whereas seed germinating in spring may suffer heavy drought losses during the ensuing summer.

Broadscale burning in summer or early autumn poses many more problems than spring burning. Fire behaviour becomes increasingly unstable in dry fuels (<10%M.C.) rendering accurate prescription of fire intensity difficult, and increasing the likelihood of suppression problems and physical damage to trees. In order to gain a better understanding of the behaviour and effects of summer/autumn fires, the then Forests Department[2] initiated a research program involving detailed small scale experiments and larger scale operational trials. This paper describes a 2200 ha aerial burn undertaken with the intention of answering the following questions about broadscale burning at low to moderate intensity during dry conditions -

- what reduction in the abundance of B.grandis can be expected?
- can widespread legume thickets be established?
- what level of physical damage will the forest growing stock suffer?
- can the behaviour of a mass ignition fire be adequately predicted and controlled during dry conditions.

[2] Now incorporated into the Department of Conservation and Land Management.

Materials and methods.

The study area

The 2200 ha study area was located in Hakea forest block about 25 km south east of Dwellingup. About two thirds of the block is lateritic upland which carries an open forest of jarrah and marri (*Eucalyptus callophylla* Lindl.) 20-30m in height. This forest forms part of the Dwellingup vegetation complex described by Heddle *et al* (1980) and generally has a low open understorey of scrub and small trees. *B.grandis* formed localised thickets in some areas before the burn, and was also present as scattered individuals. The block was logged between 1930 and 1950 under a group selection system and now carries a mixed forest with a wide range of age and size classes. Away from upland areas the vegetation ranges from low forest to scrubby flats representing elements of the Yarragil, Pindalup-Yarragil and Murray-Bindoon vegetation complexes (Heddle *et al* 1980)

There was some limited prescribed burning in the block prior to spring 1968 when the entire area was burnt. The block was burnt again in spring 1974 and thus carried 6 year old fuel and scrub at the time of the experimental autumn burn in 1980.

Pre burn assessment

Forty seven permanent 20 x 20m plots were established prior to the burn at locations chosen subjectively to sample the range of forest stand structure and understorey type. The number of B.grandis within each plot was counted and the diameter of individual plants taller than 0.5m was measured (at 0.5m) and used to calculate basal area. The understorey structure in each plot was assessed by the levy point quadrat method (Levy and Madden 1933) from 50 points made on a grid pattern. The occurence of the major legumes was determined by counting the number of individual plants of Acacia, Bossiaea and Kennedya species in each plot.

A number of healthy jarrah without existing bole defects were selected in the general vicinity of each plot according to the structure and condition of the stand. Stem diameter was measured at breast height overbark (dbhob) and logs or slash fuel within 1.5m of the tree were noted. Litter fuel was collected from four $1m^2$ quadrats in each plot and oven dried to estimate fuel loading. Additional estimates of litter fuel load were made at 126 points throughout the study area based on the depth/weight relationship developed by Sneeuwjagt and Peet (1976).

Post burn assessment

Crown scorch height was measured during August 1980 within individual plots and on a 400 x 100 m grid across the block. Broadscale patterns of legume regeneration were described at the same time by counting the number of seedlings of each species in a $10m^2$ quadrat at grid points. Counts were repeated at the same points in March 1981. Legume response within the permanent plots was assessed by counting seedling numbers on four $10m^2$ quadrats during August 1980, and by repeating the Levy point sampling in late 1982.

In August 1980 six areas from 0.5 to 2 ha were fenced to exclude grazing animals. The number of each species of legume was counted on 40 permanent $1m^2$ plots inside the fenced area and on 40 similar plots outside the fence. Counts were repeated in February 1983.

The condition of *B.grandis* and jarrah in the plots was assessed in Autumn 1981 and again during winter 1982. *B.grandis* plants were recorded as having reshot from the crown, reshot from the base or lower stem, or having died altogether. During the 1981 assessment, the presence of bole epicormics, bark cracking and cambial damage on jarrah were noted, and in 1982 the size and location of wounds was measured. Where necessary, sections of the bark were removed to expose the full extent of injury.

Planning and implementing the burn

The Hakea burn required a substantial commitment of time and resources by both local and specialist fire control staff. Adjacent forest within about 3km radius of the study area was burnt during spring 1979 to provide a fuel reduced buffer, and additonal suppression forces were brought in from outside the Dwellingup division on the day of the burn.

A detailed prescription was prepared for the burn on the basis of measured fuel loads, current fire behaviour tables (Sneeuwjagt and Peet 1976) and the considerable experience of fire control officers. Litter fuel moisture content and SDI were calculated daily from weather readings made at Dwellingup. Rainfall was recorded at the site by a portable raingauge. Field samples of litter and surface soil (0-5cm) were collected for oven drying at a range of locations on the day before, and on the day of the burn. Wind speed in the forest was measured at a location on the eastern boundary during the burn, and several nearby fire towers provided fire control staff with regular reports of wind speed and direction. Ground observers recorded fire behaviour around the perimeter, and aircraft provided some information on fire behaviour within the burn. The burn was deliberately postponed until there was a light fall of rain to moisten the surface fuels. Three millimetres of rain fell at Hakea on 20-3-1980 and the moisture content of litter fuels increased to around 50% (O.D.W.). This was the first rain recorded at the site during March. Litter dried rapidly in the absence of further rain and moisture contents had fallen to 15-20% by 1500 HRS (WST) on the following day. The rain had little effect on soil moisture and surface soils were still very dry, with upland sites being slightly drier than the lower lying areas (Table 1).

The study area was burnt on 22-3-1980. Most of the block was ignited from the air except for a small section which was lit by ground crews. Ignition began shortly after 1500 HRS and continued for about 2 hours. Incendaries were initially dropped on a 150 x 75m grid pattern but this was progressively reduced to 75 x 75m as the burning conditions declined after 1600 HRS (Table 1). Litter samples collected between 1500 and 1600 HRS had a mean moisture content of about 10% but were variable, as would be expected over a large area. Winds were light and from the SE and ESE.

TABLE 1 HERE

Fire behaviour around the perimeter of the block was relatively mild with mean flame heights up to about 1m, and head fire spread rates of 20-50m/h. These spread rates correspond to intensities of 200-250kW/m if an average fine fuel load of 9t/ha was consumed. Observation from aircraft indicated similar fire behaviour over much of the upland forest. However fire behaviour increased markedly in heavier fuels and on slopes, and was very sensitive to slight increases in wind speed. Fire intensities also became considerably greater as approaching flame fronts coalesced. Flames flared into the canopy briefly at isolated locations, and dense scrub vegetation in the low lying areas burnt fiercely with all foliage being consumed. The block was largely burnt out by 2030 HRS with no serious suppression problems being encountered.

Results

Impact on the banksia population

B.grandis was present in 37 of the 47 plots before the fire, but there was considerable variation in the population structure and plant density between plots. The densest thickets contained the equivalent of 5400 plants/ha and had a basal area of B.grandis around $17m^2/ha$, but such thickets tended to be localised and seldom exceeded a few hectares in area. Data from all plots containing B.grandis were groupd in order to examine the overall effect of the fire on population structure. Outright mortality was least among small plants (38% for plants <5cm diameter)and increased progressively with stem diameter (Fig.1.). Almost all of the plants below 5cm diameter which survived the fire had been killed back to ground level and were reshooting from basal lignotubers. Larger plants displayed a greater ability to recover from epicormics shoots in the crown and this was propotional to stem diameter.

FIG. 1 NEAR HERE

Two years after the fire the mean basal area of B.grandis in the 37 plots had fallen from 7.9 to 3.4m^2/ha with this reduction taking place relatively evenly across the area. (Fig 2.). The impact of the fire could not readily be compared between plots due to the difference in the

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FIG. 2 NEAR HERE

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structure of the banksia population, and because variability in fire behaviour could not accurately be accounted for. The reduction in the basal area of B.grandis was weakly related to the scorch height in thesurrounding forest (R = 0.32, P = 0.1) but showed no correllation with the fuel load measured in the plot before the burn.

Regeneration of native legumes

A total of 8 species of Acacia, Bossiaea and Kennedya were recorded before the fire with 32 of the 47 plots containing at least one of these species (Table 2). Most of these plants would have originated after the prescribed burn of spring 1974.

TABLE 2 NEAR HERE

Six months after the fire in 1980 all 47 plots contained at least one species of legume and most contained more. This assessment was only a subsample of each plot and most species occurred in a greater number of plots than indicated in Table 2, which explains the apparent reduction in the distribution of A.pulchella after the fire. One additional species was recorded in 2 plots after the fire (Acacia extensa Lindl.). In almost every case, individual species regenerated in plots where they had been recorded before the fire. Some species were noticeably more widespread after the fire including Acacia preissiana Meissn. B.R.Maslin, Bossiaea ornata (Lindl.) Benth, Kennedya coccinea Vent. and Kennedya prostrata R.Br. Both A.preissiana and B.ornata regenerated from existing rootstocks as well as from seed. After 2 years the mean percentage cover of each species in the plots had returned to the preburn level and in most cases exceeded it, indicating a general increase in density of the legume component of the understorey. There was no apparent relationship between the abundance of any species in the plots after the fire and either the pre burn fuel load or the scorch height in the surrounding forest.

Eleven species of legume were recorded in the broadscale surveys conducted a year after the fire, this being 2 more than in the plots. The additional species recorded were Acacia alata R.Br. and Acacia divergens Benth and both were restricted to low lying areas where there were few plots. A.extensa was also confined to these sites. The remainder of the species occurred on a wide spectrum of sites and in areas burnt at varying intensity, with a similar frequency ranking to that in the permanent plots.

Comparison of fenced exclusion plots and adjacent unfenced areas showed that similar changes had taken place in the abundance of legume species. This suggests that grazing pressure was not a major factor in determining the distribution of legumes after the Hakea fire.

Of the legumes which regenerated, only *A. pulchella* and *Acacia celastrifolia* Benth. both grow large enough and regenerate in sufficient density to form tall thickets. A density of about 1 established plant per m^2 is usually sufficient to form a thicket, and about 10% of the study area was stocked at this level after 2 years. The overall density of the thickets would depend on the subsequent growth of individual plants.

Fire damage

The crowns of the overstorey trees were fully scorched over about 40% of the study area and a futher 10% was scorched to at least 80% of tree height representing scorch heights from about 16-25m. Scorch heights were generally low around the perimeter. There were distinct strips of fully scorched forest parallel to the direction of the ignition lines which probably correspond the junction zones where fire fronts coalesced. The forest canopy recovered rapidly in the spring following the burn and after 2 years the density of foliage in the study area appeared markedly greater than in surrounding forest which had not been substantially scorched during spring prescribed burning. Ninety-nine percent of trees selected in and around the plots (dbh>10cm) had reshot from the crown within 1 year of the fire.

About a third of the trees below 20cm dbh developed epicormic shoots on the stem but the proportion declined with increasing stem diameter and there were no epicormics recorded on stems in excess of 40cm dbh.(Table 3)

TABLE 3 NEAR HERE

During the assessment it became apparent that logs and woody debris which had burnt adjacent to trees were a major cause of cambial damage. Twenty trees with no logs within 1.5m of the stem were selected at random from the sampled population and compared with a similar sample which had logs nearby. Almost all trees (95%) with logs adjacent to the stem were damaged compared with 25% for those with only litter fuels within 1.5m ($p<0.01$). Wounds exceeding 500cm^2 in area were twice as frequent on the trees with logs adjacent ($p<0.10$).

Overall, about 20% of trees which had only litter fuel within 1.5m of the stem were damaged (Table 3). Most wounds were small with two thirds being less than 100cm^2 in area. Wounding was most common on the bottom 2m of the stem andonly a few of the larger scars extended above this level.

The incidence of stem damage was compared between trees subject to 3 levels of crown scorch (Table 4). The sample was confined to trees 20-29cm dbh in order to limit the variation in actual scorch height for a given category of crown scorch. Trees which had logs within 1.5m of the stem were not considered. Trees with less than half the crown scorched displayed a lower incidence of stem damage (14%) than those scorched to a greater extent (23%).

TABLE 4 NEAR HERE

Only trees subject to more than 50% crown scorch had wounds exceeding 100cm^2 in area. However the incidence of damage to fully scorched trees was not any greater than to those with between half and complete crown scorch.

Discussion

Plant response in relation to fire characteristics

The response of vegetation to fire is influenced by the season, frequency and intensity of burning which together constitute a fire regime (Gill 1975). Accordingly, variation in fire intensity will be a major factor governing plant response following any individual fire event. Fire seldom burns with uniform intensity except over very small areas and in this respect is very different to many of the treatments traditionally applied in field experiments, such as thinning or fertilisation. Estimates of fire intensity made from measured mean fuel loads and observed fire spread rates indicate that much of the area burnt at intensities of less than 500 kW/m, which are generally regarded as low (Cheney 1981). The litter bed generally burnt away completely so that fuel loads measured before the burn would be a good estimate of the amount of fuel consumed. The broadscale pattern of crown scorch also indicates this range of fire intensity as scorch heights of 16-24 m correspond to fire intensities about 200-500kW/m under autumn conditions (Burrows 1984). Unfortunately lack of accurate measurements of fire spread rate prevented calculation of fire intensity at individual plots.

Plant response was examined in relation to scorch height and pre burn fuel load but neither showed a clear relationship to the level of tree damage (to jarrah and B.grandis) or to legume regeneration. This may partly reflect the difficulty of selecting a meaningful index for comparison of fire effect on plants between plots which vary widely in population structure or species composition. The expression of fire intensity through scorch height is also limited by the height and density of the canopy in the surrounding forest and will be strongly influenced by local wind patterns.

Burrows (1985) found that fire intensity was a reliable index of the ability of a fire to kill B.grandis stems back to ground level. The absence of a clear relationship between fuel load and the level of damage to B.grandis in this study suggests that factors other than fuel load which also contribute to intensity have an important influence on plant mortality. Burrows (1985) reported that the rate of heat energy release had a detectable bearing on the level of stem mortality, with fast spreading fires causing more damage than slower back fires. It seems reasonable to assume that fire intensity would also relate to stem damage for other woody plants protected by thick bark such as jarrah, but this could not be addressed directly with the data available from this study.

The very strong relationship between the distribution of individual legume species before and after the fire illustrates the importance of seed availability in determining the distribution of legume regeneration. Seed availablilty may also be influenced by factors which affect the local heat environment of the soil such as soil moisture and the quantity of fuel available for burning. Dense legume thickets established in some areas at Hakea which had burnt at very low intensity, and the results of this study do not support the contention that high fire intensities are essential for satisfactory legume regeneration (see Shea _et al_ 1979). Peets' (1971) study of legume regeneration following the Dwellingup fire also did not show a clear link between legume dominance and fire intensity as expressed by crown damage, with the contribution of legume species being 38% in defoliated forest, 40% in fully scorched forest and 33% in forest which retained some green crown after the fire. Legume contribution was substantially lower (20%) in forest which had been control burnt at low intensity in spring.

Implications for management

The Hakea burn was primarily designed as an operational trial and not as a detailed scientific experiment. This should be borne in mind when analysing the results of trial. Such studies do however provide a sound basis for predicting outcomes to be expected in practice. A number of conclusions can be drawn from the study in answer to the questions posed in the introduction to this paper -

1. <u>What reduction in the abundance of *B.grandis* can be expected?</u>

Low to moderate intensity autumn fires may reduce the initial basal area of *B.grandis* by up to half with reasonable uniformity over a large area. Up to half of the plants > 5cm diameter may be killed outright. Burrows (1985) reported similar levels of *B.grandis* reduction for this range of fire intensity, and showed that the level of reduction increased at higher intensities. However a single fire with this range of intensity will not achieve a lasting reduction in *B.grandis* density, as plants killed back to ground level rapidly reshoot and those above 5cm diameter which remain unaffected by the fire have the potential to produce seed and thus replenish the population (Abbott 1985). Subsequent treatment would be necessary to remove remaining larger trees and prevent regrowth from attaining seed bearing size. The detailed prescription for such a treatment in discussed by Burrows (1985).

2. Can widespread legume thickets be established?

The success of legume regeneration depends on the availabliity of a source of viable seed. The presence of plants of the desired species is the only reliable indicator of a seed source at this stage. The results of this and several other studies (Peet 1971, Shea et al 1979) have demonstrated that seed of a number of legume species is present on a wide range of sites throughout the jarrah forest. However some legumes are site specific (Havel 1975) and it is unlikely that alteration of the current fire regime would greatly effect the distribution of these species. The relationship between site and species is not constant and is influenced by rainfall and landform.

Artificial seeding would provide a more reliable method for establishing thickets of desired specied on sites where the extent or compostion of the natural seed source cannot be determined, or where thicket forming species do not naturally occur. High fire intensities do not appear to be essential for legume regeneration during dry autumn conditions. However legume regeneration and fire intensity are linked indirectly as intense fires are more common in heavy fuels and during dry conditions.

3. What level of physical damage will the forest growing stock suffer?

Logs and debris which burn adjacent to trees are a major agent of stem damage during summer and autumn fires. The level of damage during such a fire will be strongly influenced by the amount of log debris in the stand, irrespective of the fire intensity. Potential crop trees in silviculturally treated stands are currently protected by moving logs and tops away from the stem. Similar treatment would be required if crop trees were to be protected in forest burnt during dry conditions. Such an operation would be labour intensive and costly.

For jarrah, the likelihood of stem damage leading to wood degrade depends on the size of the initial wound, and wounds below $100cm^2$ in area have been shown to seldom affect the potential of a tree for wood production (McCaw 1984).Excluding trees which were damaged by burning logs, the low to moderate fire intensities experienced at Hakea damaged 7-10% of trees (>10cm dbh) to an extent which may result in commercial volume loss. The eventual magnitude of the loss will be affected by the size of the tree at the time of injury, the extent of the damage and the technique of utilisation employed.

Stand structure has a major bearing on the range of fire intensity which should be prescribed. Forest which contains a high proportion of young growing stock (<20cm dbh) is readily susceptible to crown damage and fire intensities should deliberately be kept low, as is the case with spring burning. The level of damage acceptable in a more mature stand will depend on the purposes for which the forest is managed. For example, damage levels unacceptable in a stand thinned and managed for wood production may not be of concern in forest managed primarily for nature conservation, provided that other objectives are met such as maintenance of an adequate canopy or suitable stocking of habitat trees.

4. <u>Can mass ignition fires be reliably prescribed during dry conditions?</u>

No major control problems were encountered during the Hakea burn but prescribed burning in summer or autumn involves inherently greater risks than corresponding operations in spring. The success of such operations on a routine basis would rely on detailed planning, and the implementation of extensive pre-suppression activities such as buffer burning, spring edging and the removal of stags around the perimeter of the area.

Current fire behaviour guidelines for jarrah forest (Sneeuwjagt and Peet 1976) were developed primarily for spring burning. Fire behaviour predictions extrapolated to dry conditions from existing guidelines should be treated with caution and reinforced with considerable practical experience. There is a major research program currently underway to improve understanding and prediction of summer and autumn fire behaviour (Burrows pers. comm.). Accurate local weather forecasts are vital for predicting fire behaviour on the day of the burn, as well as for avioding weather patterns likely develop into blow-up fire conditions (Burrows 1984) Suppression forces available at the a burn should be sufficient to immediately control any escapes and rapidly complete mop-up operations.

Conclusion

The Hakea burn demonstrated that a fire of low to moderate intensity during dry conditions can provide an intial reduction of B.grandis in the understorey and stimulate regeneration of native legumes.

The costs and risks associated with this type of operation are greater than with a corresponding burn in the spring and there will be a small level of damage to growing stock which may subsequently reduce wood production values.

Application of these findings will depend on the extent to which other studies confirm a beneficial response against dieback through manipulation of the forest understorey.

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TABLE 1. Summary of weather, fuel and soil conditions during the Hakea burn.

	CHARACTERISTIC					COMMENTS
			1600HRS	1800HRS	2000HRS	
Weather	Temperature (^{o}C)		27	23	18	Recorded at
	Relative humidity(%)		28	38	48	Dwellingup
	Dew point (^{o}C)		8	8	8	H.Q.
	Wind speed at 1.5m		1.8	1	N.A.	
	in forest (km/h)					Tower is 7km
	Tower wind speed(km/h)		11	5	N.A.	from Hakea
Fuel	Litter fuel load (t/ha)	Mean		9		Fuel loads
		Range		4-25(N=47)		calculated from depth measurements have similar mean & range
	Minimum moisture content (%)			9-10		
Soil	Soil Dryness Index			1600 approx		
	Moisture content 0-5cm((%ODW)-					
	Lateritic uplands	Mean		4		Dwellingup
		Range		3-7(N-48)		complex
	Low lying areas	Mean		7		Yarragil
		Range		5-10(N=49)		complex

TABLE 2. Occurrence and percentage cover of legumes in 20 x 20 m plots before and after burning.

SPECIES	NUMBER OF PLOTS WHERE SPECIES RECORDED		MEAN PERCENTAGE COVER WITHIN PLOTS[1]	
	BEFORE BURN	6 MONTHS AFTER BURNING	BEFORE BURN	2 YEARS AFTER BURNING
A.celastrifolia	5	7	2	8
A.drummondii[2]	18	20	4	10
A.extensa	0	2	0	2
A.preissiana	12	30	2	5
A.pulchella	9	7	15	15
A.urophylla[3]	4	6	0	4
B.ornata	9	35	6	6
K.coccinea	5	30	2	2
K.prostrata	1	6	0	0

1 Calculated according to Levy and Madden (1933).

2 *Acacia drummondii* Lindl.

3 *Acacia urophylla* Benth.

TABLE 3. Fire damage to jarrah visible 2 years after burn for 240 trees with only litter fuel within 1.5m of the stem.

DIAM.	PROPORTION (%) OF TREES WITHIN EACH SIZE CLASS WITH:						
(cm)	No damage	Bark cracking	Bole epicormics	Area of cambial damage (cm^2) 0-100	100-500	500-2000	>2000
10-19	53	7	31	13	-	2	5
20-29	65	7	8	13	4	5	2
30-39	69	10	6	12	4	4	2
40-44	79	0	0	21	-	-	-

TABLE 4. Stem damage to jarrah subject to 3 classes of crown scorch, for trees with only litter fuel within 1.5m of the stem.

SCORCH CLASS	NUMBER OF TREES	PROPORTION OF TREES (%) UNDAMAGED	DAMAGED WITH: WOUNDS <100cm^2	WOUNDS 100-1000cm^2	WOUNDS 1000cm^2
Less than 50% of crown scorched	30	86	14	-	-
50-90% crown scorched	44	77	11	5	7
Complete crown scorch	39	77	13	3	7

FIG. 1 ı'OCKING OF *B. grandis* BEFORE AND TWO YEARS AFTER AUTUMN BURN AT HAKEA

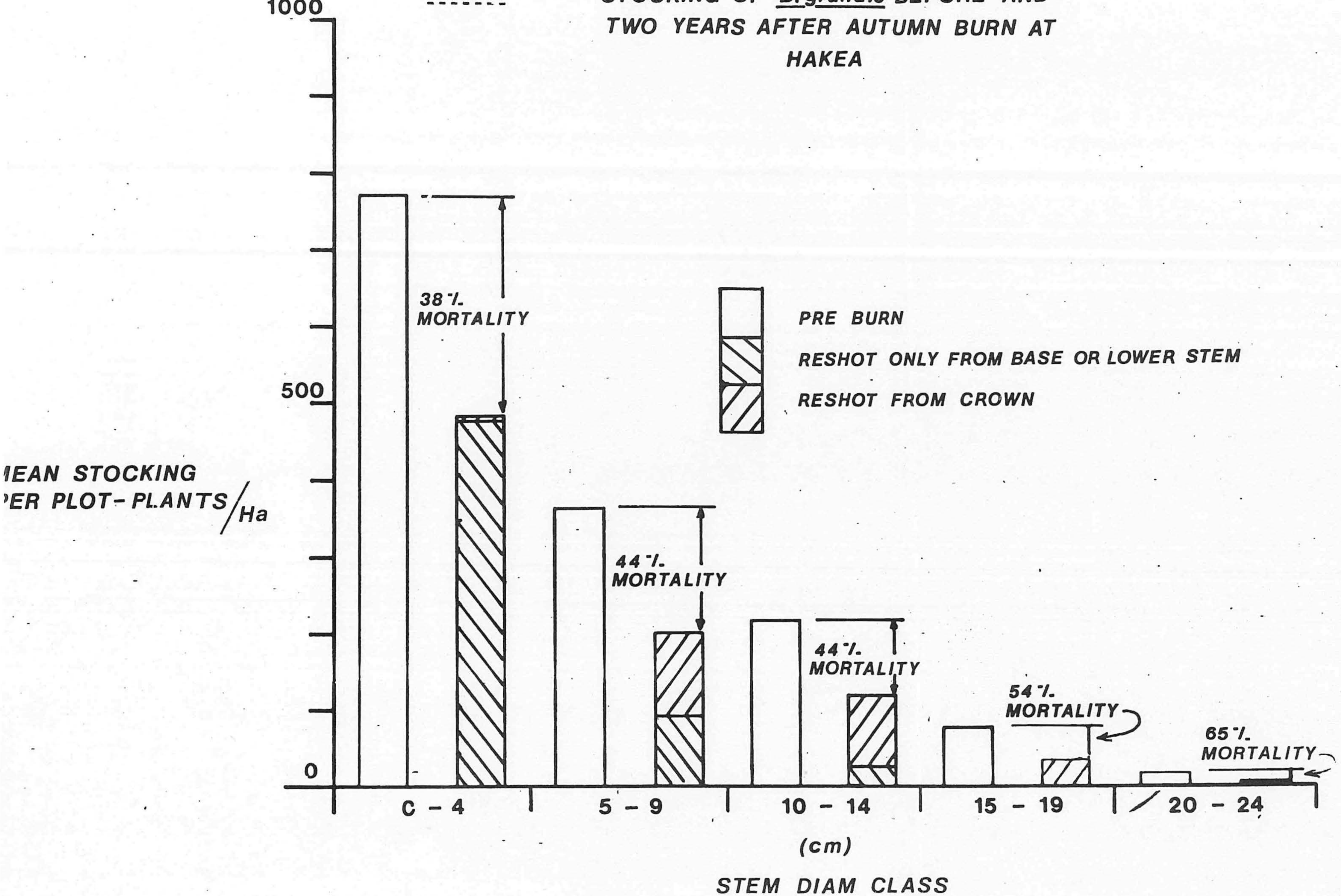

FIG. 2 BASAL AREA OF BANKSIA GRANDIS BEFORE AND 2 YEARS AFTER FIRE.