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COMPETITION BETWEEN BRIGALOW (ACACIA HARPOPHYLLA) SUCKERS AND ESTABLISHING PASTURES FOLLOWING PULLING AND BURNING

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SUMMARY

The regeneration of brigalow following pulling and burning, and the effect of Rhodes grass on its survival, were studied in 5 successive years from 1963 to 1968.

Sucker emergence was of sigmoid form with approximately 10%, 50% and 80% of maximum emergence being recorded 5, 10 and 15 weeks after burning.

The establishment of Rhodes grass in the first 12 months after pulling and burning did not appear to lower brigalow sucker density in any of the trials, though a thick cover of grass markedly reduced the size of established suckers. Even under the most favourable conditions Rhodes grass did not exert any marked competitive influence on other components of the pasture until the fifteenth week after sowing.

I. INTRODUCTION

Brigalow (*Acacia harpophylla* F. Muell) is a leguminous tree which once dominated forest communities over approximately 6·5 million hectares, mainly in Queensland. These communities are best developed in the 600 to 750 mm rainfall belt on heavy cracking clay soils. The communities and soils have been described by numerous authors (Isbell, 1962; Johnson, 1964).

The soils supporting brigalow forest are relatively fertile, though phosphorus is often inadequate (Isbell, 1962). To utilize this inherent soil fertility for beef production, the forest is cleared and native vegetation replaced by more highly productive sown pastures. Johnson (1964) has described various methods of clearing the original vegetation. Since 1954, the most common method has been to use either a heavy chain or heavy cable and chain dragged between two high-powered bulldozers. With these machines, most of the woody vegetation is pulled to the ground. Burning follows pulling and seed of introduced pasture species is sown into the ash.

One of the major factors limiting productivity from these sown pastures has been the presence of brigalow suckers. Brigalow posseses a well-developed, horizontal root system from which suckers can be produced following damage to the above ground parts. Suckers appear within a few weeks of burning and the extent of suckering depends on a number of factors (Johnson, 1964).

The author, during the course of a field survey of brigalow lands, obtained evidence from a few isolated areas that the presence of a thick stand of pasture helped in the suppression of brigalow regrowth (Johnson, 1964). This information was purely subjective and it was decided to test its validity by a series of field trials. If these grasses could suppress regrowth, then the management of establishing pastures could play an important part in the control of brigalow regrowth.

Three grass species, buffel grass (*Cenchrus ciliaris* L.), green panic (*Panicum maximum* Jacq. var. *trichoglume* Eyles) and Rhodes grass (*Chloris gayana* Kunth) are commonly sown into the ash following burning, either mixed or less commonly alone. Of these species, Rhodes grass, though often the least persistent and least productive, is potentially the most rapid colonizer of bare areas. At normal rates of sowing, it has much higher pure live seed content per acre than the other species (Siller, 1963) and has the additional advantage that it is able to colonize by surface runners. For this reason, this species was selected for use in this series of trials.

Though the annual rainfall of the area in which these trials were conducted is approximately 700 mm a year, the variability in the rainfall distribution is high (Fitzpatrick, 1968). Grass establishment would have to be rapid if any marked suppression of brigalow were possible. This would require a season of average to above average rainfall. To encompass as much of the seasonal variability as possible, these trials were repeated in a number of years.

Despite pasture establishment, many cleared areas have reverted to brigalow-dominant communities within a few years after burning. Alternative and complementary methods of control such as spraying are available. Johnson (1964) showed that spraying with 2,4,5–T was most effective when applied to young regrowth after the initial burn. So that this method of control could be placed on a sounder basis, it is necessary to know something of the rate of emergence of suckers following the initial burn.

The purpose of this study was to determine the rate of emergence of brigalow suckers and the effectiveness of a sown pasture in controlling brigalow regrowth following the initial burn.

II. EXPERIMENTAL METHODS

These trials were carried out on the Brigalow Research Station, 32 km north-west of Theodore. Separate trials were established in 5 consecutive years, the methods and design being modified in succeeding years to account for refinements in techniques and variations in the size and shape of available uniform areas.

Brigalow suckers which originate from an existing root system appear to have an early competitive advantage over Rhodes grass plants which have to establish from seed. Once established, the more rapid growth and coverage of Rhodes grass could tip the balance in its favour. For this reason, it was decided initially to stagger plantings of Rhodes grass so that the rate of grass coverage could be controlled.

Rainfall recorded at the Brigalow Research Station during the course of the trials is given in table 1.

Trial 1. The trial area was originally covered with a brigalow—Ellangowan poison bush (*Myoporum deserti* A. Cunn. ex Benth)—wilga (*Geijera parviflora* Lindl.) forest (A2—Johnson, 1966). The soil is a heavy dark grey brown cracking clay (Northcote Ug5.24) and gilgaies are scattered throughout the area.

The standing brigalow scrub was pulled to the ground by a chain dragged between two high-powered bulldozers in September–October 1963 and the trash burnt on 4 December 1963. The burn was patchy and the trial was confined to areas where burning had been complete.

Seven treatments were applied.

1. Control, unsown.
2. Plots sown to Rhodes grass at 0·55 kg ha^{-1} on 17 Dec. 63.
3. Plots sown to Rhodes grass at 1·1 kg ha^{-1} on 17 Dec. 63.
4. Plots sown to Rhodes grass at 2·2 kg ha^{-1} on 17 Dec. 63.
5. Plots sown to Rhodes grass at 1·1 kg ha^{-1} on 14 Jan. 64.
6. Plots sown to Rhodes grass at 1·1 kg ha^{-1} on 20 Feb. 64.
7. Plots sown to Rhodes grass at 1·1 kg ha^{-1} on 17 Mar. 64.

Treatments 2, 3 and 4 were applied to evaluate the effect of rate of sowing, while treatments 3, 5, 6 and 7 were applied to assess the effect of delay in establishment of Rhodes grass following sowing.

Six replicates of each treatment were established in a randomized block design. Plot size was 20 m x 20 m.

Total counts of brigalow suckers were made on the control plots at monthly intervals from January to June. In all these counts, any root suckers separated by more than 15 cm were regarded as individuals. In June, a count was made of all Rhodes grass plants in each plot excluding a 2 m margin and the diameter of each plant was measured. On 3 and 4 December 1964, all plots were sampled using a 100 cm x 40 cm quadrat. Twenty quadrats were sampled in each plot on a systematic grid. Using the technique described by Daubenmire (1959), the number and canopy coverage of brigalow and of Rhodes grass were recorded from each quadrat. When changing to this method of sampling, it was found more convenient to define individuals as single stems or groups of stems separated by more than 7·5 cm. This definition was maintained in all subsequent trials.

Owing to delays in the erection of boundary fencing, the growing pastures were subjected to periods of heavy grazing from the time of burning until June 1964. Grazing pressure was reduced until November 1964, when all stock were removed.

All density data were analysed using a square root transformation and equivalent means and transformed means are given in all tables. Percentage canopy covers were analysed untransformed and using an inverse sine transformation. The latter transformation considerably reduced the coefficient of variation but did not greatly alter the level of significance. The untransformed analyses have been used in presentation of canopy cover data in all tables.

Trial 2. The trial area was originally covered with a brigalow-Dawson gum (*Eucalyptus cambageana* Maiden)-wilga forest (C6—Johnson, 1966) with most of the brigalow in the whipstick growth form (Johnson, 1964). The soil is a mosaic of dark grey brown uniform cracking clay (Northcote-Ug5·24) and dark grey brown texture-contrast soil (Northcote-Db1·43) with the clays predominant and the texture-contrast soils occupying some of the more elevated areas. Incipient gilgai development occurs throughout the trial area.

The forest was knocked to the ground in July 1964 with a Le Tourneau Tree Crusher and the trash was burnt on 19 December 1964.

Six treatments were undertaken.

1. Control, unsown.
2. Plots sown to Rhodes grass at 2·2 kg ha^{-1} on 23 Dec. 64.
3. Plots sown to Rhodes grass at 2·2 kg ha^{-1} on 26 Jan. 65.
4. Plots sown to Rhodes grass at 2·2 kg ha^{-1} on 26 Feb. 65.
5. Plots sown to Rhodes grass at 2·2 kg ha^{-1} on 1 Apr. 65.
6. Plots sown to Rhodes grass at 2·2 kg ha^{-1} on 19 May 65.

Treatments were replicated four times in a randomized block design and plot size was 20 m x 20 m.

Forty quadrats each 100 cm x 40 cm were sampled on a systematic grid in each plot. The number and canopy coverage of brigalow, canopy coverage of Rhodes grass, native grass, native forbs and individual woody weed species and the percentage of bare ground were recorded at each time of sampling.

The first sampling was carried out on 26 January 1965 and each treatment thereafter was sampled at the time of sowing and at approximately monthly intervals following sowing. Sampling was discontinued in the winter when sucker emergence had ceased and a final sampling was made in December 1965, 12 months after burning.

The trial area was fenced and cattle were excluded.

Trial 3. The site was originally covered by a brigalow-wilga-sandalwood (*Eremophila mitchellii* Benth.) forest (A4-Johnson, 1966).

The soil is predominantly a shallow dark grey-brown, sandy clay loam over a very dark, greyish-brown clay (Dd1·13) with patches of a dark brown cracking clay (Ug5·24).

The forest was pulled down in September 1965 and the trash burnt on 20 January 1966. The area available allowed for only two treatments to be applied.

1. Control, unsown.
2. Plots sown to Rhodes grass at 2·2 kg ha^{-1} on 25 January 1966.

Five replicates of each treatment were established in plots 10 m x 10 m.

A sampling technique similar to that described in Trial 2 was used. Twenty 100 cm x 40 cm quadrats were sampled in a systematic manner in each plot. The initial sampling was undertaken on 25 February 1966 and subsequent samplings were made at intervals of 4 to 6 weeks until 23 August 1966 when it was considered maximum emergence had occurred.

In March, 1966, the trial area was damaged during fence clearing operations and only five of the 10 plots were undisturbed. Sampling from 30 March onwards was continued only on undisturbed plots. Two of these plots were sown and three were unsown. In addition, because of the very sparse suckering which occurred over the trial area, complete counts of suckers were made in each plot.

Cattle were excluded from the trial area.

Trial 4. A virgin brigalow-wilga-sandalwood forest (A4-Johnson, 1966) was selected for this trial.

The soil is predominantly a dark, grey-brown uniform cracking clay (Ug5·24) with minor patches of a shallow dark, grey-brown sandy clay loam texture contrast soil (Dd1·13).

The forest was pulled to the ground in June 1966 and burnt on 28 November 1966.

Results from previous trials showed little indication of any reduction in density being produced by the grass cover. For this reason, it was felt that the only hope for such a result lay in a rapid grass cover being obtained before most of the suckers had emerged. Treatments were therefore maintained at two in this trial.

1. Control, unsown.
2. Plots sown to Rhodes grass at 2·2 kg ha^{-1} on 1 December 1966, 3 days after burning.

Because the only suitable area was small in size, plots were maintained at 10 m x 10 m and replication was increased to 15 x 1.

A preliminary study of data obtained in the previous trials indicated that, although sample estimates of cover appeared reasonably accurate, more quadrats needed to be counted to obtain a reliable estimate of numbers where cleared, virgin forest communities were being sampled. To overcome this, a 100 cm x 100 cm quadrat was used divided by an internal rod into a 100 cm x 40 cm and a 100 cm x 60 cm portion. Similar data to that recorded in previous trials were collected from the 100 cm x 40 cm portion but, in addition, numbers of brigalow suckers were recorded in the 100 cm x 60 cm portion.

Ten quadrats were counted in each plot on a systematic grid and, in this trial, the position located at the initial count was permanently marked using two pieces of mild steel rod driven into the ground at diagonal corners. This removed any variation as a result of position from sampling date to sampling date.

The initial count was made on 4 January 1967 and sampling was continued at 4 to 5 week intervals until 9 June 1967 when it was considered that maximum emergence had been achieved. A final count was recorded on 10 November 1967. The area was ungrazed during this period.

Because, in previous trials, unsown plots were contaminated by seed from sown plots, Rhodes grass seedlings were chipped from the control plots. Chipping was discontinued after the June 1967 sampling.

Trial 5. A virgin brigalow-wilga forest (A2 and A6-Johnson, 1966) was used in this trial.

The soil is a dark, grey-brown cracking clay (Ug5·24) with occasional gilgaies and at the western end patches of texture contrast soil (Dd1·13) are associated with cracking clay.

The forest was pulled to the ground in March and April 1967 and burnt on 17 November 1967.

Treatments and sampling techniques were similar to those used in the previous trial. Plot size was increased to 20 m x 20 m and 20 quadrats were sampled in each plot. Each treatment was replicated eight times. The two treatments were—

1. Control, unsown.
2. Plots sown to Rhodes grass at 2.2 kg ha^{-1} on 4 December 1967, 2 weeks after the burn.

TABLE 1

RAINFALL AT BRIGALOW RESEARCH STATION 1963–1968

Year	Jan		Feb		Mar		Apr		May		Jun	
	T	D	T	D	T	D	T	D	T	D	T	D
1963	..	..	..	..	..	..	..	..	..	..	..	..
1964	37	−74	98	−16	31	−40	18	−61	44	+17	10	−75
1965	241	+132	0	−100	15	−20	89	+97	0	−100	13	−68
1966	36	−66	61	−48	102	+35	0	−100	12	−68	48	+19
1967	156	+50	37	−68	44	−42	8	−83	14	−62	92	+231
1968	96	−8	107	−8	88	+17	122	+170	53	+41	0	−100
District mean ..	104		117		76		45		38		40	

TABLE 1

Year	Jul		Aug		Sep		Oct		Nov		Dec		Year	
	T	D	T	D	T	D	T	D	T	D	T	D	T	D
1963	..	..	..	..	0	−100	0	−100	65	−8	84	−11	..	..
1964	72	+107	0	−100	55	+122	25	−52	1	−99	62	−34	453	−47
1965	14	−60	0	−100	36	+47	30	−44	145	+108	77	−18	660	−8
1966	33	−4	100	+386	25	+2	52	−2	59	−25	66	−29	594	−17
1967	7	−80	34	+65	0	−100	83	+56	34	−52	75	−21	584	−19
1968	55	+60	30	+46	33	+33	6	−88	21	−70	119	+26	730	+2
District mean	34		21		25		53		70		94		717	

T = Total rainfall (mm).
D = Percentage departure from expected average.

TABLE 2

NUMBER OF BRIGALOW SUCKERS IN CONTROL PLOTS AT INTERVALS FOLLOWING BURNING TRIAL 1

Date of Count	Weeks After Burn	Numbers at Various Heights (cm.)					Total	% of Maximum
		0–7·5	>7·5–15·0	>15·0–22·5	>22·5–30·0	>30·0		
15, 16 Jan 64 ..	6	282	217	45	45	45	544	7
18 Feb 64	11	1 218	1 772	868	265	155	3 278	45
17, 18 Mar 64 ..	15	790	2 007	1 422	875	940	6 034	83
16 Apr 64 ..	19	767	2 245	1 728	1 287	1 188	7 215	99
20 May 64 ..	24	1 022	2 365	1 583	1 162	1 128	7 260	100
9, 10 Jun 64 ..	27	643	2 338	1 622	1 043	1 308	6 954	96

The initial count was made on 20 December 1967 and sampling was continued at 4 to 6-week intervals until 17 May 1968, when it was considered maximum emergence had been recorded. A final count was carried out on 8 December 1968. The control plots were kept free of Rhodes grass until 17 May 1968 by regular chipping.

The area was ungrazed during the trial.

III. RESULTS AND DISCUSSION

The rainfall recorded during the summer and early autumn in each of the trials was well below the expected average as shown in table 1.

Trial 1

1. Emergence of brigalow suckers. Counts of suckers made at intervals of 3 to 6 weeks on the unsown plots are shown in table 2. Maximum density was recorded approximately 19 to 24 weeks after burning. Good rain was received immediately after burning but subsequent summer and autumn rainfall was well below average. Relatively little regrowth had emerged at the time of the first count, 6 weeks after burning. At this stage, only 7% of the eventual maximum density was recorded. Rapid emergence of suckers followed over the next 9 weeks and, 15 weeks after the burn, 83% of the eventual maximum density had emerged. The rate of emergence was much slower from this point onwards and there was virtually no difference between the densities recorded 19 and 24 weeks after burning. A few new suckers did emerge after the twenty-fourth week, but deaths among emerged suckers greatly exceeded the number of new suckers.

Because the technique involved in counting was changed at the final count, comparison of density figures for brigalow suckers with those recorded from earlier counts is not possible. The results obtained from quadrat counts in December 1964 are shown in table 3.

TABLE 3

Density and Cover Estimates of Brigalow and Rhodes Grass 12 Months After Burning December 1964 Trial 1

Sowing Rate Rhodes grass (kg ha^{-1})	Date of Sowing	Weeks after Burning	Brigalow		Rhodes Grass	
			Number per 16 m^2	% Cover	Number per 16 m^2	% Cover
Unsown—Control (1) ..	..	..	36·9 (4·356)*	15·8	0·5 (0·880)	4·3
0·55 (2) ..	17 Dec. 63	1	32·4 (4·088)	11·5	1·4 (1·085)	6·8
1·1 (3) ..	17 Dec. 63	1	21·8 (3·375)	7·2	3·6 (1·523)	16·3
2·2 (4) ..	17 Dec. 63	1	30·9 (3·994)	13·3	11·3 (2·476)	17·5
1·1 (5) ..	14 Jan. 64	6	28·5 (3·905)	12·9	6·6 (1·944)	10·0
1·1 (6) ..	20 Feb. 64	11	19·5 (3·205)	10·0	2·6 (1·332)	12·2
1·1 (7) ..	17 Mar. 64	15	30·3 (3·960)	9·9	27·6 (3·780)	35·5
Necessary differences for significance	5% level		(1·066)	6·9	(0·858)	12·0
	1% level		(1·435)	9·3	(1·156)	16·1

* Transformed values ($\sqrt{x + \frac{1}{2}}$)

2. ESTABLISHMENT OF RHODES GRASS. Estimates of the density and percentage cover of Rhodes grass made on 9 and 10 June are shown in table 4. On no plots was a cover of more than 5% achieved. Most plots had less than 1% cover of Rhodes grass and only two plots had more than a 2% cover. Rainfall was almost 50% below average from the time of sowing until June and the combination of heavy grazing and hot, dry seasonal conditions was responsible for the poor coverage of Rhodes grass.

At the June count, the density of established Rhodes grass plants in plots sown at different rates in December 1963 was approximately proportional to the number of seeds sown. There was little difference between the densities recorded on plots sown at different times with the same rate except in those plots sown in March 1964. Only 18 mm of rain was recorded in the 10 weeks between the March sowing and 30 May, when 44 mm of rain fell. Any small Rhodes grass seedlings which resulted from the May rain were not counted at the sampling in June and this would account for the low density in plots sown in March.

At the final count in December 1964 (table 3), densities were approximately in the same order as those recorded in June (table 4) except there was a significant increase in the density on plots sown in March 1964. Further germination of seed in the plots sown in March 1964 followed the good winter-spring rain but similar good germination did not occur in the plots sown at the earlier dates. The latter occurrence must be attributed to spoilage of seed which could have resulted from numerous small falls of rain associated with hot, dry conditions, from removal by ants, or from heavy grazing of young seedlings. The better germination and establishment following the March sowing resulted in a significantly better coverage of Rhodes grass in December.

Although the density of Rhodes grass plants increased with increased sowing rates, there was little difference in coverage between plots sown at 1.1 and 2.2 kg ha^{-1}. Under the conditions which applied in this trial, no advantage was gained by sowing at the higher rate. However, even after 12 months, the cover of Rhodes grass was meagre. Sampling at intervals over the succeeding 6 years has shown that the Rhodes grass cover following any of the sowings rarely exceeded 50%.

3. INFLUENCE OF RHODES GRASS ON BRIGALOW SUCKERS. Rhodes grass was unable to compete strongly with the establishing suckers because of a combination of heavy grazing and hot, dry seasonal conditions, both of which contributed to the poor coverage recorded in June. Rhodes grass colonized some of the bare ground between June and December but there were still large areas of bare soil in all plots in December.

TABLE 4

DENSITY AND PERCENTAGE COVER OF RHODES GRASS PLANTS JUNE 1964 TRIAL 1

Sowing Rate (kg ha^{-1})	Date of Sowing	Plants/ha^{-1}	% Cover	
			Range	Average
Unsown—control ..	..	205	0·0–0·17	0·06
0·55	17 Dec. 63	395	0·01–1·14	0·24
1·1	17 Dec. 63	1 220	0·06–1·55	0·83
2·2	17 Dec. 63	1 820	0·03–5·33	1·62
1·1	14 Jan. 64	900	0·0–0·66	0·34
1·1	20 Feb. 64	1 030	0·0–4·66	1·10
1·1	17 Mar. 64	90	0·0–0·09	0·04

At the final count, the control plots had considerably more suckers than the sown plots. Because of the extremely contagious distribution of brigalow suckers, variations in density from plot to plot and replicate to replicate were very great. This tends to obscure differences which may occur between treatments. The only treatment which resulted in significantly fewer suckers than in the control was the February sowing and this significance cannot be attributed to any treatment effect. Competition by Rhodes grass would have been no more severe in these plots than in other sown plots and there was insufficient native grass and forbs to have influenced the result.

The cover of brigalow suckers in the sown plots was significantly less than the cover in the unsown plots only following the December sowing using Rhodes grass at 1.1 kg ha^{-1}. It is logical to assume that the control obtained by sowing Rhodes grass at 2.2 kg ha^{-1} at the same time would be as good as or even better than that following the sowing of Rhodes grass at 1.1 kg ha^{-1}. However, this was not so and these anomalies strengthen the belief that in this trial recorded differences between treatments were fortuitous.

An analysis of covariance for both density and canopy cover of brigalow and canopy cover of Rhodes grass gave a significant error regression ($P<0.05$) and for density and cover of brigalow the error regression was highly significant ($P<0.01$). Though a negative relationship was established between brigalow and Rhodes grass, it is felt that brigalow suckers were the dominating plants in this trial and Rhodes grass was best able to colonize plots on which brigalow was sparse.

Trial 2

Details of quadrat counts made during the course of the trial are set out in table 5.

1. Emergence of brigalow suckers. Brigalow suckers began to emerge within a month of burning and 10 to 20% of the maximum density was achieved 5 to 6 weeks after burning. The rate of emergence increased up until mid-February, 10 weeks after burning, when two-thirds of the suckers had emerged. A marked drop in the rate of emergence then occurred with a slight increase following good rain in April. Maximum emergence on control plots was recorded 26 weeks after burning and this pattern of emergence was similar on most of the sown plots. There was little evidence of fresh suckering after this time but some mortality among the emerged suckers occurred between June and December.

2. Establishment of Rhodes grass. Based on the number of seedlings which established, the sowing on 1 April was significantly better than all others. The initial sowing in December was followed by a severe storm in which more than 50 mm were recorded one evening. This apparently caused severe run-off and loss of seed from the trial plots. Hot dry conditions which followed could have contributed to the poor initial establishment. No fall of rain exceeding 13 mm followed any of the three subsequent sowings until 25 April. Although there was mass germination of seed following the April sowing, the response of the earlier sowings to the same rain was much less marked, indicating that many of the sown seed were either removed from the trial area, eaten by ants, or had been destroyed following light falls of rain.

TABLE 5

DENSITY AND COVER ESTIMATES OF BRIGALOW AND RHODES GRASS AT VARIOUS TIMES AFTER BURNING TRIAL 2

Sowing Rate Rhodes Grass (kg ha^{-1})	Date of Sowing	Weeks after Burn	26 Jan 65				26 Feb 65				1 Apr 65			
			Brigalow		Rhodes		Brigalow		Rhodes		Brigalow		Rhodes	
			D	C	D	C	D	C	D	C	D	C	D	C
Control Unsown (1) ..	..	..	8·5[1] (3·003)*	1·05[1]	0	0·0	29·6[1] (5·485)	5·2[1]	0	0·0	32·7[1] (5·762)	8·7[1]	0	0·0
2·2 (2) ..	23 Dec 64 ..	1	2·8 (1·831)	0·5	8	0·1	9·1 (3·099)	1·8	13	1·2	15·2 (3·968)	4·8	13	4·6
2·2 (3) ..	26 Jan 65 ..	5·5	1·6[1] (1·465)	0·2[1]	0	0·0	9·2 (3·121)	1·4	10	0·5	12·1 (3·550)	4·5	10	1·7
2·2 (4) ..	26 Feb 65 ..	10	NR	NR	NR	NR	19·8[1] (4·501)	3·7[1]	0	0·0	26·7 (5·215)	8·9	4	0·4
2·2 (5) ..	1 Apr 65 ..	15	NR	NR	NR	NR	NR	NR	NR	NR	14·9[1] (3·920)	4·4[1]	0	0·0
2·2 (6) ..	19 May 65 ..	21·5	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR	NR
Necessary differences for significance		.. 5% / 1%	(1·763) (2·672)	1·07 1·62			(1·880) (2·700)	3·4 4·9			(1·707) (2·394)	6·0 8·4		

* Transferred values $\sqrt{x + \frac{1}{2}}$.
D = Density—plants per 16 m^2.
C = % Canopy Cover.
NR = Not Recorded.
[1] = Duplicate plots within columns.

TABLE 5—continued

DENSITY AND COVER ESTIMATES OF BRIGALOW AND RHODES GRASS AT VARIOUS TIMES AFTER BURING TRIAL 2—continued

Sowing Rate Rhodes Grass (kg ha⁺¹)	Date of Sowing	Weeks after Burn	19 May 65				18 Jun 65				20 Dec 65			
			Brigalow		Rhodes		Brigalow		Rhodes		Brigalow		Rhodes	
			D	C	D	C	D	C	D	C	D	C	D	C
Control Unsown (1) ..	..	..	34·6[1] (5·923)	12·1[1]	23·0 (4·850)	4·3	42·1 (6·525)	14·8	26·7 (5·220)	9·3	35·9 (6·039)	27·6	NR	39·8
2·2 (2) ..	23 Dec 64 ..	1	13·1 (3·685)	6·9	2·6 (1·755)	26·1	14·0 (3·811)	7·8	5·6 (2·474)	32·3	13·2 (3·703)	12·8	NR	70·7
2·2 (3) ..	26 Jan 65 ..	5·5	18·7 (4·378)	7·9	19·5 (4·470)	15·5	17·2 (4·211)	7·4	14·5 (3·883)	26·8	13·2 (3·703)	14·4	NR	67·4
2·2 (4) ..	26 Feb 65 ..	10	29·0 (5·433)	12·1	35·3 (5·988)	4·6	28·4 (5·377)	12·8	45·7 (6·799)	16·5	30·8 (5·598)	24·2	NR	65·2
2·2 (5) ..	1 Apr 65 ..	15	16·3 (4·098)	7·0	794·8 (28·202)	13·1	13·2 (3·702)	6·3	530·3 (23·040)	31·7	17·9 (4·285)	13·8	NR	88·9
2·2 (6) ..	19 May 65 ..	21·5	33·1[1] (5·793)	13·4[1]	0·0 (0·0)	0·0	42·2 (6·536)	16·1	6·8 (2·708)	2·9	39·1 (6·292)	30·1	NR	33·4
Necessary differences for significance ..		5% / 1%	(1·697) (2·346)	7·4 10·3	(3·416) (4·789)	12·6 17·6	(1·764) (2·439)	7·6 10·5	(3·118) (4·310)	15·7 21·7	(1·914) (2·647)	13·1 18·1		33·2 45·9

* Transferred values $\sqrt{x} + \frac{1}{2}$.
D = Density—plants per 16 m².
C = % Canpoy Cover.
NR = Not Recorded.
[1] = Duplicate plots within columns.

At the sampling on 18 June 1965, the following Rhodes grass densities were recorded—

Date of Sowing	Plants m^{-2}
December	0.35
January	0.90
February	2.85
April	33.15

This indicates that seed spoilage and loss in the 5-week period between the February and March sowings was in excess of 90%.

Because rainfall was generally well below average, Rhodes grass was very slow to cover the trial plots and it was not until 26 weeks after burning that Rhodes grass became prominent. At this stage, coverage recorded by the few plants which established following the initial sowing was equally as extensive as that recorded by the more successful later sowings. Quadrat counts 12 months after burning showed best coverage following the April sowing. However, there was no significant difference in canopy coverage among any of the treatments, except the control plots and the final sowing in May, which were greatly inferior.

As shown by the canopy coverage of Rhodes grass in the control plots, some inter-plot contamination did occur, but seed production from established plants within sown plots and colonization by runners tended to nullify in 12 months the initial advantage gained by the excellent germination conditions which followed the April sowing. However, at the final count, coverage following the April sowing still appeared superior to all others though the difference was not significant.

3. INFLUENCE OF RHODES GRASS ON ESTABLISHMENT OF BRIGALOW SUCKERS. In December 1965, there were significantly fewer suckers ($P<0.05$) in plots sown in December 1964 and January 1965 than in unsown plots and in plots sown in May 1965, 5 months after burning. This indicates that sowing soon after burning resulted in a significant reduction in density.

However, from the commencement of this trial, plots sown in December 1964 and January 1965 had significantly fewer suckers ($P<0.05$) than the control. This can be seen by comparing the results from duplicate plots in table 5. At the time of any particular sowing, the plots about to be sown had received no treatment and therefore these plots and the unsown control plots can be regarded as duplicates. In duplicate plots at the time of the January sowing, the control plots had five times as many suckers as the plots about to be sown while, as early as February 1965, there were significantly fewer suckers in plots sown in December 1964 and January 1965 than in the controls. At this time, the coverage of Rhodes grass was less than 2% in the sown plots and it is inconceivable that these significant differences in brigalow densities could be due to competition from Rhodes grass.

As in the previous trial, there was an inverse relationship between brigalow density and cover and Rhodes grass cover. However, as brigalow establishment was much more rapid than Rhodes grass during the first 15 weeks, it is again felt that the relationship, thought not significant, was due to the dominance of brigalow suckers rather than Rhodes grass.

An analysis of covariance for density and cover of brigalow and canopy cover of Rhodes grass gave a highly significant error regression and the significant differences in canopy cover of Rhodes grass between treatments appear to reflect sucker densities.

This trial was conducted under adverse seasonal conditions and this situation would be expected to favour the brigalow suckers which arise from an existing root system and are able to grow on subsoil moisture alone.

Trial 3

Because of extensive damage to the trial area little information could be obtained. Quadrat data were not statistically analysed and the limited results obtained are given in table 6.

1. EMERGENCE OF BRIGALOW SUCKERS. Rainfall was again well below average. Ten weeks after burning, 35% of the maximum density had been achieved in control plots and approximately 60% in the sown plots. Maximum density was recorded approximately 25 to 30 weeks after burning.

2. EFFECT OF RHODES GRASS ON THE ESTABLISHMENT OF BRIGALOW SUCKERS. Rhodes grass was slow to establish and, 10 weeks after burning, a cover of only 15% had been achieved. At this time, approximately 810 suckers ha^{-1} had emerged on unsown plots compared with 1 380 suckers ha^{-1} on the sown plots. This difference could probably be attributed to inter-plot variation rather than treatment variation. The great increase in Rhodes grass cover occurred following above average March rains and, from this stage onwards, the rate of emergence of suckers on sown plots was much less than on the unsown plots. Approximately 640 suckers ha^{-1} an increase of 46%, emerged on the sown plots in the 10 to 30-week period compared with 1 580 suckers ha^{-1}, an increase of 194%, on unsown plots. In this trial, however, these data were obtained from only two sown and three unsown plots.

Trial 4

Details of quadrat counts made during the course of the trial are set out in table 7. Significance levels indicated in the table involve comparisons between sown and unsown plots at particular sampling dates for particular pasture components.

In both trials 4 and 5, the sampling technique was refined and permanent quadrats were used to assess changes. This allowed more reliability to be placed on differences in density and cover from one sampling period to the next because the data were no longer confounded by variation due to the position of the quadrat.

1. EMERGENCE OF BRIGALOW SUCKERS. On the sown plots, maximum density was recorded 20 to 24 weeks after burning. The rate of emergence was similar to that in trial 2, with only approximately 5% of the suckers having emerged in the first 5 weeks after burning. A marked increase in the rate of emergence occurred during the next 10 weeks. Emergence was more rapid on the unsown plots and maximum density was recorded 15 weeks after burning. Hot, dry conditions associated with large areas of bare soil resulted in deaths among the emerged suckers between fifteenth and twentieth weeks on control plots. This was not recorded in the well-grassed sown plots where, during the same period an increase was recorded. Mortalities among emerged suckers in the unsown plots exceeded new suckers from the twenty-fourth week onwards and in the sown plots from the twenty-ninth week onwards.

TABLE 6

DENSITY AND COVER OF PASTURE COMPONENTS AT VARIOUS TIMES AFTER BURNING TRIAL 3

Date of Sampling	Weeks after Burn	Brigalow				Rhodes Grass				Native Grass		Native Forbs		Bare Ground	
		No. per 16 m²		% Cover		No. per 16 m²		% Cover		% Cover		% Cover		% Cover	
		S	U	S	U	S	U	S	U	S	U	S	U	S	U
25 Feb 66	5	NR	NR	NR	NR	27	0	0·90	0·0	0·45	1·38	0·00	0·00	97·20	96·60
30 Mar 66	10	2·2	1·3	0·05	0·01	20	0	15·50	0·0	0·55	2·03	0·95	3·17	81·75	93·25
10 May 66	16	2·7	2·7	0·40	0·40	24	0	44·88	0·0	0·95	2·80	3·25	7·83	52·10	86·08
23 Jun 66	22	3·0	3·3	0·85	0·70	NR	NR	49·05	0·0	0·7	1·96	2·98	7·00	48·40	87·60
26 Jul 66	27	3·4	3·7	0·88	1·17	NR	NR	40·75	0·0	1·4	3·07	4·05	9·30	53·25	86·30
23 Aug 66	32	3·3	3·9	0·80	0·88	NR	NR	39·56	0·25	3·06	2·45	1·38	7·88	57·18	92·25

S = Sown.
U = Unsown.
NR = Not recorded.

TABLE 7

DENSITY AND COVER OF PASTURE COMPONENTS AT VARIOUS TIMES AFTER BURNING TRIAL 4

Date of Sampling	Weeks after Burn	Brigalow						Rhodes Grass				Native Grass		Native Forbs		Bare	
		No. per 16 m²		% Cover		Mean Cover per sucker (cm²)‡		No. per 16 m²		% Cover		% Cover		% Cover		% Cover	
		S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U
4 Jan 67 ..	5	0·8	0·4	0·1	0·02	85	..	8·8	0·0	0·4	0·0	0·6	0·9	1·0	0·8	98·1	98·4
6 Feb 67 ..	10	4·8	5·5	0·9	0·5	218	145	15·7	0·0	13·1	0·0	2·0	2·8	12·1	9·5	74·5	87·7†
13 Mar 67 ..	15	9·0	11·0	1·8	1·4	295	271	13·6	0·0	49·6	0·0	2·9	5·0	27·5	28·3	34·0	66·2†
17 Apr 67 ..	20	10·7	10·2	2·5	2·3	351	412	NR	0·0	60·8	0·0	3·2	6·2	23·4	30·7*	26·3	62·9†
15 May 67 ..	24	10·3	10·6	2·7	3·4	364	570	NR	0·0	62·8	0·0	2·7	5·9	18·7	26·1*	26·6	66·8†
19 Jun 67 ..	29	11·6	10·2	2·9	3·5	424	598	NR	0·0	65·8	0·0	2·7	5·8	15·0	22·8*	25·6	69·2†
10 Nov 67 ..	50	9·1	9·5	3·1	6·4*	477	1 087	NR	NR	93·2†	31·5	2·3	13·7†	12·1	40·8*	4·6	29·2†

* Significantly different at 5% level.
† Significantly different at 1% level.
‡ Data not analysed.
S = Sown plots.
U = Unsown plots.
NR = Not recorded.

2. EFFECT OF RHODES GRASS ON THE ESTABLISHMENT OF BRIGALOW SUCKERS. There was little effective rain in the first 5 weeks after sowing and grass establishment was slow. Only a 13% cover of grass was recorded 10 weeks after burning and, at this stage, more than 50% of the suckers had emerged. Table 7 shows that the presence of Rhodes grass had little effect on the eventual sucker density, suckering being just as prolific on sown as unsown plots. However, at 12 months there was a significant difference in the canopy cover of the suckers. Individual suckers in plots sown with Rhodes grass occupied only half the area of the suckers in the unsown plots and the effect of Rhodes grass was confirmed by cutting and weighing individual suckers. Fifteen suckers were sampled at random in sown and unsown plots and weighed. The average weight of suckers in the unsown plots was 112 g compared with an average weight of 19 g in the sown plots.

This trial showed that, under prevailing conditions, the presence of Rhodes grass has no effect on the number of suckers which emerged but did influence the size of the individual suckers.

3. EFFECT OF RHODES GRASS ON OTHER COMPONENTS OF THE PASTURE. During the first 10 weeks after sowing, Rhodes grass had little effect on the regeneration of other components of the pasture. At that stage, 75% of the ground in sown plots was bare and little competition between components was obvious. From the fifteenth week, however, when the area of bare soil was reduced to 34%, competition between species and individuals was in evidence. Rhodes grass began to dominate the pasture preventing any increase in native grass cover and producing a decrease in the cover of native forbs. Twenty weeks after burning, the cover of native forbs was significantly less ($P<0.05$) in the sown than in the unsown plots and this difference increased with time. The most prominent forbs were Sesbania pea (*Sesbania cannabina* (Retz.) Poir) and one of the flannel weeds (*Abutilon oxycarpum* F. Muell.). While native forbs rapidly colonized bare areas, the native grasses were very slow to re-establish even though the unsown plots contained in excess of 60% bare soil for at least 6 months. Approximately 6 months after burning, native grasses occupied only 6% of the total area of unsown plots and it was only in the final count, 12 months after burning, that the unsown plots contained significantly more ($P<0.01$) native grass.

Following the June count when chipping of Rhodes grass plants in the control plots ceased, Rhodes grass rapidly colonized the bare areas and areas rendered bare by the death of the annual forbs.

Trial 5

Details of quadrat counts made during the course of the trial are set out in table 8. Significance levels indicated in the table involve comparisons between sown and unsown plots at particular sampling dates for particular pasture components.

1. EMERGENCE OF BRIGALOW SUCKERS. Maximum emergence was achieved within 10 weeks of burning. Again, the rate of emergence was very slow up until the fifth week and then increased rapidly up until the tenth week. Deaths greatly exceeded the emergence of new suckers over the next 5 weeks, during which time good rainfall was received. Some of these deaths appeared to be related to excessive soil moisture. A slight but steady decline in sucker density continued until the final count in December 1968.

TABLE 8

DENSITY AND COVER OF PASTURE COMPONENTS AT VARIOUS TIMES AFTER BURNING TRIAL 5

Date of Sampling	Weeks after Burn	Brigalow						Rhodes Grass				Native Grass		Native Forbs		Bare	
		No. per 16 m²		% Cover		Mean Cover per sucker (cm²)‡		No. per 16 m²		% Cover		% Cover		% Cover		% Cover	
		S	U	S	U	S	U	S	U	S	U	S	U	S	U	S	U
20 Dec 67 ..	5	0·6	0·2	0·03	0·09	64	..	36·4	0	0·7	0·0	1·2	0·4	1·8	1·7	97·2	97·9
25 Jan 68 ..	10	1·6	3·6	0·23	0·39	189	144	41·0	0	12·9	0·0	1·9	1·3	22·7	19·9	67·0	78·4
1 Mar 68 ..	15	1·3	2·0	0·25	0·30	251	197	NR	NR	58·9	0·0	2·2	2·8	41·1	39·7	20·0	58·2†
19 Apr 68 ..	22	1·2	1·8	0·16	0·25	253	273	NR	NR	74·2	0·0	2·1	3·7	29·9	44·6†	15·0	53·3†
17 May 68 ..	26	1·3	1·7	0·30	0·36	351	353	NR	NR	82·1	0·0	2·3	5·9*	35·1	50·7*	7·7	44·5†
18 Dec 68 ..	56	1·2	1·8	0·30	0·58	350	632	NR	NR	89·6†	37·9	2·0	7·3†	13·8	33·2†	7·9	33·0†

* Significantly different at 5% level.
† Significantly different at 1% level.
‡ Data not analysed.
S = Sown plots.
U = Unsown plots.
NR = Not recorded.

2. Effect of Rhodes grass on the emergence and growth of brigalow suckers. A similar rate of coverage to that in trial 4 was attained by Rhodes grass though rainfall in the present trial seemed more effective. A 13% cover of Rhodes grass was recorded on the tenth week, and it was not until after the tenth week that the influence of Rhodes grass was noticeable.

The relatively more favourable time of pulling and longer delay between pulling and burning resulted in a lower density of regrowth than in the previous year. Though fewer suckers were recorded on sown than on unsown plots, the difference was not significant. Following counting at the tenth week, it was considered that too few suckers had emerged for reliable results to be obtained from the sample size selected and additional quadrats were established in sown and unsown plots so that the influence of Rhodes grass could be assessed more accurately. Following the establishment of additional quadrats, counts of suckers showed the presence of Rhodes grass had little effect on the density of regrowth from the tenth week onwards.

At the final count, the average size of individual suckers in the sown plots was much smaller than that recorded in the unsown plots.

3. Effect of Rhodes grass on other components of the pasture. As in the previous trial, native forbs showed they were much more efficient colonizers of the ash seedbed than the native grasses. In the early stages of establishment, they outgrew the Rhodes grass but from the fifteenth week onwards, when bare ground had been reduced to 20%, Rhodes grass began to dominate the pasture. This caused a reduction in the coverage of native forbs and prevented any increase in the cover of native grass. The cover of native forbs was significantly greater ($P<0.01$) on unsown plots 22 weeks after burning and the difference was maintained at the final count. As in trial 4, native grasses occupied only 6% of the total area of the unsown plots 6 months after burning but in this trial there was significantly more ($P<0.05$) native grass on unsown plots from the twenty-sixth week onwards.

Following the May count when chipping of Rhodes grass plants in the control plot ceased, Rhodes grass rapidly colonized the bare areas and areas rendered bare by the death of annual forbs.

IV. CONCLUSIONS

1. Emergence of brigalow suckers. The rate of emergence of brigalow suckers following burning was similar in four of the five trials. Only in trial 5 did any marked variation in the pattern occur.

The population density 5 weeks after burning was always less than 20% of the eventual maximum density. The most rapid emergence during this period occurred in trial 2 and is partially related to the biomass of the initial stand. Whipstick brigalow does not provide as much fuel as virgin trees and the fire in this trial was less severe. In addition, although conditions were drier before treatment than in subsequent trials, rainfall was higher in the first few weeks after burning.

Except for trial 5, a rapid rate of emergence was maintained from the fifth to the fifteenth week when between 75% and 85% of the maximum density was achieved. Maximum density was recorded 25 weeks after burning in trials 1, 2 and 4 while, in trial 3, 98% of the suckers had emerged at this time. The data from the latter trial are the least reliable of all and sampling error could easily account for this variation.

In trial 5, maximum density occurred 10 weeks after burning. At this time, rainfall received both before and immediately after burning was not greatly different from that in previous years. However, rainfall in the succeeding 4 months was average to above average. Some waterlogging occurred during this period and it is considered that the moist soil conditions contributed to the marked death in emerged suckers.

In the other trials, rainfall during this period was below average and it could be speculated that, if waterlogged conditions had not occurred in trial 5, the rate of emergence in this trial may have been continued until the fifteenth week.

It can be concluded that the general pattern of emergence is for approximately 10% of maximum density to be achieved 5 weeks after burning with approximately 50% being recorded 10 weeks after burning and approximately 80% fifteen weeks after burning. Maximum density is expected to occur between 20 and 25 weeks after burning. This is represented diagrammatically in figure 1. This pattern can be modified by excessive soil moisture during the period of emergence.

Maximum density does not infer that all suckers have emerged. From this point, deaths among emerged suckers exceeded the production of new suckers. However, in trials 4 and 5 where additional information was collected, only 2% of the suckers present 12 months after burning had emerged after the twenty-fifth week.

From this information, it should be possible to make a general prediction on the eventual sucker density from estimates approximately 10 weeks after burning. This would allow an early decision on the need for control measures and would enable preparations to be made well in advance. It also indicates that, where spraying is to be used to control suckers following the initial burn, the treatment should be delayed until at least 20 to 25 weeks after burning to allow all suckers to emerge.

2. Establishment of Rhodes grass. Heavy grazing during the first summer and autumn severely affected the establishment of Rhodes grass in trial 1 and the effect was permanent.

In the second trial in which the dates of sowing were also staggered, best germination resulted when sowing was followed as closely as possible by a period of steady rainfall. This also appeared to occur in the first trial (table 1). Severe seed spoilage occurred where a long delay between sowing and suitable germination conditions occurred, but this loss in viable seed was partly compensated for by seed production from established plants and by the extension of vegetative runners.

Though results from both trials suggest that autumn is the most favourable time for sowing, it is considered that the unusual rainfall pattern which occurred in both years was an important factor. In the first trial, the rainfall during summer and autumn was markedly below normal, whereas in the winter period rainfall was above average. In the second trial (excluding the severe storm which followed the initial sowing), rainfall was again well below average except immediately after the April sowing. In contrast, sowing in December 1966 and November 1967 (trials 4 and 5) resulted in establishment equally as satisfactory as that recorded from the autumn sowings in 1964 and 1965. In 1966 and 1967, the rainfall during the summer period was closer to normal. None of the summer sowings in any of the trials, except in trial 1 where severe grazing occurred, was unsatisfactory.

3. EFFECT OF RHODES GRASS ON THE EMERGENCE AND GROWTH OF BRIGALOW SUCKERS. In none of the trials was there any evidence that the competition by Rhodes grass resulted in a marked reduction in the density of regrowth 12 months after burning. By this time, pastures are normally grazed and selective grazing would alter the competitive balance in favour of the brigalow suckers. In every trial, however, there were fewer suckers in the plots sown soon after burning than in the control plots. This difference was usually noticeable within 10 weeks of burning when the cover of Rhodes grass was less than 15% and the major portion of the sown plots was still bare. It seems more logical to regard this difference as being due largely to chance rather than to any competitive effect.

In the first two trials, the cover of Rhodes grass did not affect the size of individual suckers as measured by canopy cover. In both trials, grazing and adverse seasonal conditions resulted in poor establishment of Rhodes grass. However, in the last two trials, there was a marked reduction in the size of individual suckers within 12 months of sowing. This was reflected in the canopy coverage measurements and measured by the random sampling of suckers in trial 4. In both these trials, the use of permanent quadrats enabled a more accurate estimate of parameters from one sampling date to the next while the exclusion of animals and the better seasonal conditions gave the grass the opportunity to compete more successfully with the brigalow suckers.

The rate of colonization of Rhodes grass in the last two trials indicates that any competitive pressure it may exert would not take effect until about the fifteenth week at which stage 80% of the brigalow suckers have emerged. It is possible that, under ideal conditions, more rapid colonization could reduce the eventual sucker density but under field conditions these situations would be rare. However, even under average conditions, Rhodes grass does slow the growth of brigalow suckers. Once the grass is well established, it is more economical to graze the pasture and accept the faster growth of the suckers. Except under exceptional circumstances it is felt that no grass species under field conditions would be capable of markedly reducing the eventual sucker density: the selection of pasture species should be related to establishment, coverage, persistence and productivity characteristics. If suckers are common in the early stages of pasture establishment, pasture grasses will not control them and some positive method of control is essential if pasture productivity is to be maintained.

4. EFFECT OF RHODES GRASS ON OTHER COMPONENTS OF THE PASTURE. In the last two trials the successional pattern was very similar. Native forbs were the most efficient early colonizers with *Sesbania cannabina* (Retz) Poir and *Abutilon oxycarpum* F. Muell. being abundant while native grasses were very slow to colonize. Rhodes grass began to compete noticeably with the native herbage at about the fifteenth week, causing a marked reduction in the coverage of native forbs and preventing any increase in the cover of native grass. Where Rhodes grass was not sown, native grasses occupied less than 6% of the total area at the end of the autumn.

Following the initial burn, plants regenerating from existing perennating organs have an initial advantage in establishment over plants which have to grow from seed. The survival of these organs depends largely on the severity of the burn. If the fire is a hot one, as it was in the last three trials, most plants except brigalow are killed. Under these conditions, native grasses were slow to re-establish so, even if grass establishment of introduced species is delayed, there is little likelihood that the native grasses will occupy a dominant position in the first few years.

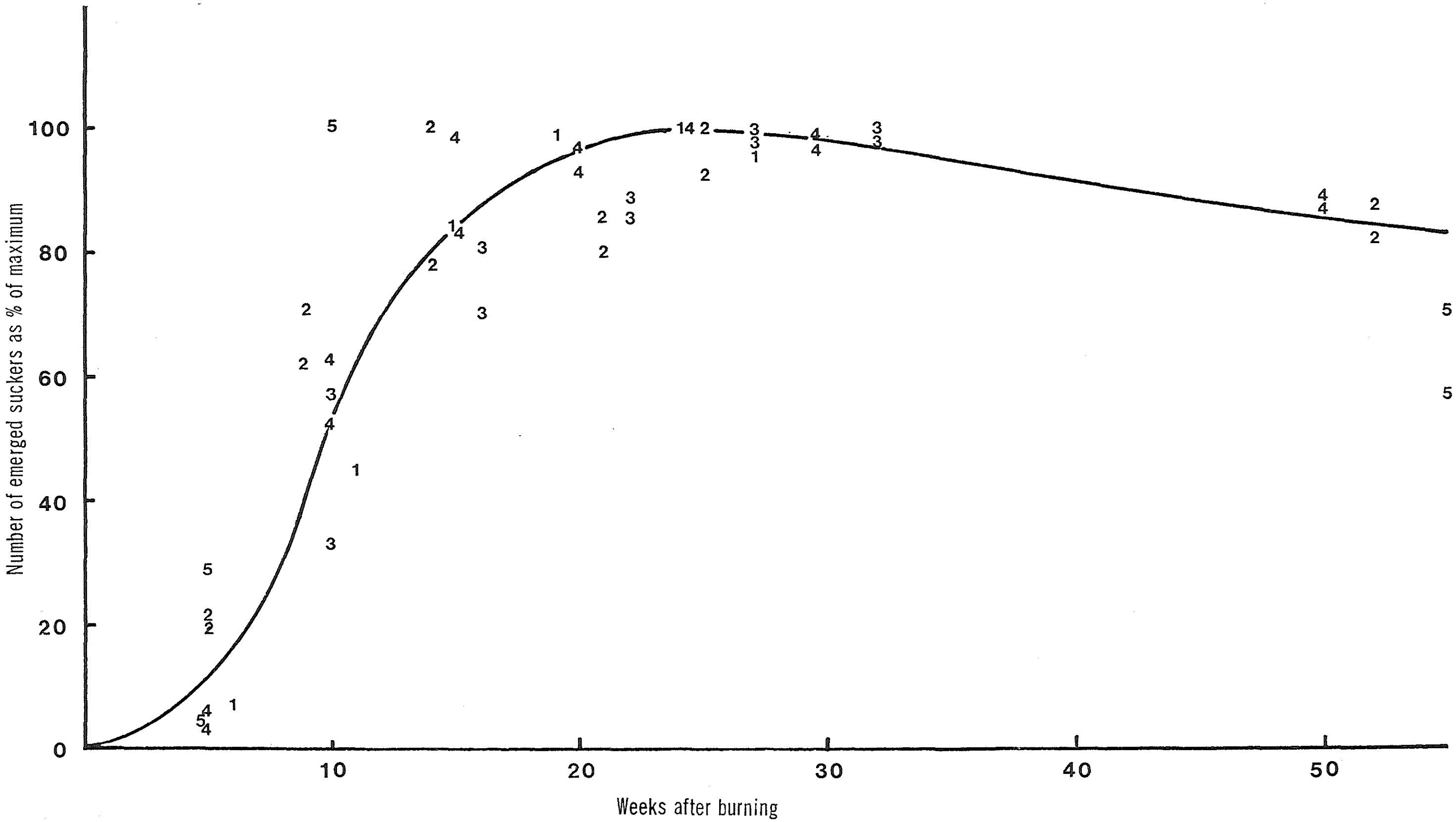

Figure 1.—Emergence of brigalow suckers following pulling and burning. Numbers are trial numbers, with data from control plots and plots sown immediately after burning.

The severity of the initial burn is related to the density and structure of the community before pulling. In the last three trials where native grass cover was assessed, the particular communities treated were virgin and the amount of trash left after pulling was sufficient to kill most of the relatively sparse ground flora in the initial burn. In more open, immature or disturbed communities where native grasses are well established, the amount of trash is minimal and native grasses can become prominent within a year of burning. Results from these trials cannot be extrapolated to this type of community and any delay in establishment would favour re-establishment of the native species.

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