CHAPTER 10

SEEDLING EMERGENCE AND SURVIVAL OF EIGHT NATIVE PERENNIAL GRASSES

Results of studies on the effects of temperature (Experiment 7) and the role of dormancy (Experiment 6) in the germination of some warm season and yearlong green native perennial grasses suggested that some months of the year may be more favourable than others for the emergence and establishment of these species. Harradine and Whalley (1980) from a study of seedling emergence and survival of Aristida ramosa on the Northern Slopes found that seedling establishment was controlled primarily by moisture availability and the degree of competition from annual species. Autumn germinations were generally the most successful as they allowed very young A. ramosa seedlings to avoid the hot dry summers.

The months of emergence of seedlings of some other dominant native perennial grasses and the interaction of temperature, moisture availability and competition on their establishment and survival over a two year period were investigated in this study. Experiments were conducted in both natural pastures and in sown monospecific plots to determine the months in which seedlings of A. ramosa, B. macra, D. sericeum, S. elongatus E. leptostachya, C. truncata, S. scabra and D. linkii emerged and had the best chance of establishing successfully.

Experiment 8A. Natural pastures

A. Materials and Methods

Permanent quadrats, 0.25 m^2, containing plants of the above species were established at Study area 1 site 1 and Study area 2 described in Experiments 1 and 4A and Appendices 1, 5A and 5B. At the Study area 1 site 1 one set of ten quadrats (Study area 1 1976) was maintained from March 1976 to February 1977 and another set of ten (Study area 1 1977) from December 1976 to March 1978. Ten quadrats were maintained from December 1976 to March 1978 at Study area 2.

At the end of each month throughout the experimental period all new seedlings of the above native grasses that had emerged in the permanent quadrats were marked with a coloured pin. Different pin colours were used to represent each month of emergence and where possible seedlings were identified to species. To avoid bird theft of the pins the permanent quadrats were enclosed in cages one m^2 in area. To check whether these enclosures had any effect on seedlings, emergence was also observed in 10 uncaged permanent 0.25 m^2 quadrats.

For each month of emergence surviving seedlings were identified to species in autumn (April) and spring (November). Pins that no longer marked a living seedling were removed and counted. After April 1978 the enclosures were removed and the surviving seedlings were marked with large galvanised roofing clouts. Observations were also made in spring and autumn on the appearance of any inflorescences on the surviving seedlings.

Survivorship curves were constructed for each month of emergence, for the total number of seedlings, by the method of Hett and Loucks (1971). The number of surviving seedlings was plotted against time in a power function model:

$$N = N_o t^{-b}$$

where N = number of seedlings at any time (t), N_o = initial number of seedlings, t = time, b = mortality constant. This function is the simplest model that describes a Deevey type III curve (Deevey 1947). The model was transformed to the linear equation:

$$\log_e N = \log_e N_o - b \log_e t$$

with the regression coefficient (b) being the mortality constant.

B. Results

A total of 2387 seedlings were marked, but by November 1978 less than two percent of these had survived. There was no observed effect of the enclosures on seedling emergence.

At each of the Study areas very low numbers of seedlings or no seedlings of any species appeared in spring and early summer (Fig. 10.1). Seedlings that did emerge in this period generally failed to survive the hot conditions of the following summer. This low seedling emergence may be partly because of the below average rainfall from September to December 1977 at Study area 1 site 1 and in October and December at Study area 2

(Appendix 5A). However, in spring and early summer 1976, few seedlings emerged and survived at Study area 1 even though soil moisture was adequate. Seedling emergence and survival in spring may also be limited by the wide range recorded in minimum and maximum temperatures (Appendix 5B) and by competition from rapidly growing annual species as well as from the warm season native perennial grasses recommencing growth (Fig. 6.1).

Highest numbers of seedlings emerged in May and June 1976 and March 1977 at Study area 1 and in January and March 1977 at Study area 2 (Fig. 10.1). For each month of emergence seedling mortality was high (Fig. 10.1; Table 10.1) and most seedlings died within one or two months of emergence. For seedlings which survived the experimental period, mortality constants were lowest for those emerging in April, May and June 1976, and March and April 1977 at Study area 1, and in February, July and August 1977 at Study area 2.

Problems were encountered in the positive identification of all species at emergence, and because many seedlings died before they could be positively identified it was impossible to construct seedling mortality curves for individual species. To determine seedling survival of individual species from the data available the total number of positively identified seedlings which emerged in any one month at each of the study areas was counted. This number was expressed as a percentage of the total number of perennial grass seedlings emerging in that month (Table 10.2).

The months when any seedlings of each species emerged and (in parenthesis) the months when maximum seedling numbers of each species emerged (from field notes) were as follows: C. truncata seedlings were observed to emerge in January, March-May and November (January, March); S. scabra in January, March-August, October (May-August); B. macra January-June, August, November (April-June); D. linkii January-September (April-June); D. sericeum January-July, September, November, December (January-February); A. ramosa January-April, June, July, November (November, January). Only three seedlings of S. elongatus emerged at Study area 1 in January 1977, but no seedlings of E. leptostachya were observed in any of the Study areas. Seedlings of all species emerged in the summer when the average maximum soil surface temperature in exposed areas exceeded 50°C and seedlings of the C_4 grass D. sericeum emerged in July 1977 at

Figure 10.1

Survivorship curves for each month of emergence of native perennial grass seedlings at Study area 1 site 1 from April 1976 to March 1977 (●), from January 1977 to March 1978 (○) and Study area 2 from January 1977 to March 1978 (△). All curves on the base line indicate zero survival.

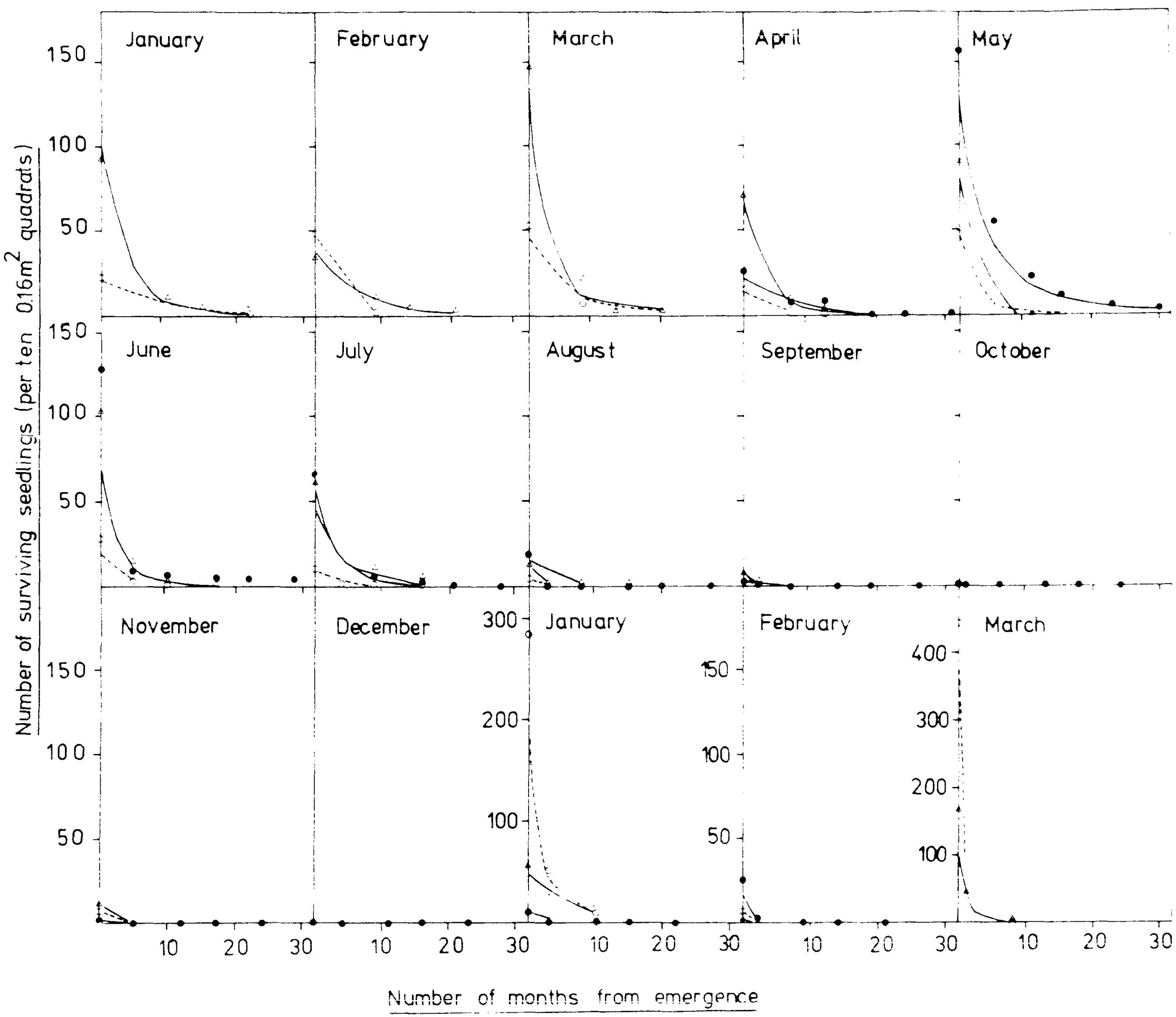


Table 10.1. The mortality constants for native grass seedlings emerging in each month from April 1976 to March 1977 and January 1977 to March 1978 at Study area 1 site 1 and from January 1977 to March 1978 at Study area 2. Standard errors are given in parentheses for seedlings that survived longer than 3 months.

	Mortality constants		
Month of emergence	Study area 1 1976 to 1977	Study area 1 1977 to 1978	Study area 2 1977 to 1978
January		-0.674 (0.284)	-1.263 (0.309)
February		-1.672	-0.833 (0.205)
March		-0.814 (0.072)	-1.306 (0.297)
April	-0.712 (0.253)	-1.009 (0.137)	-1.127 (0.102)
May	-0.937 (0.185)	-0.959 (0.260)	-1.129
June	-0.910 (0.144)	-1.356	-1.518 (0.241)
July	-1.183 (0.095)	-	-0.002 (0.189)
August	-	-	-0.910 (0.346)
September	-	-	-1.772
October	-	-	-
November	-	-	-
December	-	-	-
January	-0.957 (0.443)	-1.390 (0.120)	-1.632 (0.513)
February	-2.341	-1.767	
March		-2.481 (0.088)	-2.025 (0.066)

Study area 2 when the average minimum temperature was -0.6°C.

In general maximum survival occurred in those seedlings of warm season grasses that emerged in summer and autumn and in seedlings of yearlong green grasses that emerged in autumn and winter (Table 10.2). The months in which individual grass species emerged and had the highest chance of survival were: April 1976 (B. macra); February 1977, January 1978 (A. ramosa); May 1976, January-April and July 1977, January 1978 (D. sericeum); May, June 1976 and April, June 1977 (D. linkii); May, June 1976 and March, June-August 1977 (S. scabra). No seedlings of C. truncata or S. elongatus survived for the experimental period.

Table 10.2. Emergence and survival of seedlings of individual native perennial grasses at Study area 1, site 1 and Study area 2. Data only for months in which seedlings emerged and survived throughout the experimental period - No emergence in any one month; 0, no survival. Percentage of surviving seedlings expressed as percentage of total number that appeared.

	Percentage of surviving seedlings																
	Study area 1	Emergence month			Study area 1	Emergence month				Study area 2	Emergence month						
	1976	1976			1977	1977			1978		1977						1978
Species	Measurement month	Apr.	May	June	Measurement month	Mar.	Apr.	June	Jan.	Measurement month	Jan.	Feb.	Mar.	Apr.	June	July	Aug.	Jan.
C.truncata	Apr. 77	4.0	0.6	-	Nov. 77	0	-	-		Nov. 77	1.1	-	-	-	-	-	-	
	Nov. 77	0	0		Apr. 78	0			0.7	Apr. 78	0							
	Apr. 78	0	0		Nov. 78	0			0	Nov. 78	0							
	Nov. 78	0	0															
[illegible].scabra	Apr. 77	4.0	1.9	0.8	Nov. 77	5.6	-	0		Nov. 77	-	-	0.7	-	3.9	12.8	8.3	
	Nov. 77	0	1.3	0.8	Apr. 78	5.8		0	0	Apr. 78			[illegible]		2.0	6.5	8.3	
	Apr. 78	0	0.6	0.8	Nov. 78	3.8		0	0	Nov. 78			0.7		1.0	3.2	8.3	
	Nov. 78	0	0.6	0.8														
B.macra	Apr. 77	4.0	-	-	Nov. 77	-	-	0		Nov. 77	1.1	0	-	-	1.1	-	0	
	Nov. 77	4.0			Apr. 78			0	0	Apr. 78	1.1	0			0		0	[illegible]
	Apr. 78	4.0			Nov. 78			0	0	Nov. 78	0	0			0		0	0
	Nov. 78	4.0																
D.linkii	Apr. 77	4.0	5.1	3.1	Nov. 77	3.8	5.6	2.9		Nov. 77	-	-	0.7	-	1.1	0	4.8	
	Nov. 77	4.0	3.8	3.1	Apr. 78	1.9	5.6	2.9	2.8	Apr. 78			0		0	0	0	
	Apr. 78	0	1.9	3.1	Nov. 78	0	5.6	2.9	0	Nov. 78			0		0	0	0	-
	Nov. 78	0	0.6	3.1														
D.sericeum	Apr. 77	0	1.9	-	Nov. 77	3.8	-	5.9		Nov. 77	8.9	14.7	5.4	5.7	5.9	4.8	-	
	Nov. 77	0	1.3		Apr. 78	1.9		2.9	7.6	Apr. 78	7.3	8.8	0.7	[illegible]	2.0	4.2		[illegible]
	Apr. 78	0	1.3		Nov. 78	1.9		0	1.4	Nov. 78	1.1	0	0.7	[illegible]	0	1.6		[illegible]
	Nov. 78	0	0.6															
A.ramosa	Apr. 77	0	-	-	Nov. 77	-	0	0		Nov. 77	-	8.8	0.7	1.4	-	3.2	-	
	Nov. 77	0			Apr. 78		0	0	0.7	Apr. 78		2.9	0.7	0		0		0
	Apr. 78	0			Nov. 78		0	0	1.4	Nov. 78		2.9	0	0		0		0
	Nov. 78	0																

Several other features of seedling emergence and establishment were noted during these studies. Most emerged in the exposed spaces between the tussocks of mature plants and their survival was enhanced by a light cover of litter. Few seedlings emerged close to mature plant bases and those that did died. Seedlings grew extremely slowly; after 31 months surviving seedlings were restricted to 3 to 4 tillers and all were less than 10 cm high (Plate 10.1). Only two seedlings flowered during the experimental period and up to April 1979 when some seedlings were 36 months old. One B. macra seedling that emerged in April 1976 at Study area 1 had flowered by April 1978, but was dead in November 1978. The other was a D. sericeum seedling which emerged in January 1977 at Study area 2 and was flowering in April 1979. No seedling deaths could be attributed directly to frosts which were common in the winter at each of the Study areas.

Experiment 8B. Monospecific plots

A. Materials and Methods

To overcome the difficulty of identifying positively seedlings in natural pasture, monospecific plots of A. ramosa, B. macra, D. sericeum, S. elongatus, E. leptostachya, C. truncata, S. scabra and D. linkii were planted in a fallowed cultivation paddock at Tamworth in October 1977. The soil at the experimental site was a red-brown earth.

Plants from a glasshouse pot experiment sown 11 October 1976 were used to establish plots one m^2 of each species (Plate 10.2). Each pot from the glasshouse contained five plants, and after removal from the pots five groups of plants were established in each plot; one pot in each corner of a one m^2 quadrat and one in the centre of the quadrat. Two plots were planted for each species. Plots were separated by a distance of five metres and this area was cultivated to avoid invasion of each plot by other species.

Permanent quadrats, 0.25 m^2, were centrally located over the middle group of plants in each one m^2 quadrat. Seedlings that emerged in these permanent quadrats were identified and marked with coloured pins (as described in Experiment 8A) at the end of each month from January to December 1978. For each month of emergence seedling survival was determined every month for 12 months after emergence by counting coloured pins that marked surviving seedlings. Observations were also made on the appearance of any inflorescences on surviving seedlings.

Survivorship curves were constructed for each month of emergence for seedlings of each native grass using the power function model described previously in Experiment 8A. The regression coefficients (mortality constants) for different months of emergence for each species were compared by the method described by Snedecor and Cochran (1969).

B. Results

Mature plants of all species flowered in the first summer after planting out. Seedfall commenced about one month after flowering and the first seedlings of all species except S. scabra emerged in January 1978, following 143 mm of rain and about three weeks after seedfall (Table 10.3). Seedlings of S. scabra first appeared in March 1978.

Maximum emergence of the yearlong green grasses D. linkii and S. scabra occurred in June or July 1978 respectively (Fig. 10.2) when mean ambient temperatures were around 10^{o}C (Table 10.3). Highest numbers of warm season grasses emerged in January (E. leptostachya) and December 1978 (C. truncata, B. macra, A. ramosa, S. elongatus, D. sericeum) when the mean monthly temperatures were 26.3^{o}C and 21.7^{o}C, respectively. No seedlings emerged in August and small numbers emerged in February and April when rainfall was low (Table 10.3). Seedling emergence was also low in September and October when mean minimum temperatures were below 10^{o}C (Table 10.3) and there may have been some intraspecific competition from mature plants recommencing growth.

The number of seedlings surviving 12 months after emergence depended on the number which emerged in each month, the magnitude of the mortality constant, and the shape of the mortality curve. Mortality constants for each month of emergence were significantly different ($P < 0.05$) for A. ramosa, B. macra, D. sericeum and D. linkii seedlings which emerged in each month (Table 10.4), but were not significantly different for seedlings of C. truncata and E. leptostachya. Of the 694 S. elongatus seedlings marked none survived for longer than three months after emergence.

Table 10.3. Monthly rainfall, screen temperatures and frost occurrence at the Tamworth Agricultural Research Centre from December 1977 to December 1978. A frost was recorded as a screen temperature of 2°C or less.

	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Rainfall mm	21.8	143.0	3.9	71.4	10.6	62.4	93.7	75.8	17.1	66.2	41.6	79.2	110.9
No. Rain days	5	14	5	10	5	9	17	12	6	10	8	10	13
Mean Min 0°C	17.5	20.2	22.5	16.2	8.0	7.4	6.1	3.6	3.5	7.5	9.1	13.5	14.9
Lowest Min 0°C	9.8	16.0	11.6	11.1	-2.5	-1.5	-0.2	-3.0	-3.8	-1.0	2.0	5.0	7.5
Mean Max 0°C	34.2	32.4	33.9	30.2	24.4	18.9	14.1	14.3	16.9	19.8	24.3	27.9	28.5
Highest Max 0°C	39.3	38.0	39.5	34.4	30.8	25.4	19.3	23.7	24.4	26.3	29.9	34.5	34.4
Monthly Mean 0°C	25.8	26.3	28.2	23.2	16.2	13.2	10.1	9.1	10.2	13.6	16.7	20.7	21.7
No. of frosts	0	0	0	0	3	3	5	10	14	2	1	0	0

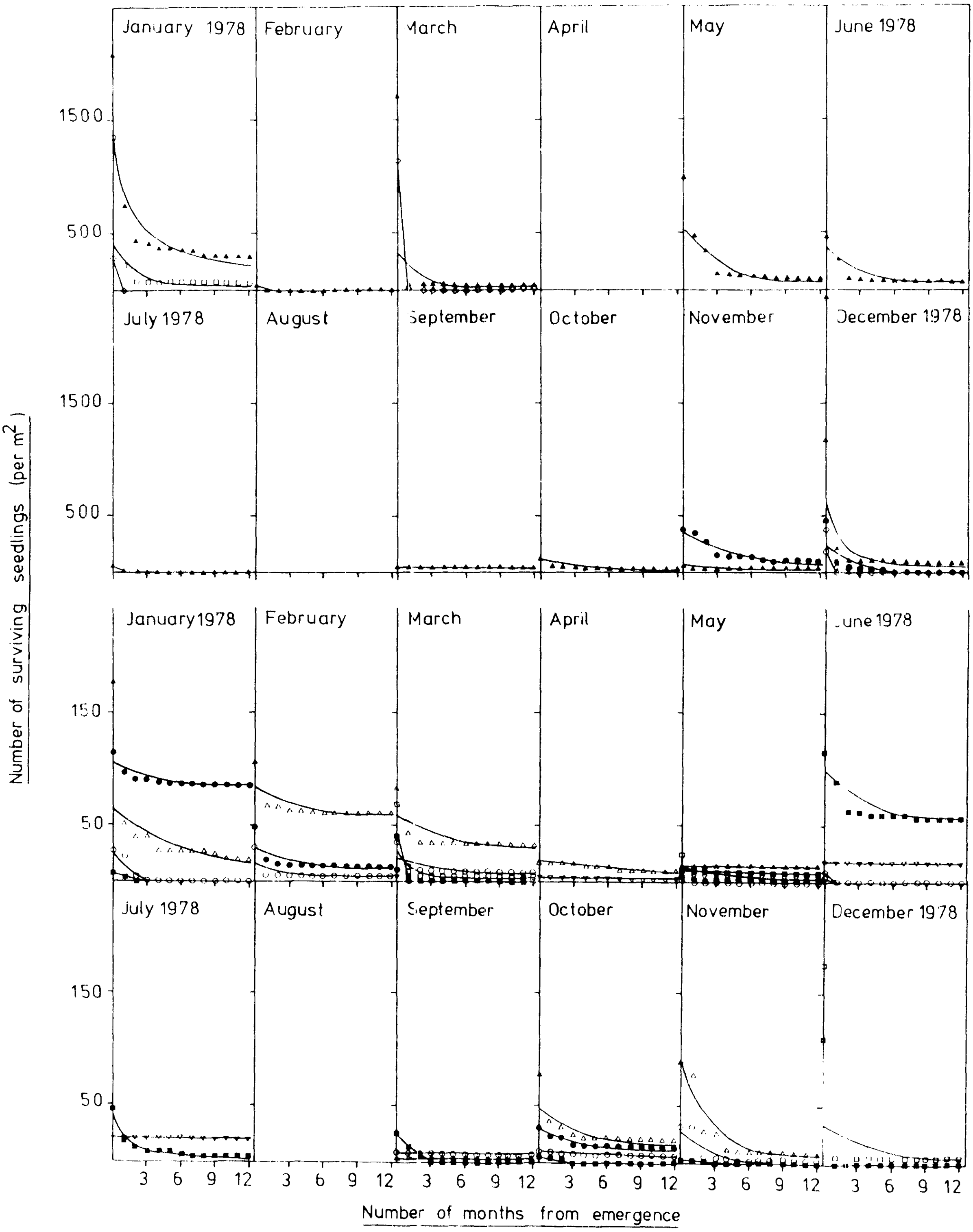


Figure 10.2 Survivorship curves for each month of emergence in monospecific sown plots for seedlings of A. ramosa (○), B. macra (●), D. sericeum (△), S. elongatus (◇), E. leptostachya (□), C. truncata (▲), S. scabra (▽), and D. linkii (■) from January 1978 to December 1978. All points on the base line indicate zero survival.

Seedlings of A. ramosa that emerged in February and March had the best chance of successfully establishing, whilst those that appeared in January, May, June and December failed to survive for 12 months (Table 10.4). B. macra seedlings which emerged in January survived better than those in February, but those emerging in May and December did not survive the experimental period. Emergent seedlings of D. sericeum in February-May had a better chance of successfully establishing than those emerging in January, and although numbers of seedlings were maximal in December none of these survived. Survival of D. linkii seedlings which emerged in May and June was higher than for those in July, and seedlings which emerged in the warmer months of January, March, September, December failed to survive. S. scabra seedlings emerged only from March to June and all emerging in April-June survived; the March seedlings died. C. truncata seedlings that emerged in January, March, May and June had similar survival rates, as did those of E. leptostachya emerging in January, March and May. Although the highest number of A. ramosa, B. macra, D. sericeum, S. elongatus and C. truncata seedlings appeared in December, all except 3.3 percent of the C. truncata seedlings failed to survive for 12 months.

In this experiment most seedlings again emerged in open spaces between mature plants and those close to plant bases did not survive. Surviving seedlings in the monospecific plots grew rapidly compared to those in the natural pastures (Plates 10.3 and 10.4), and all seedlings of the warm season species which emerged in January 1978 flowered within one month of emergence, with those of S. scabra and D. linkii flowering in November 1978.

C. Discussion

In natural pastures and sown plots the most favourable period for the emergence and successful establishment of warm season native perennial grasses was from mid-summer to early autumn. Yearlong green native perennial grasses established best from seedlings that appeared from mid-autumn to late winter. These times of emergence are in general agreement with the temperature ranges for optimum germination in these species determined in Experiment 7, and are consistent with published information on the optimum temperatures for the growth of these species (e.g. Groves 1965; Cook et al. 1976; Hagon and Groves 1977). In summer maximum emergence of

Table 10.4. Mortality constants for eight native perennial grass seedlings emerging in each month from January 1978 to December 1978 in monospecific plots. Standard errors are given in parentheses for seedlings that survived 12 months. No seedling emergence is indicated by (-) and a blank space indicates seedlings that emerged but did not survive for one month.

	Month of emergence					
Species	January	February	March	April	May	June
A. ramosa	-1.743	-0.436 (0.138)	-0.316 (0.072)	-	-1.583	-1.583
B. macra	-0.087 (0.013)	-0.299 (0.077)	-3.170	-	-0.311	-
D. sericeum	-1.028 (0.167)	-0.166 (0.034)	-0.242 (0.061)	-0.282 (0.052)	0	-
S. elongatus	-2.784	-	-	-		-1.654
C. truncata	-0.678 (0.088)	-1.783	-0.949 (0.266)	-	-0.865 (0.084)	-0.740 (0.096)
E. leptostachya	-0.847 (0.208)	-	-0.580 (0.188)	-	-0.769 (0.173)	-
S. scabra	-	-	-1.580	0	0	0
D. linkii	-1.001	-	-3.487	-	-0.179 (0.036)	-0.263 (0.037)

Species	July	August	September	October	November	December
A. ramosa	-	-	0	0	-1.027 (0.125)	-2.669
B. macra	-	-	-	-0.468 (0.056)	-0.417 (0.047)	-2.513
D. sericeum	-	-	0	-0.462 (0.073)	-1.044 (0.114)	-3.968
S. elongatus	-	-	-	-	-	-3.145
C. truncata	-1.776	-	-0.192	-0.510 (0.080)	-0.297 (0.046)	-0.912 (0.239)
E. leptostachya	-	-		-	-	-0.707 (0.221)
S. scabra	0	-	-	-	-	-
D. linkii	-1.113 (0.079)		-2.562	-1.497	-1.583	-2.057

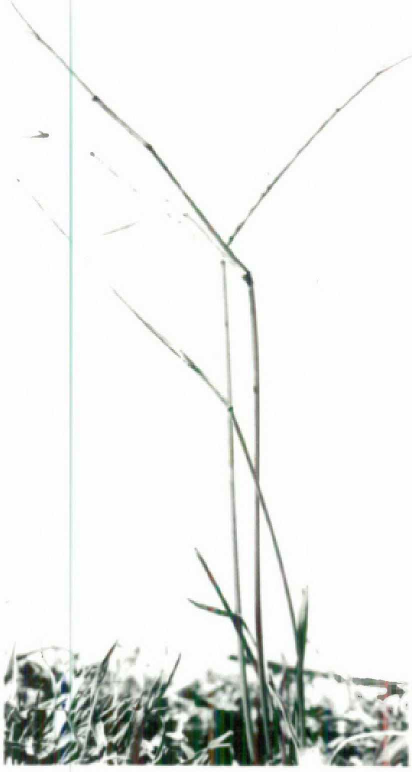
warm season species rarely resulted in maximum survival, but in the cooler months successful establishment of yearlong green grasses often occurred when high numbers of seedlings emerged.

Data on the effect of temperature on germination were used by Hagon (1976) to predict that *Danthonia* spp. and *Stipa bigeniculata* would germinate best in autumn and *B. macra* in spring; and Moore (1958) suggested that *Danthonia* spp. would establish best on the southern Tablelands of New South Wales in autumn and spring and *B. macra* in summer. In the Study areas, however, very few seedlings were observed to germinate in spring in the field, probably as a result of either wide fluctuations in temperature, low mean minimum temperatures or intra and interspecific competition. Results of similar studies in this environment (Harradine and Whalley 1980) also showed that few seedlings of *A. ramosa* appeared in spring, although spring emergence in this species was common at higher elevations on the northern Tablelands.

With suitable temperature and rainfall conditions, seedlings of most species germinated in the sown plots within one month of seed maturity. The germination of freshly fallen seed in the field confirms the laboratory results of Experiment 6 and further demonstrates that, provided conditions are favourable for germination, seed dormancy in these species does not completely limit germination during and immediately after seedfall. The breakdown of dormancy in these species in the field may also have been similar to that observed in soil (Tothill 1977) for dispersal units of *Heteropogon contortus*.

Harper (1977), in a review of available literature, found little evidence that germination was enhanced by a cover of vegetation, and in the present study seedling emergence and survival were highest for all species that germinated in the open spaces between the bases of plant tussocks. High mortality of native perennial grass seedlings may also have resulted from intraspecific competition from neighbouring native plants of the same species whose phenologies would be synchronized to those of the seedlings (Harper 1977), as well as competition from rapidly growing annual species (Harradine and Whalley 1980).

In these experiments negatively skewed curves (Deevey Type III, Deevey 1947) were fitted to the data. This function suggested that for



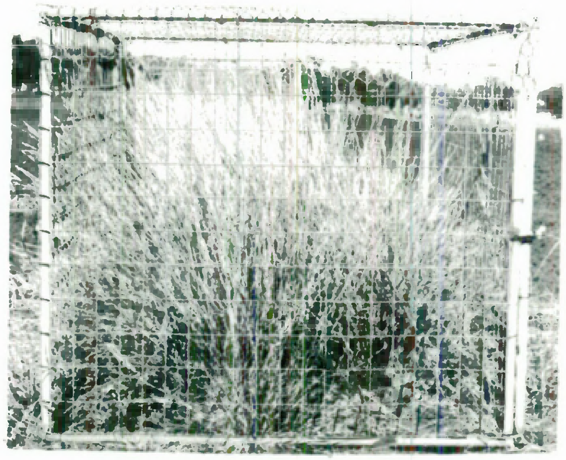


Plate 10.2 An enclosed A.ramosa monospecific plot in a fallow paddock at Tamworth Agricultural Research Centre.

Plate 10.1 A 26 month-old A.ramosa plant 9 cm high that emerged in February 1977 in natural pasture at Study area 2, but had not flowered.

Plate 10.3 An eight month-old A.ramosa seedling 13 cm high that emerged in a monospecific plot in December 1978, but had not flowered.

Plate 10.4 An 18 month-old A.ramosa plant 36 cm high that emerged in a monospecific plot in February 1978 and had flowered.

these native perennial grasses the death risk in the vegetative phase decreased with age, although the exact shape of the curve depended on the species, their time of emergence and the climate. In a semi-arid environment S. scabra was shown to have a half-life measured in months (Williams and Roe 1975), although in the more temperate environment of the study area seedlings of S. scabra survived for at least 20 months. The survivorship curves for the native perennial grasses were remarkably smooth despite seasonal variations in temperature and rainfall. This indicates that climatic variations may be less important in seedling mortality than has been suggested by Williams (1970), Williams and Roe (1975) and Harradine (1976). They presented survivorship curves that showed little difference in the mortality risk over time. For such data Harper (1977) proposed that survivorship curves were determined at the time of seedling recruitment rather than at death and, if so, competition factors at the site of emergence and climatic factors at the time of emergence would be critical in determining survival. Hence, the safest sites for the successful establishment of seedlings of different species will be where both the site and climatic requirements of the seedlings are met. In this context the term 'safe sites' for germination and establishment is an extension of that used by Harper (1977) for seedling recruitment.

The shape of the survivorship curves determined in these studies suggests that in these pastures the seedling death risk decreases with age. Only seedlings which emerge in safe sites, in terms of both space and time, have the best chance of successfully establishing. Seedlings which emerge in very poor sites or opportunistically appear at the wrong time of the year when no sites are safe are the first to die. In the natural pastures studied very few seedlings survived to flowering and maturity, i.e. there were few safe sites. More seedlings established in the monospecific plots, presumably because the previous cultivation and lack of competition from established plants increased the number of safe sites. The marked difference between seedling survival and growth in the natural pasture and the monospecific plots indicates the need to investigate the physical site characteristics required by seedlings of different species for successful emergence and establishment.

Seedlings growing in natural pasture spent long periods in the vegetative stage compared with the early flowering of seedlings in the monospecific plots. Tamm (1956) found that only long-established individuals flowered in grasslands, so apparently the seedlings in natural pasture were under considerable stress. In the pastures studied only two seedlings flowered over 700 days after emergence; many others persisted for up to 2 years but died without producing seed. These findings suggest that the adult populations of the species studied are relatively stable with little recruitment occurring in the pastures examined, in contrast to sites studied by Harradine and Whalley (1980) where there was recruitment of A. ramosa seedlings into the population.

Evaluation studies (Experiments 4A and 4B) indicated that Danthonia linkii is a highly regarded species of natural pastures whilst Aristida ramosa is an undesirable pasture species that has a low palatability and its seed causes fleece (Cornish and Beale 1974) and meat (Lodge and Hamilton 1981) contamination. By extrapolation from the results presented in this section, the abundance of desirable species such as D. linkii could be increased in the native and natural pastures of the study area by either artificially sowing seed or manipulating grazing to reduce competition from the existing vegetation, thereby enabling D. linkii plants to ripen seed in summer and early autumn and establish seedlings in late autumn and winter. Similarly, the abundance of undesirable species such as A. ramosa could be decreased by heavy grazing in summer and early autumn, thereby reducing the flowering of mature plants and thus the chances of the successful establishment of A. ramosa seedlings.

Section 5 A GRAZING MANAGEMENT SYSTEM FOR NATIVE AND NATURAL PASTURES

CHAPTER 11

GRAZING MANAGEMENT SYSTEMS DESIGNED TO DECREASE THE ABUNDANCE OF A. RAMOSA AND INCREASE D. LINKII

The abundance of an individual species in a pasture is influenced by climatic and edaphic factors and management, although ultimately it depends on the recruitment of seedlings of that species into the adult population. Grazing management systems designed to match the reproductive biology of individual species can affect seed reserves in the soil and the probability of successful seedling establishment, and so the rate of recruitment of seedlings of desirable and undesirable native perennial grasses. Management practices such as the time and intensity of grazing and the strategic use of fire, herbicide and fertilizer can also be used to affect the vigour of mature plants and to manipulate the degree of competition from the existing vegetation.

Phenological data collected in Experiments 5, 6, 7, 8A and 8B were used to construct a grazing management system to reduce the abundance of the undesirable native perennial grass, A. ramosa, and to increase the amount of the desirable native grass, D. linkii, in pastures of the study area. This management system was designed to match the timing and intensity of grazing to the phenology of the species, with the aim of discouraging A. ramosa and encouraging D. linkii plants and seedlings. Because of the widespread dominance of A. ramosa in the study area the natural pastures are of low productivity and are generally grazed by wethers for wool production. Hence, any changes to pasture composition would need to be achieved by methods which are, initially, low cost.

Reducing the abundance of A. ramosa

A. ramosa plants flower from late spring to early autumn depending on rainfall. Pastures should be grazed heavily at stocking rates greater than 10 DSE's/ha/year from early summer to early autumn (Fig. 11.1) to prevent a large build up of A. ramosa seed.

In summer high temperatures would favour the germination of A. ramosa and plants would establish best from seedlings that appear from mid-summer to early autumn. Heavy grazing at these times would also be unfavourable for newly emerged A. ramosa seedlings and the abundance of Aristida species decreases at high stocking rates (Brownlee 1973; Lodge and Roberts 1979). If high stocking rates cannot be maintained in summer, either because of the low nutritional value of A. ramosa herbage, or prolific pasture growth in wet summers, then burning in early autumn may have to be used to reduce the amount of standing A. ramosa herbage in the pasture (Fig. 11.1). Traditionally many native and natural pastures in the study area are burnt in spring, however, this would be unfavourable to yearlong green plants such as D. linkii which are actively growing at this time. An autumn burn would also have the advantage of destroying the seed crop of the flowering A. ramosa plants as well as being unfavourable for the establishment of newly emerged seedlings. After defoliation the A. ramosa plants would recover slowly (Harradine 1976) and with decreasing temperatures in autumn and the onset of frosts, flowering would not occur. In mild autumns A. ramosa plants may regrow after burning. The new regrowth would contain highly digestible green leaf and as the new shoots are palatable to sheep (Harradine 1976) it should be grazed to further reduce the plant reserves.

Increasing the abundance of D. lirkii

Removal of stock from pastures in mid-spring would enable D. linkii plants to flower and produce seed in late spring and early summer (Fig. 11.1). Plants of D. linkii may also flower again in late summer and early autumn provided that summer rainfall has been adequate and the mean minimum temperature exceeds 15^{o}C, but this flowering period may coincide with seeding of A. ramosa plants.

Over summer the germination of D. linkii would be restricted by high temperatures and the germination of freshly fallen seed, although initially limited by dormancy would be satisfactory after a period of 10-12 weeks provided suitable temperature and soil moisture conditions occurred. From mid-autumn through to the end of winter conditions would be favourable for the emergence of D. linkii seedlings and to enhance establishment stock should be removed from the pasture during this period. No grazing or light

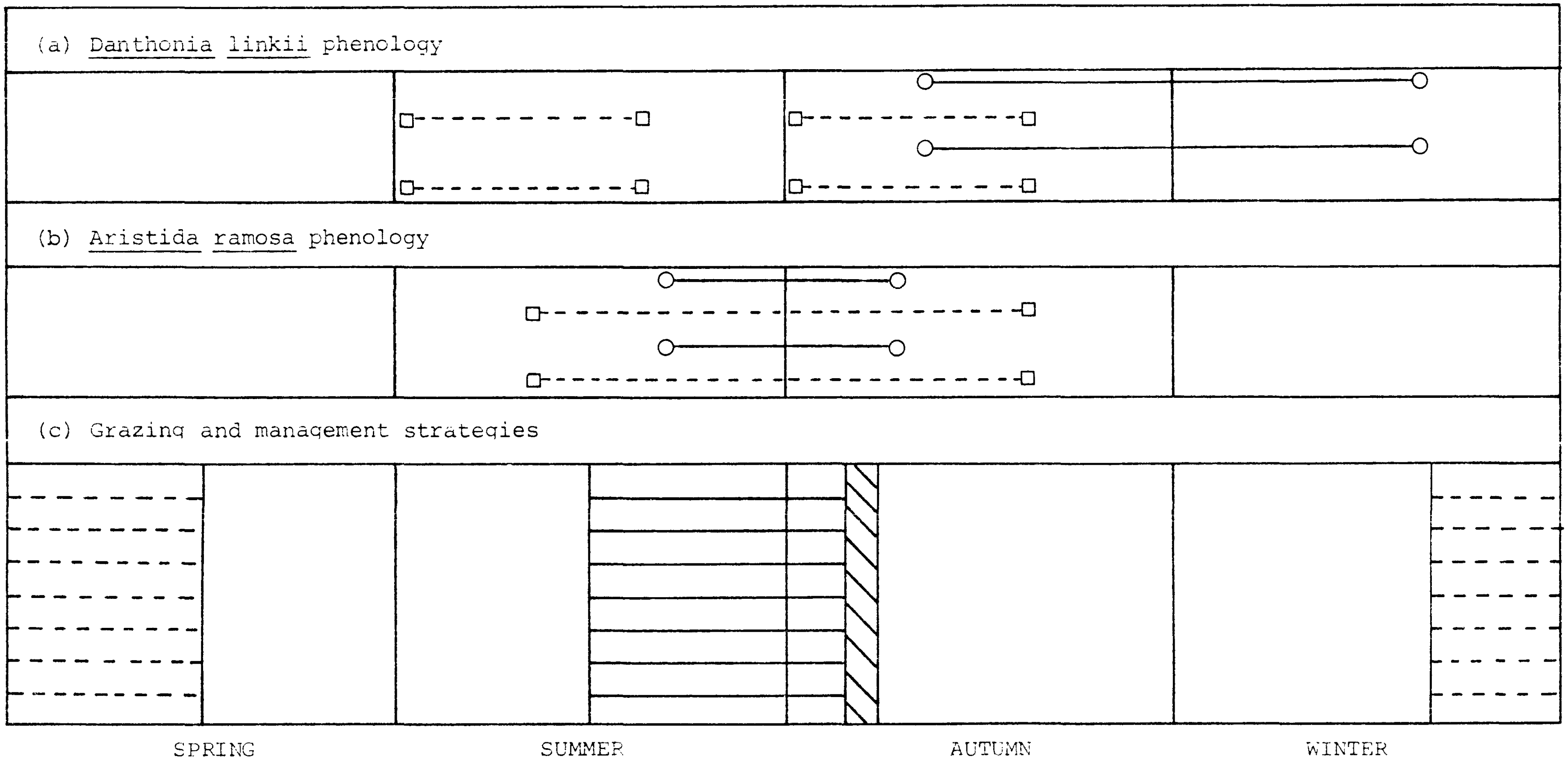


Figure 11.1 The phenology of (a) the yearlong green native perennial grass Danthonia linkii and (b) the warm season grass Aristida ramosa, and (c) a grazing management system designed to increase the abundance of D. linkii and decrease the abundance of A. ramosa. The main flowering periods (□-□) and times of successful seedling emergence (o-o) are shown for each species. In the management system indicates periods of light grazing (1-2 DSE's per ha), heavy grazing (25 DSE's per ha), burning and times at which pastures should be rested from grazing.

intermittent grazing (1-2 DSE's per ha) in winter would also enable mature D. linkii plants to increase plant reserves and recover vigour. Heavy grazing over summer to reduce A. ramosa abundance may also favour Danthonia as the trampling of freshly fallen D. linkii seeds would enhance their chances of successful establishment and Danthonia plants persist under heavy grazing (Robinson and Dowling 1976).

Soil seed reserves of D. linkii could also be artificially increased by the harvesting and sowing of seed. Satisfactory germination could be obtained from carefully threshed caryopses that had been stored for at least three months. Seed should be sown in autumn and winter to enhance the establishment of D. linkii seedlings as their emergence and survival may be limited by high summer temperatures.

Post seeding management

The high seedling mortalities of A. ramosa and D. linkii in natural pastures (Experiment 8A) clearly indicate that seedlings of these species are susceptible to intra- and inter-specific competition. To increase the abundance of D. linkii plants, competition from the existing vegetation should be minimized to favour maximum seedling survival and ensure that the time from emergence to first flower is as short as possible. Hence, in early spring it may be necessary to graze to control competition, particularly from cool season annual grasses and legumes. However, in the first few years after implementing this grazing management system there may not be a sufficient reduction in the perennial grass cover of pastures dominated by warm season species to allow the germination and establishment of cool season annual species, particularly where pastures have been stocked at a low rate.

With adequate rainfall in mid-spring the pastures should be rested from grazing in the late spring-early summer period to again allow D. linkii plants to flower and accumulate seed reserves in the soil. This cycle of grazing heavily in summer to reduce the vigour of A. ramosa plants, and late autumn and winter resting to allow D. linkii seedlings to establish should then be continued for as long as necessary to achieve the desired change in the pasture species assemblages. Substantial reductions in the abundance of A. ramosa plants and increases in the abundance of D. linkii plants could occur within 2-3 years, provided climatic conditions were favourable.

Role of fertilizer

With few cool season annual species in the pasture, superphosphate may be applied to encourage the growth of mature Danthonia plants (Davies et al. 1934; Experiment 3A) and seedlings (Harradine and Whalley 1978). However, the application of fertilizer to pastures containing cool season annual species may also increase their competitive ability (e.g. Davies et al. 1934) and so be unfavourable for the establishment of D. linkii seedlings. Seedlings and mature plants of Danthonia species also respond to N fertilizer (Harradine and Whalley 1978; Robinson 1976), although in low productivity pastures its application would not be economical. Superphosphate application would also increase the growth of responsive warm season grasses, such as B. macra and C. truncata. The provision of a vigorous competing pasture association would severely disadvantage both A. ramosa seedlings and mature plants which have a low competitive ability (Harradine 1976) and will ultimately lead to its control. Both Moodie (1934a) and Berman (1954) reported that superphosphate applications to natural pasture increased the clover content and decreased the proportion of Aristida spp. on the northern Tablelands. Resting of pastures from grazing from mid-autumn to the end of winter could also enhance the establishment of autumn sown legume species. However, the successful establishment and persistence of these species is dependent on fertilizer application (Archer 1981), which would add a substantial cost in the initial year of pasture development.

Testing of the grazing management system

Firstly, it must be established by field experimentation that the grazing management system outlined in Fig. 11.1 will alter species composition in the desired direction. Secondly, such grazing management strategies would then have to be integrated into a whole farm system which would need to be further tested to see if they lead to increases in whole farm animal productivity and pasture stability.

The results of three field studies undertaken to investigate the possibility of decreasing the abundance of A. ramosa and increasing the abundance of D. linkii, using the grazing management system outlined, are reported in this thesis. Further studies to investigate the feasibility of integrating such grazing management systems into a whole farm commenced in February 1983.

CHAPTER 12

A GRAZING MANAGEMENT SYSTEM DESIGNED TO DECREASE THE ABUNDANCE OF *A. RAMOSA*

Experiment 9. The effects of grazing with sheep and cattle and the strategic use of fire, herbicide and defoliation on the herbage mass and abundance of *A. ramosa*

The grazing management system outlined in Chapter 11 (Fig. 11.1) to reduce the abundance of the undesirable native perennial grass *A. ramosa* was tested over a three year period at a field site near Manilla, New South Wales.

A. Materials and Methods

The experimental site (Study area 3) was an 0.84 ha area of unfertilized natural pasture near Manilla (Fig. 3.1). The site was located on a red-brown earth soil type (Dr 2.23) (Northcote 1971), previously stocked at a rate of about 1 sheep per ha.

The experiment was a split plot design in two replicated blocks. In each block the experimental plots consisted of 3 grazing treatments (main plots) in which 3 treatments (sub-plots) were applied at 2 different times. Within each main plot treatments and times of application were duplicated to give 12 sub-plots (3 x 2 x 2). Main plots (1350 m^2) were grazed at two rates of stocking and the sub-plot (9 x 10 m) treatments were to either slash, burn or apply herbicide in spring 1979 or autumn 1980. Main plots were randomly allocated within replicate blocks and sub-plots were randomly allocated within main plots.

Grazing treatments commenced in December 1979. Plots were stocked for four months of the year from December until the end of March. In each replicate two main plots were grazed with either sheep (high stocking rate sheep, HSR sheep) or cattle (high stocking rate cattle, HSR cattle) at a rate equivalent to 39.2 DSE's ha^{-1} $year^{-1}$; the remaining main plot was stocked with sheep at 4.9 DSE's ha^{-1} $year^{-1}$ (low stocking rate sheep, LSR sheep). These stocking rates were achieved by grazing either 16 dry Merino ewes or two Angus steers per plot at the high stocking rate and two dry Merino ewes per plot at the low stocking rate for four months of the year. For the remaining eight months of the year all plots were unstocked. Over the experimental period three cycles of grazing occured each commencing in December 1979, 1980 and 1981. With dry summers during the experimental period some modifications to the grazing period were necessary. In the first year stock remained on the plots for four months, but required a maintenance ration of either grain oats (HSR sheep) or lucerne hay (HSR cattle). In 1980-81 and 1981-82 the plots were grazed for only eight weeks.

In spring 1979 (November 21) and autumn 1980 (May 15) duplicate sub-plots were either burnt, mown to a height of 5 cm above ground level, or sprayed with herbicide at a rate of 5.6 kg a.i. of 2,2 DPA per ha. Treatments were applied only at these times and not repeated in subsequent years.

Herbage mass was estimated every eight weeks from November 10, 1979 by harvesting to ground level two randomly located 0.16 m^2 quadrats from each of the sub-plots using the rank set method of MacIntyre (1952). Within each quadrat all of the A. ramosa plants were counted and harvested separately; the remainder of the herbage in the quadrats was bulked. At the start and end of the experiment the plant basal areas of all individual plants sampled from all quadrats were estimated using the UOG method described in Experiment 1.

These data together with plant density and herbage mass estimates were collected to assess the relative importance of the different plant components using the technique described in Experiment 2. Harvested A. ramosa plants were dried for 48 hours at 80^{o}C in a forced draught dehydrator and weighed. Other herbage in the quadrat was hand-sorted into green and dead grass and weeds and legumes before drying and weighing.

The percentage basal cover of the native perennial grasses and of bare ground in each sub-plot was estimated in May and November of each year using a single wheel-point apparatus (von Broemsben 1966). Each of the sub-plots was stratified into four equal areas (each 22.5 m^2) and within each strata 75 wheel-point estimates were collected using the method of Lodge and Gleeson (1979).

Herbage mass, plant density and percent basal cover data were examined by analysis of variance. Examination of the residuals showed that no transformations of the data were necessary. Because of limitations on space and resources no treatment controls (untreated sub-plots and ungrazed main plots) were included in the design. However, the autumn 1980 treatment plots in each of the different stocking rate treatments, can be regarded as "control" plots during the first grazing period because the slashing, burning and herbicide treatments were not applied until May 1980.

To simplify presentation, data for the grazing treatments were averaged over all the sub-plot treatments. The grazing x treatment x time of application interaction was often significant ($P < 0.05$) but these differences only occurred as a result of significant differences in the LSR sheep treatments. In the HSR sheep and cattle plots there were no significant differences between the sub-plot treatments for the parameters measured. Hence data for the effects of slashing, burning and herbicide treatments and their time of application have only been examined for the LSR sheep grazing plots.

In the latter stages of the experiment *A. ramosa* herbage mass and density values and other dead and green grass components were often zero in the HSR sheep treatments. When this occurred only data from the HSR cattle and LSR sheep treatments were examined.

B. Results

The interaction between grazing and spring applied treatments (Table 12.1) indicated that treatments applied in spring followed by heavy summer grazing with sheep and cattle reduced the *A. ramosa* herbage mass to about the same level as that obtained by heavy summer grazing alone. After the spring treatment a high stocking rate of sheep and cattle reduced *A. ramosa* herbage mass by 98% and 89% respectively, whereas stocking reduced it by 99% and 92% respectively. In the LSR sheep plots, however, summer grazing following spring treatment reduced the *Aristida* herbage mass by 74% (Table 12.1) and summer grazing alone reduced *A. ramosa* herbage mass by only 17%. Hence in the high stocking rate treatments grazing had a major effect on *A. ramosa*, whereas in the low stocking rate treatments the slashing, burning and herbicide treatments had a greater initial effect.

Initially *A. ramosa* herbage masses ranged from around 1700 kg ha^{-1} (LSR sheep) to 2000 kg ha^{-1} (HSR sheep and cattle) but were not significantly different between treatments. Grazing for a 19 week period in summer 1979-80

Table 12.1 The herbage mass (kg ha^{-1}) of *A. ramosa* in the spring and autumn treatment plots. Data were collected before the treatments were applied in spring and autumn, and before and after the first grazing period.

		Plots in which treatments were applied in spring			Plots in which treatments were applied in autumn		
		Slash	Herbicide	Burn	Slash	Herbicide	Burn
				kg ha^{-1}			
HSR sheep	Nov. 1979	2029	1572	1859	1850	2081	2563
	April 1980	84	10	47	15	23	16
HSR cattle	Nov. 1979	1489	1903	2537	1490	2005	2697
	April 1980	123	237	278	164	238	82
LSR sheep	Nov. 1979	1645	2096	1380	1551	2392	1156
	April 1980	327	826	200	1514	1652	1005

(Fig. 12.1b) reduced A. ramosa herbage mass from 1700 to around 900 kg ha^{-1} in the LSR sheep plots, and from 2000 kg ha^{-1} to about 200 kg ha^{-1} in the HSR cattle plots and to 20 kg ha^{-1} in the HSR sheep plots. The herbage mass of Aristida in the HSR cattle treatments remained below 200 kg ha^{-1} for the next two years, until March 1982, when with above average rainfall (Fig. 12.1a) it rapidly increased to 550 kg ha^{-1}. After the first grazing period the A. ramosa herbage mass in the HSR sheep plots further decreased to less than 10 kg ha^{-1} and generally remained below this level until the end of the experiment. At most harvests after grazing commenced substantial significant differences ($P < 0.05$) occurred in A. ramosa herbage mass in the different grazing treatments, with the rankings being LSR sheep > HSR cattle > HSR sheep (Fig. 12.1). Even in the LSR sheep plots Aristida herbage mass declined to less than 1000 kg ha^{-1} for most of the experiment (Fig. 12.1b) reflecting the below average rainfall in 1980-82 and the dry summers in these years (Fig. 12.1a).

At the start of the experiment A. ramosa plant density was about 30 plants m^{-2} and remained at this level during the first grazing period (Fig. 12.1c). A. ramosa plant densities in the different grazing treatments started to differ significantly ($P < 0.05$) in autumn 1980, after which time they were significantly different ($P < 0.05$) on most occasions. In the HSR sheep plots the plant densities of A. ramosa had declined to less than 5 plants m^{-2} by autumn 1981 and were reduced to zero or near zero after winter 1982. In the HSR cattle plots A. ramosa plant densities initially increased to around 50 plants m^{-2} in winter 1980, but over the remainder of the experimental period they declined to less than 20 plants m^{-2}. Aristida plant densities in the LSR sheep treatment, however, were relatively stable declining from around 30 plants m^{-2} at the start, to 25 plants m^{-2} at the end of the experiment.

Grazing substantially reduced the mean plant mass, basal area, mass per unit basal area and density of the A. ramosa plants in the HSR sheep treatments (Table 12.2). However, with data available for only one plant in the HSR sheep plot at the end of the experiment it was not possible to use the procedures of Henderson and Hayman (1960) to assess the relative importance of the herbage mass components in this treatment in November 1982. For all treatments at the start of the experiment and for the HSR cattle and LSR sheep treatments at the end of the experiment the components that contributed significantly ($P < 0.05$) to the herbage mass were plant basal area

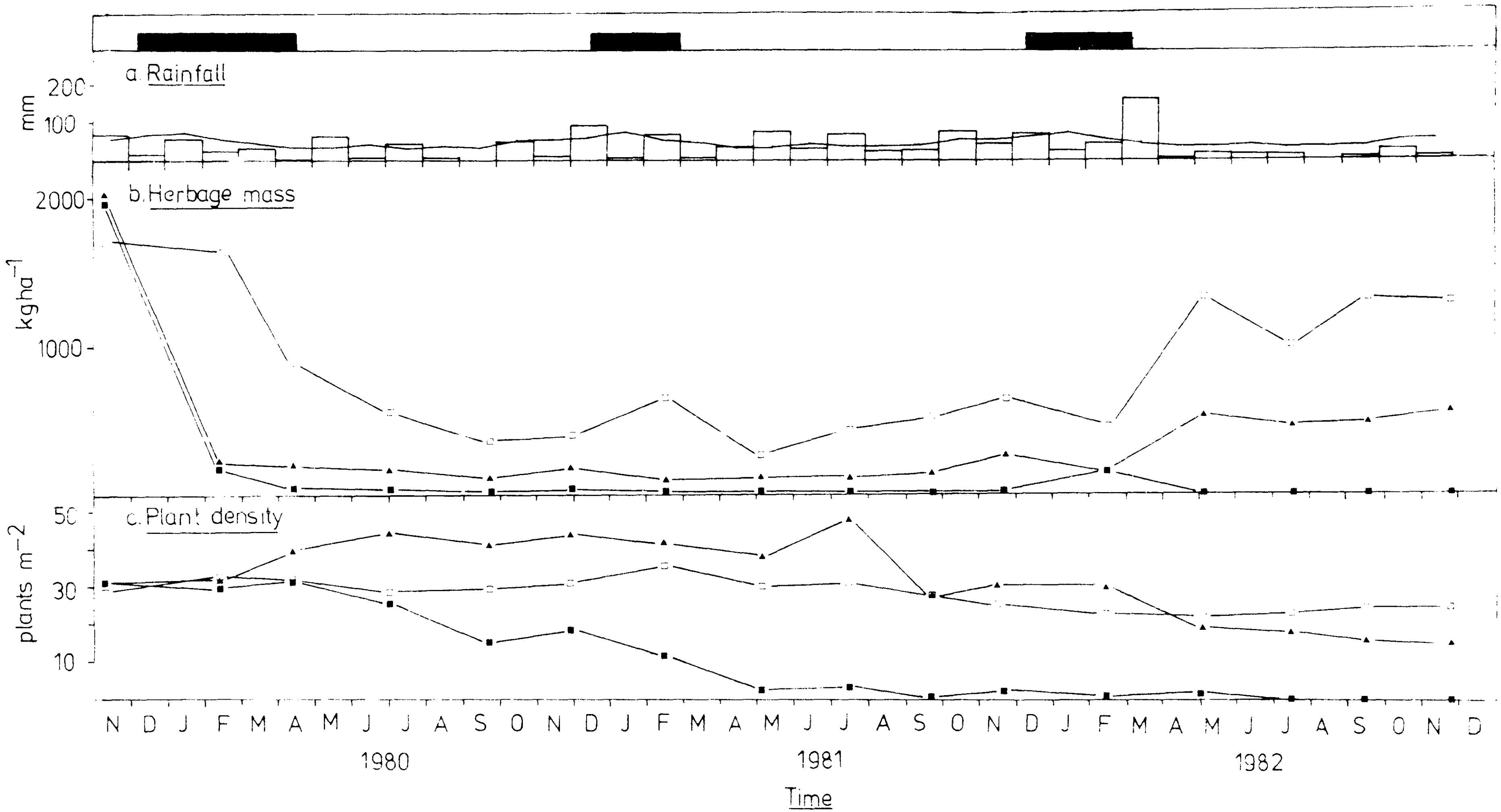


Figure 12.1 (a) The monthly rainfall (mm) at Study area 3 together with the long term average at Manilla (-), and (b) the herbage mass (kgha^{-1}), and (c) density (plants m^{-2}) of *A. ramosa* in the LSR sheep (□), HSR cattle (▲) and HSR sheep (■) treatments. Grazing periods are indicated by ■.

Table 12.2 The mean plant mass (g $plant^{-1}$), mean basal area (cm^2 $plant^{-1}$), mean mass per unit basal area (g cm^{-2}), and mean density (plants m^{-2}) of *A. ramosa*, in the HSR sheep and cattle and the LSR sheep plots, at the start (November 1979) and end (November 1982) of Experiment 9

	Mean plant mass (g $plant^{-1}$)		Mean basal area (cm^2 $plant^{-1}$)		Mean mass/unit basal area (g cm^{-2})		Mean density (plants m^{-2})	
	Nov. 1979	Nov. 1982	Nov. 1979	Nov. 1982	Nov. 1979	Nov. 1982	Nov. 1979	Nov. 1982
HSR sheep	5.36	0.24+	5.27	1.51	1.00	0.17	30.75	0.12
HSR cattle	5.27	15.38	4.56	12.62	1.03	1.18	31.00	12.38
LSR sheep	4.92	34.34	4.72	23.61	1.03	1.39	28.60	19.55

+Data for the HSR sheep plots in November 1982 are based on only one observation.

and plant density. Although A. ramosa plant density decreased in all three grazing treatments, both mean plant mass and mean basal area per plant increased substantially in the HSR cattle and the LSR sheep treatments (Table 12.2).

For the species other than A. ramosa in these pastures most of the herbage mass was dead material (Fig. 12.2). Initially dead herbage mass ranged from about 900 to 1350 kg ha^{-1}, but after spring 1980 it was always less than 500 kg ha^{-1}. Dead herbage mass was generally higher ($P < 0.05$) in the LSR sheep plots than the other two treatments, although grazing in each year substantially reduced the amount of dead herbage in all of the treatments. The amount of other green herbage in all grazing treatments was around 250 kg ha^{-1} at the start of the experiment. This declined to less than 150 kg ha^{-1} in all treatments (Fig. 12.2) and was never significantly different between the grazing treatments. Warm season native perennial grasses contributed most of the other green grass herbage, with few cool season annuals, such as V. myuros and H. leporinum, appearing in spring 1981 and winter 1982. Until spring 1982 other weed and legume species contributed little to the pasture herbage mass and there were no significant differences between grazing treatments. The major forb species present in these pastures were the yearlong green perennials Dichondra repens, Boehavia diffusa and Oxalis corniculata. In spring 1982 the herbage mass of the forbs was about 400 kg ha^{-1} and the main species were the cool season annuals Medicago minima, Trifolium campestre, Trifolium arvense and Erodium cicutarium. In autumn and winter 1982 the HSR sheep plots were infested with Argemone ochroleuca (Mexican poppy) which significantly increased ($P < 0.05$) the herbage mass of the forbs in this treatment.

After the first grazing period in summer 1979-80, the percentage of bare ground was always significantly higher ($P < 0.05$) in the HSR sheep treatments than in the HSR cattle and LSR sheep treatments (Fig. 12.3a). Grazing in the first year reduced the percent basal cover of A. ramosa from an initial mean level of around 12% to 4% in the LSR sheep and HSR cattle treatments (Fig. 12.3b), and to less than 1% in the HSR sheep plots. The percentage basal cover of B. macra (Fig. 12.3c) was reduced from a mean level of 2% at the start of the experiment to less than 1% at the end of the experiment for all treatments.

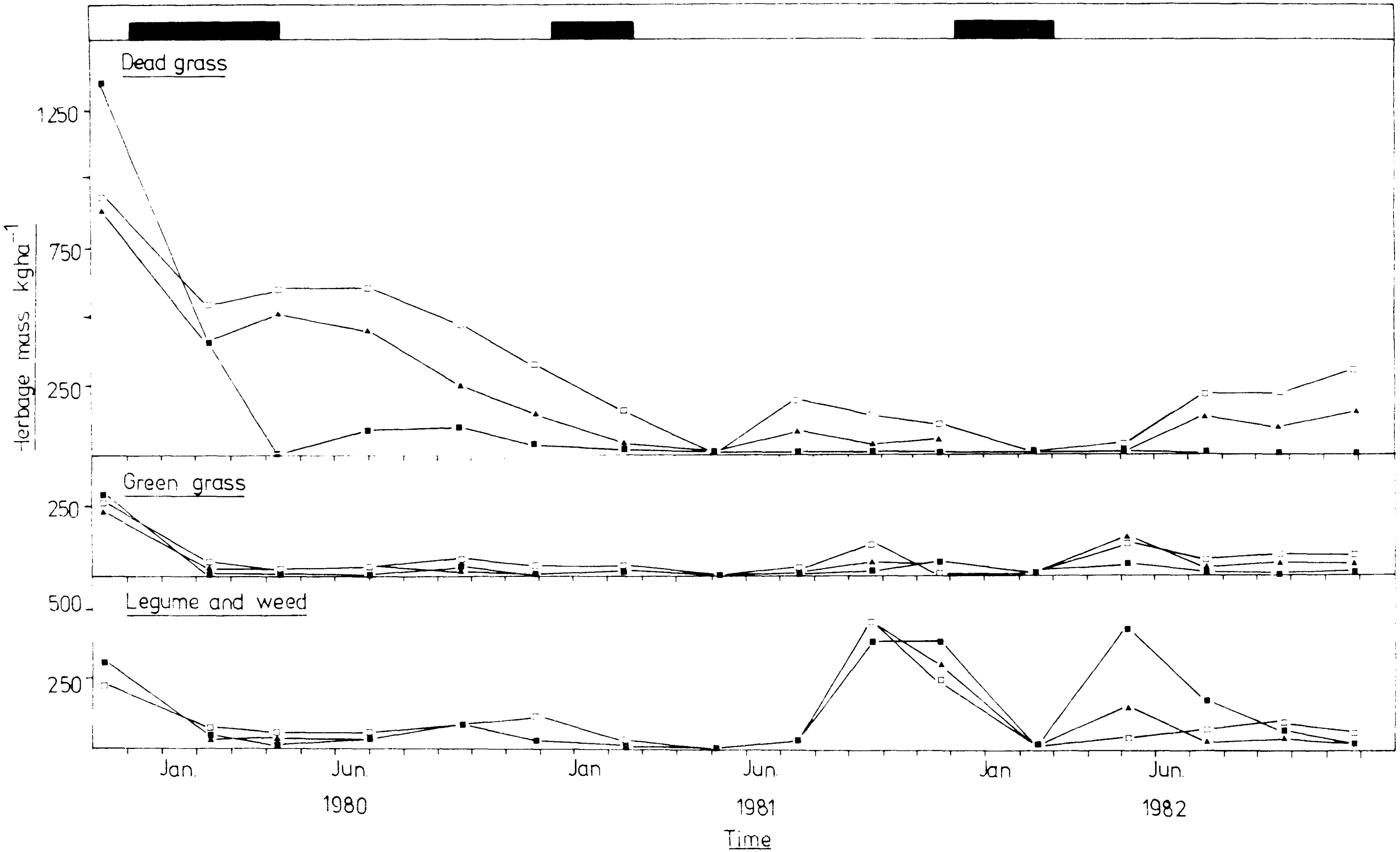


Figure 12.2 The herbage mass (kgha^{-1}) of dead and green grass other than A. ramosa, and legumes and weeds in the LSR sheep (□), HSR cattle (▲) and HSR sheep (■) treatments. Grazing periods are indicated by a ■ .

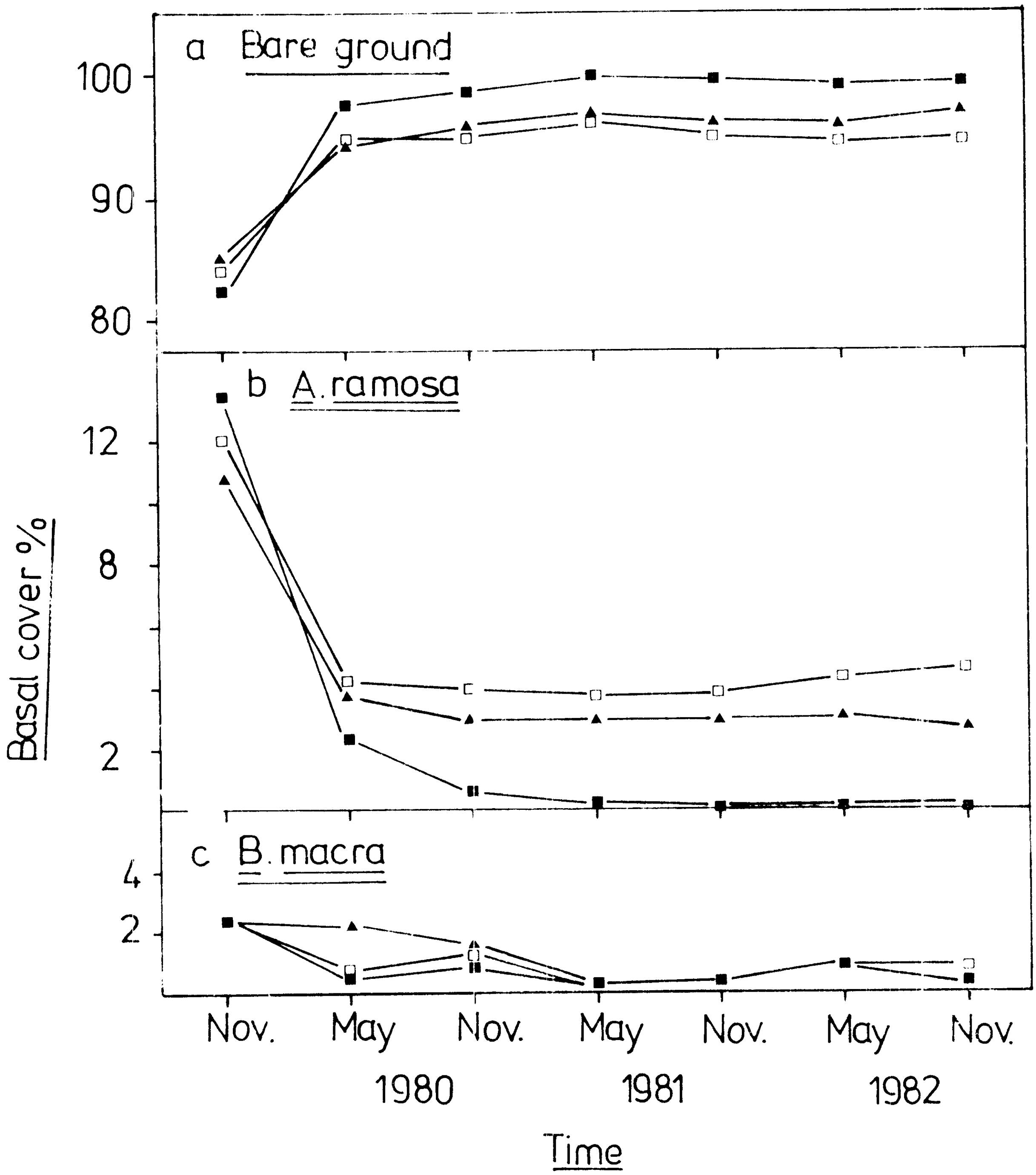


Figure 12.3 The percentage basal cover of (a) bare ground, (b) *A. ramosa*, and (c) *B. macra* in the LSR sheep (□), HSR cattle (▲), and HSR sheep (□) grazing treatments.

All three treatments applied in both spring and autumn reduced the herbage mass of A. ramosa by at least 50% initially (Fig. 12.4). However, it should be remembered that at a low stocking rate, grazing *per se* in the first year had little effect on the herbage mass of A. ramosa (Table 12.1), but had a much larger effect in the HSR sheep and cattle treatments. By May 1982 the plots that were either slashed or had received herbicide application in spring 1979 had significantly less ($P < 0.05$) A. ramosa herbage mass than those that were treated in autumn 1980. However, by the end of the experiment in November 1982 there were no significant differences between the time of application for each of the treatments.

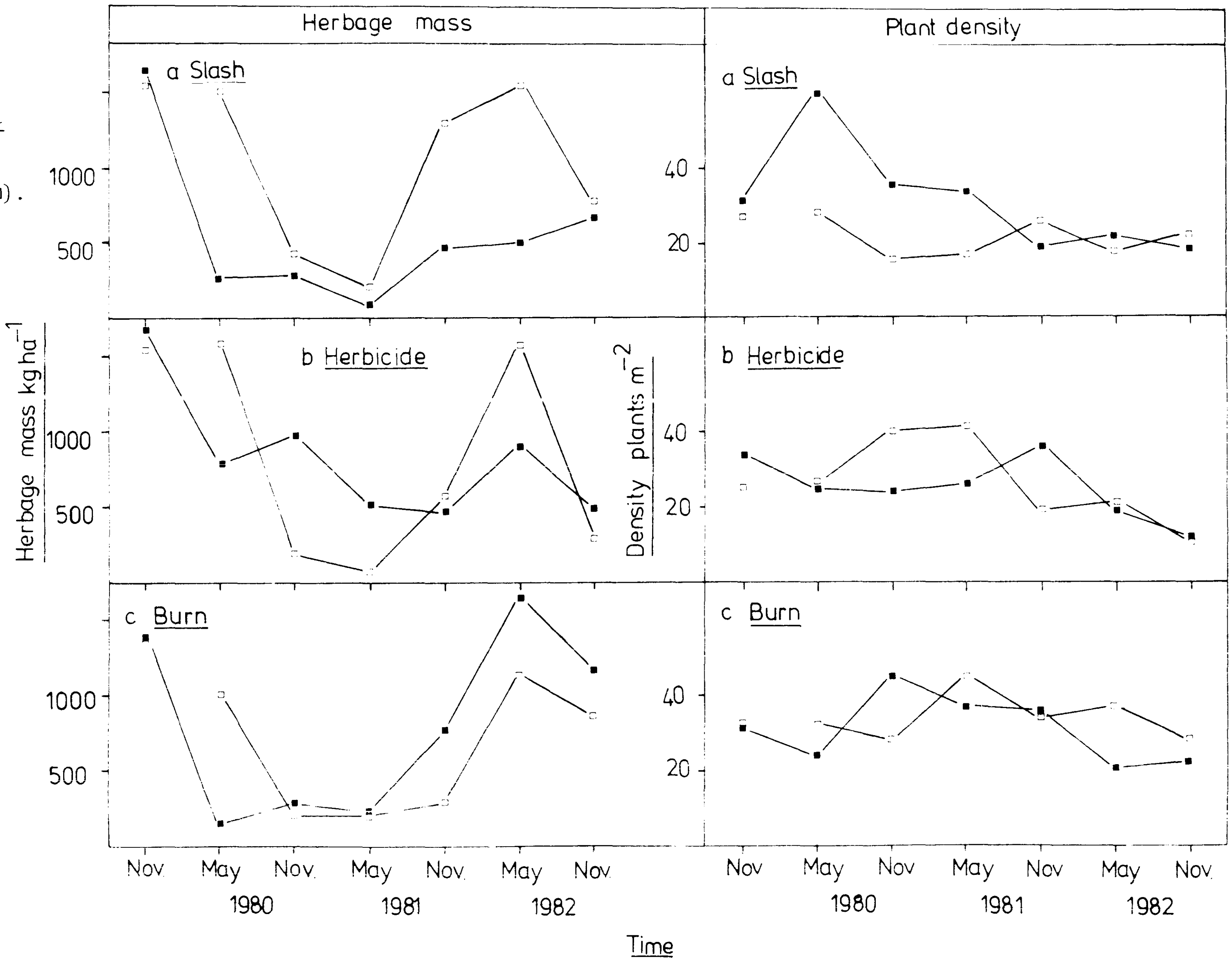
For all of the treatments there were no consistent effects of time of application on the plant density of A. ramosa (Fig. 12.4). Slashing reduced A. ramosa plant density from a mean of around 30 plants m^{-2} at the start of the experiment to 20 plants m^{-2} at the end (Fig. 12.4a); herbicide application from 30 to 11 plants m^{-2} (Fig. 12.4b), and, burning from 32 to 26 plants m^{-2} (Fig. 12.4c).

Six months after treatment application in either spring or autumn the percent basal cover of A. ramosa decreased from a mean of 12% to 4% in both the plots that were slashed (Fig. 12.5a) and those that had herbicide applied (Fig. 12.5b). Initially, burning decreased the basal cover of A. ramosa from a mean of around 13% to 3% (Fig. 12.5c), but over the remainder of the experimental period A. ramosa basal cover in the burnt plots increased to about 5%. For all treatments no significant differences were apparent between times of application.

Although this experiment was not designed specifically to collect information on livestock production, bodyweights were monitored. Sheep in the high stocking rate plots lost 15-20% of their bodyweight during each of the three grazings, while the cattle in these treatments lost 12-18% of their bodyweight. The sheep in the low stocking rate treatments lost 12-15% of their bodyweight and were observed to have higher levels of grass seed contamination in their wool, than those in the high stocking rate treatments.

Figure 12.4

The herbage mass ($kgha^{-1}$) and density (plants m^{-2}) of A. ramosa in slash, burn and herbicide treatments applied in either spring 1979 (■) or autumn 1980 (□). Data are from the LSR sheep grazing treatments.



C. Discussion

The herbage mass, density and percent basal cover of A. ramosa was substantially reduced by heavy grazing with sheep in summer and early autumn and resting of pasture from grazing from mid-autumn to early summer. Cattle were not as effective as sheep in the long-term control of Aristida with contrasts with the data of Hall and Lee (1980) who suggested that in a more arid environment heavy cattle grazing could be used to prevent a build up of Aristida spp. The possibility of grazing with both sheep and cattle either together or sequentially was not investigated but may be an alternative management option.

These changes in pasture structure and composition were achieved over a three year interval during which drought and below average summer rainfall occurred and this undoubtably interacted with the heavy grazing pressure. With higher summer rainfall and regrowth of A. ramosa two or three years of defoliation may have been required to achieve the same result. However, these data are some of the first reported for the higher rainfall rangelands of Australia to positively demonstrate that the abundance of an individual species can be controlled by grazing management. Heavy grazing of these pastures, increased the percentage of bare ground, although they remained dominated by the warm season native perennial grass B. macra, which persists under heavy grazing (Robinson and Dowling 1976; Whalley et al. 1978). Observations of the plots following good autumn rainfall and mild conditions in 1983 indicated that there had been little regeneration of A. ramosa, but considerable growth of B. macra in the high stocking rate plots. Cattle grazing A. ramosa resulted in a fragmentation of the original large tussocks into a number of smaller plants, similar to the effect observed by Hall and Lee (1980) for cattle grazing Astrebla.

Harradine (1976) reported that heavy grazing usually increased the abundance of Aristida and that its eradication under grazing would be difficult because of its low palatability and selective avoidance by livestock. However, A. ramosa is susceptible to defoliation (Harradine 1976) and if stocking rates are high enough to prevent stock from grazing selectively than both sheep (Moodie 1934a; Brownlee 1973; Lodge and Roberts 1979) and cattle (Hall and Lee 1980) can reduce its abundance. Compared with continuous grazing at a high stocking rate the matching of the season and intensity of grazing to the reproductive biology of A. ramosa in a rest-rotation grazing

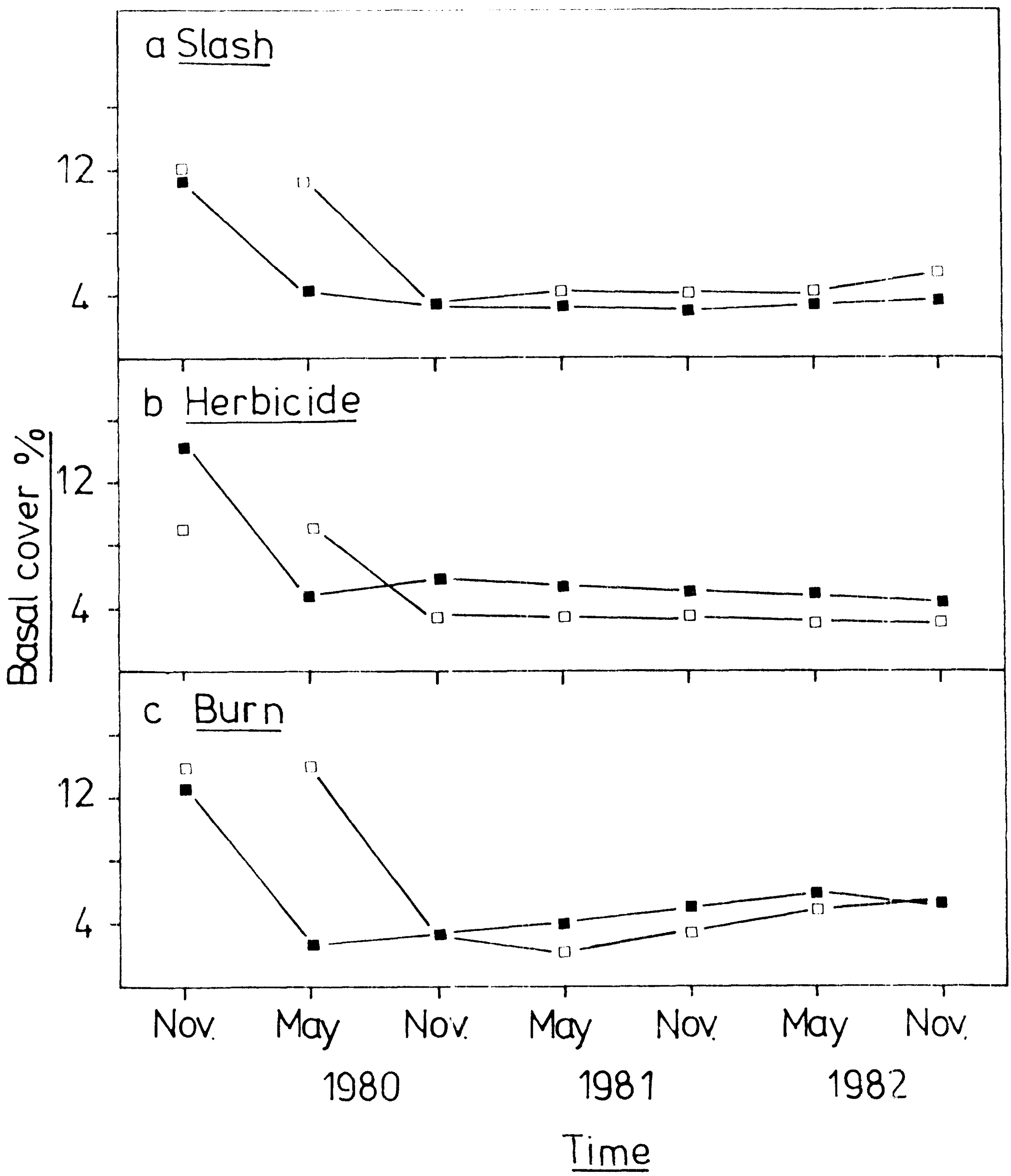


Figure 12.5 The percentage basal cover of *A. ramosa* in the (a) slash, (b) herbicide, and (c) burn treatments applied in either spring 1979 (■) or autumn 1980 (□).

management system would more rapidly decrease the abundance of A. ramosa and so have less harmful effects on the abundance of other species in the pasture and on the livestock.

Although Harradine and Whalley (1980) suggested that management aimed at preventing the seeding of adult A. ramosa plants was unlikely to succeed, because of its high potential for seed production, the outcome of any such management will depend on the interaction of stocking rate and weather. With dry summers and low seed production, as in the present experiment, seeding of adult plants was controlled by heavy grazing by sheep and cattle. However, in wetter years the seed production of A. ramosa is likely to be higher and may have to be controlled by other means.

With such a large effect of grazing in the high stocking rate plots the conclusions that can be made about the effectiveness of the slashing, burning and herbicide treatments are limited. In the low stocking rate treatments, burning tended to have the least effect on A. ramosa herbage mass and plant density and herbicide the most, over the period of the experiments. However, the widespread application of herbicide or the slashing of large areas may be both uneconomical and impractical and would appear to be of little benefit unless the treated areas were heavily stocked to further control A. ramosa. For the three treatments studied there was little apparent difference in the time of application. However, treatments such as spring burning would be harmful to any yearlong green species in the pasture that were actively growing at the time of the burn (Curtis and Partch 1948) and so should be discouraged. Late summer or early autumn treatment would appear to be more preferable as it may reduce the seed production of the adult plants and reduce the establishment of newly emerged seedlings. Treatment application at this time may also enhance the successful establishment of either yearlong green seedlings such as D. linkii or introduced legumes sown into the pasture in late autumn and early winter.

Experiment 10. The effects of grazing with sheep and cattle on the herbage mass and abundance of A. ramosa

This study was similar to Experiment 9 except that no sub-plot treatments were applied and the plots were grazed at a lower rate of stocking for six instead of four months of the year.

A. Materials and Methods

The experimental site (Study area 4) was a 2.43 ha area of unfertilized natural pasture located approximately 1 km from Study area 3 (Fig. 3.1). Species composition, soil type and previous stocking history were similar to those described for Study area 3.

The experiment consisted of three replicates of three grazing treatments in nine plots. Plot size varied from 0.202 ha for sheep to 0.404 ha for cattle. Plots were stocked for six months of the year, from the start of November until the end of May and grazing commenced in November 1979. Within each replicate the grazing treatments consisted of; (1) grazing with sheep at a rate equivalent to 29.4 DSE's ha^{-1} $year^{-1}$, high stocking rate sheep (HSR sheep); (2) grazing with cattle at a rate equivalent to 29.4 ha^{-1} $year^{-1}$, high stocking rate cattle (HSR cattle), and, (3) grazing with sheep at 4.9 DSE's ha^{-1} $year^{-1}$, low stocking rate sheep (LSR sheep). These stocking rates were achieved by grazing either 12 dry Merino ewes or two Angus steers per plot at the high stocking rate and two dry Merino ewes per plot at the low stocking rate for six months of the year. The plots were not stocked for the other six months. Over the experimental period three cycles of grazing were conducted commencing in December 1979, 1980 and 1981. In the first year plots were stocked for six months of the year although a maintenance ration as described in Experiment 9 had to be fed. In 1980-81 and 1981-82 plots were grazed for only eight weeks.

Each plot was divided into strata of equal area (506 m^2) (Lodge and Gleeson 1979) to give four strata in the plots grazed by sheep and eight strata in the cattle plots. Herbage mass was estimated every eight weeks from November 15, 1979 by harvesting to ground level two 0.16 m^2 quadrats from each strata using the rank set method of MacIntyre (1952). Within each quadrat all <u>A. ramosa</u> plants were counted and harvested separately, dried for 48 hours at 80^oC and weighed. Data collection for other herbage in the sampled quadrats and the measurement of plant basal area were as described in Experiment 9. The percentage basal cover of the native perennial grasses and of bare ground was estimated in May and November of each year using a single wheel-point apparatus. Within each of the plots 250 points were collected in each strata.

Herbage mass, plant density and percent basal cover data were examined by analysis of variance. Examination of the residuals showed that no transformation of the data was necessary. When data for the HSR sheep treatments was zero these plots were excluded from the analyses.

B. Results

At the start of the experiment, A. ramosa herbage mass was not significantly different between treatments and averaged about 900 kg ha^{-1} (Fig. 12.6b). Grazing with either sheep or cattle at the high stocking rate for a 24 week period in summer 1979-80 and autumn 1980 reduced the herbage mass of A. ramosa to less than 100 kg ha^{-1} in these treatments by June 1980. In comparison the Aristida herbage mass in the LSR sheep plots was around 1000 kg ha^{-1}, and significantly higher ($P < 0.05$) than that of the higher stocking rate treatments. After June 1980 the herbage mass of A. ramosa in the HSR sheep plots generally remained below 20 kg ha^{-1} for most of the experiment (Fig. 12.6b) and in the HSR cattle plots it did not exceed 100 kg ha^{-1} until after November 1981. However, by the end of the experiment in November 1982 the herbage mass in the HSR cattle plots had increased to about 500 kg ha^{-1}. Despite below average rainfall (Fig. 12.6a) the herbage mass of Aristida in the LSR treatments remained above the initial level until the start of the second grazing period. It then gradually declined to around 50 kg ha^{-1} in November 1981, but increased again to be about 450 kg ha^{-1} by the end of the experiment. The herbage mass of Aristida in the HSR sheep treatments was significantly ($P < 0.05$) lower than that in the LSR sheep plots for all harvests except November 1979, 1981 and February 198_, and was significantly lower ($P < 0.05$) than that in the HSR cattle plots from February 1982 until the end of the experiment.

In November 1979 the plant density of A. ramosa averaged over all treatments was 20 plants m^{-2} (Fig. 12.6c) and not significantly different between treatments. After this time the plant densities of Aristida in the LSR sheep and HSR cattle treatments were always significantly higher ($P < 0.05$) than those in the HSR sheep treatments. A. ramosa plant densities in the LSR sheep and HSR cattle plots gradually declined throughout the experimental period (Fig. 12.6c) to be around 6 plants m^{-2} at the end of the experiment. In the HSR sheep plots A. ramosa plant density declined most rapidly within the first year of grazing to around 5 plants m^{-2}, gradually decreasing to near

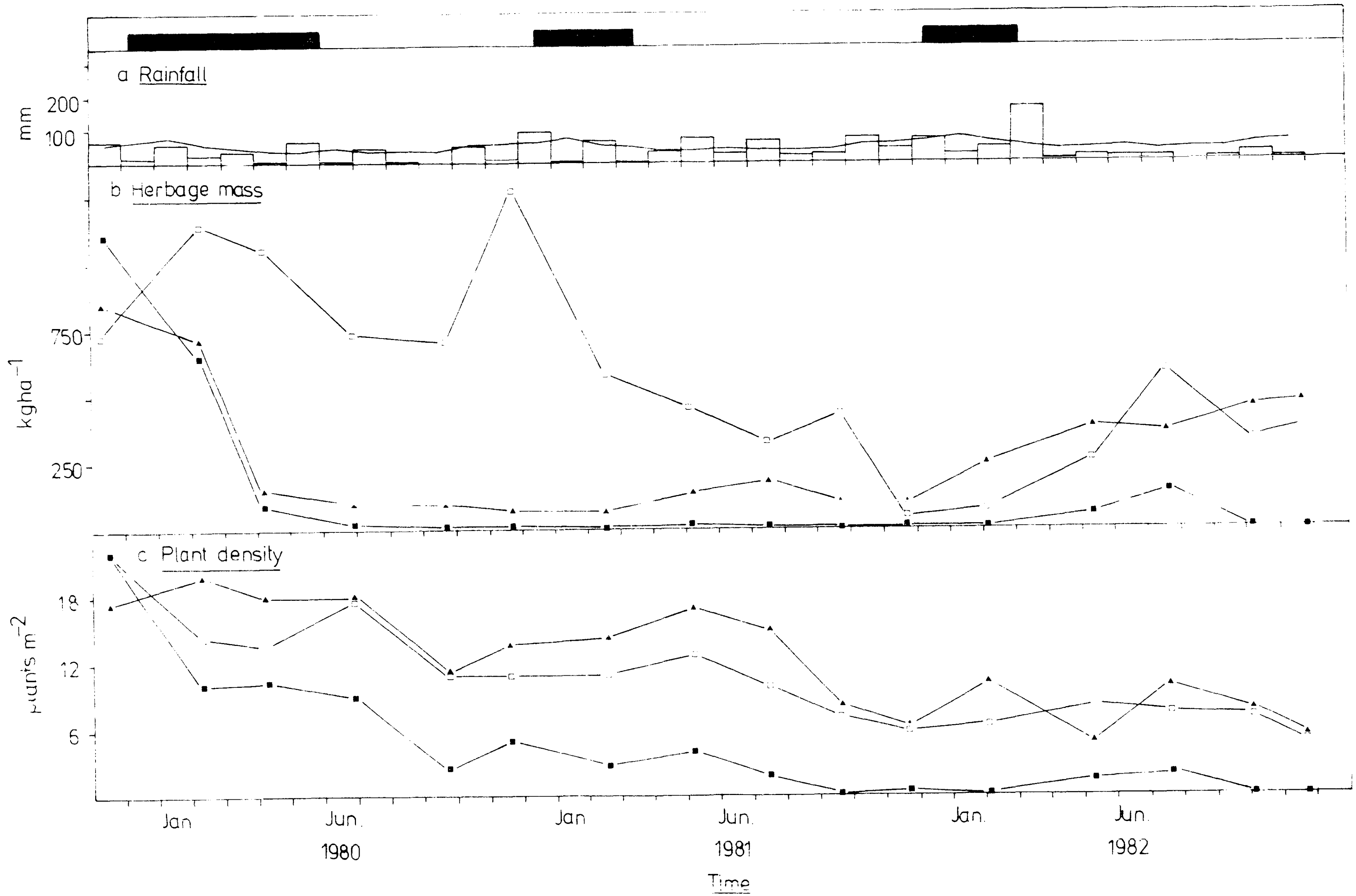


Figure 12.6 (a) The monthly rainfall (mm) at Study area 4 together with the long term average at Manilla (-), and (b) the herbage mass ($kgha^{-1}$), and (c) density (plants m^{-2}) of A. ramosa in the LSR sheep (□), HSR cattle (▲) and HSR sheep (■) treatments. Grazing periods are indicated by ■■ .

zero by the end of the experiment.

Grazing at a high stocking rate with sheep substantially reduced the plant mass, basal area, mass per unit basal area and density of A. ramosa plants (Table 12.3). With a limited number of observations in November 1982 data for this sampling time could not be analysed to assess the relative importance of these components. However, for the other sampling times and grazing treatments the analysis of Henderson and Hayman (1960), again indicated that plant density and basal area were significant ($P < 0.05$) components of the herbage mass of A. ramosa. Despite the decline in A. ramosa plant density in the LSR sheep and HSR cattle treatments the individual plants that remained in these treatments at the end of the experiment had higher masses than those at the start (Table 12.3), mainly because of a large increase in their basal area.

Most of the herbage other than A. ramosa in the grazing treatments of this experiment was dead grass (Fig. 12.7), although legume and weed species were of some importance in spring 1981 and 1982. From the end of the first grazing period until November 1980 the LSR sheep and HSR cattle treatments had significantly more dead grass ($P < 0.05$) than the HSR sheep treatments. After November 1980 there were no significant differences between treatments. Initially the herbage mass of the other green grass component, predominantly the warm season perennials was around 400 kg ha^{-1} in all treatments. With grazing this rapidly declined to less than 50 kg ha^{-1} (Fig. 12.7) and was only significantly different ($P < 0.05$) between treatments in September 1981 when Vulpia myuros, D. linkii, S. scabra, Dichelachne micrantha and Enneapogon nigricans occurred in the HSR sheep plots. At the start of the experiment the mean herbage mass of legumes and weeds was about 80 kg ha^{-1} in the three grazing treatments. Legume and weed herbage masses were not significantly different between the three treatments and remained at or below this level except for late winter and spring 1981 and 1982. At these times legume and weed herbage mass, mainly from Trifolium arvense, Medicago minima, Boehavia diffusa and Carthamus lanatus (saffron thistle), differed significantly ($P < 0.05$) between the three grazing treatments. The only other forbs that were common in these plots were Vittidinia caneata and Wahlenbergia communis.

After the first grazing period the basal cover percentage of bare ground substantially increased (Fig. 12.8a) from a mean of 88.2% to 97.2% and

Table 12.3 The mean plant mass (g $plant^{-1}$), mean basal area (cm^2 $plant^{-1}$), mean mass per unit basal area (g cm^{-2}), and mean density (plants m^{-2}) of A. ramosa and D. linkii in the HSR sheep and cattle and the LSR sheep plots, at the start (November 1979) and end (November 1982) of Experiment 10

	Mean plant mass (g $plant^{-1}$)		Mean basal area (cm^2 $plant^{-1}$)		Mean mass/unit basal area (g cm^{-2})		Mean density (plants m^{-2})	
	Nov. 1979	Nov. 1982	Nov. 1979	Nov. 1982	Nov. 1979	Nov. 1982	Nov. 1979	Nov. 1982
A. ramosa								
HSR sheep	5.43	0.55+	3.86	1.02	1.38	0.11	21.90	0.35
HSR cattle	5.29	34.57	3.58	18.19	1.50	1.42	17.34	5.61
LSR sheep	4.58	44.53	3.25	28.97	1.06	1.52	21.89	5.23
D. linkii								
HSR sheep	0	1.44	0	9.93	0	0.15	0	6.25
HSR cattle	0	0	0	0	0	0	0	0
LSR sheep	0	0	0	0	0	0	0	0

+Data for A. ramosa in November 1982 for the HSR sheep plots are based on only one observation.

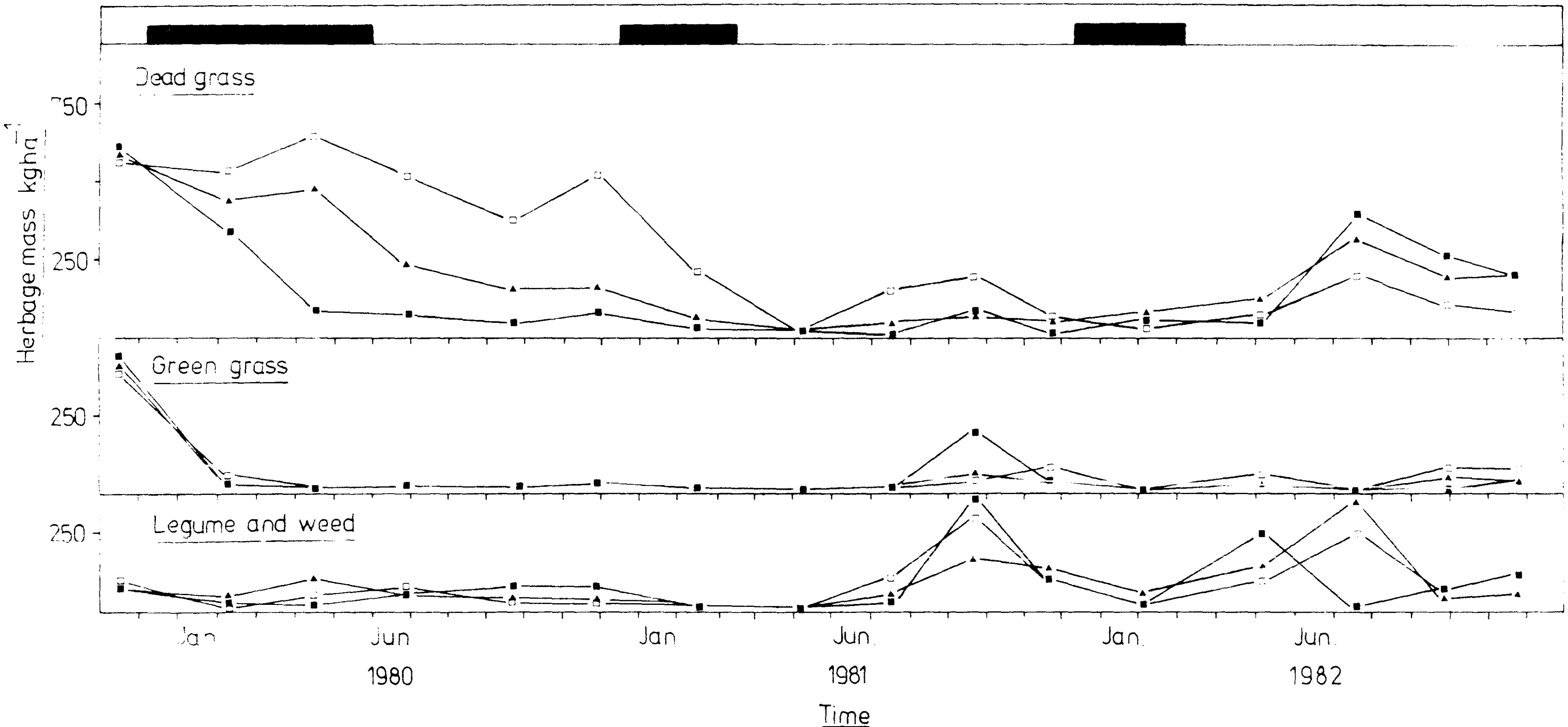


Figure 12.7 The herbage mass (kgha^{-1}) of dead and green grass other than A. ramosa and legumes and weeds in the LSR sheep (□), HSR cattle (▲), and HSR sheep (■) treatments. Grazing periods are indicated by ■■ .

the mean percent basal cover of A. ramosa and B. macra decreased by about 3% (Fig. 12.8b and 12.8c). In all of the treatments the percent basal cover of B. macra was not significantly different on any occasion. However, the percent basal cover of A. ramosa in the LSR sheep treatments was generally significantly higher ($P < 0.05$) than that in the HSR sheep treatments.

In November 1979 the percentage basal cover of the warm season perennials was on average 11 times higher than that of the yearlong green perennials (Table 12.4) with the only common yearlong green species being S. scabra. However, by the end of the experiment summer and autumn grazing over the three years had considerably altered the total basal cover of the different species in the pasture. In the HSR sheep treatments the yearlong green species were 13 times more abundant than the warm season perennials, but in the LSR sheep treatments the total percent basal cover of the warm season species was 27 times that of the yearlong green species. In the HSR cattle plots, however, these two species groups occured in approximately equal proportions. Although D. linkii was observed in the HSR sheep and cattle plots from May 1981 (Table 12.4) its basal cover was not recorded until November 1981 (Fig. 12.8). At the end of the experiment the percentage basal cover of D. linkii was 2.7% in the HSR sheep treatments and 0.3% in the HSR cattle treatments, but it was not recorded in the LSR sheep plots.

The sheep in the high stocking rate plots lost 8-10% of their bodyweight in each grazing period, while in the low stocking rate treatments bodyweights declined by 16-22%. Cattle bodyweights declined by about 10% at each grazing. Again, less grass seed contamination was observed in the wool of the HSR sheep, particularly in the second and third grazing periods.

C. Discussion

Heavy grazing for six months of the year in summer and autumn reduced the herbage mass and percentage basal cover of A. ramosa. This confirms the results of Experiment 9 in which plots were grazed for a shorter period (4 months of the year) at a higher stocking rate. Again sheep were more effective than cattle in controlling A. ramosa.

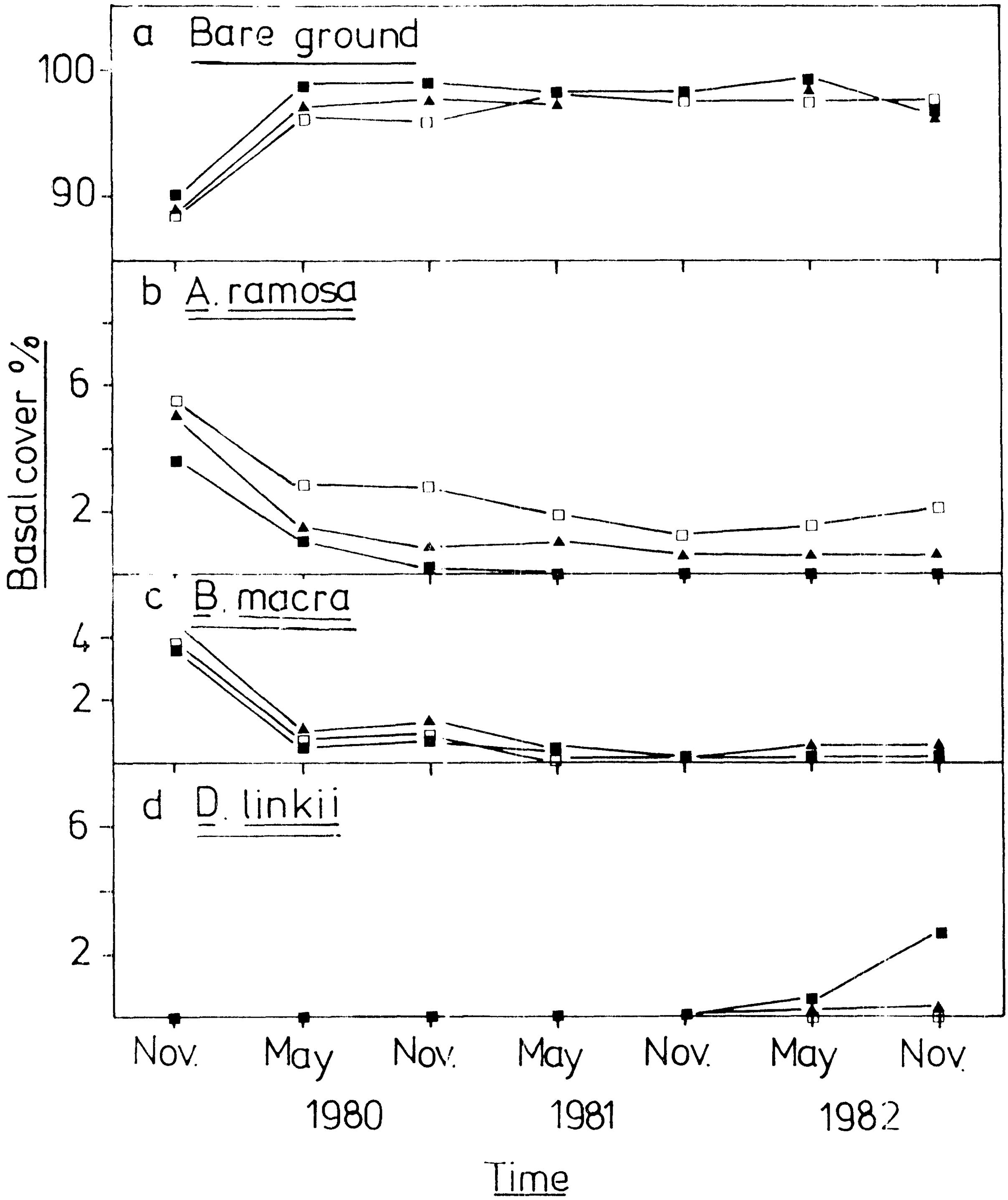


Figure 12.8 The percentage basal cover of (a) bare ground, (b) *A. ramosa*, (c) *B. macra*, and (d) *D. linkii* in the LSR sheep (□), HSR cattle (▲) and HSR sheep (■) grazing treatments of Experiment 13.

Table 12.4 The percentage basal cover of the warm season perennial and yearlong green native perennial grasses in the HSR sheep, HSR cattle and LSR sheep grazing treatments, for November 1979, May 1981 and November 1982

	Nov. 1979			May 1981			Nov. 1982		
	HSR sheep	HSR cattle	LSR sheep	HSR sheep	HSR cattle	LSR sheep	HSR sheep	HSR cattle	LSR sheep
Warm season perennials									
A. ramosa	3.6	4.5	5.5	<0.1+	1.0	1.9	<0.1	0.8	2.1
B. macra	3.6	4.2	3.8	0.3	0.4	0	0.2	0.6	0.3
S. elongatus	0.9	0.7	1.0	0	<0.1	0	0	0	0
D. sericeum	1.6	1.5	1.5	0	0.3	0	0	0	0
C. truncata	0.7	0.8	0.7	0	<0.1	0	0	0	0
Total	10.4	11.7	12.5	<0.4	<1.8	1.9	<0.3	1.4	2.7
Yearlong green perennials									
D. linkii	0	0	0	0.1	0.3	0	2.7	0.3	0
S. scabra	0.9	1.4	0.8	<0.1	0.2	<0.1	0.9	1.4	0.1
D. micrantha	<0.1	<0.1	<0.1	0.1	0.1	0	0.1	0.1	0
E. nigricans	<0.1	<0.1	<0.1	0.1	0.1	0	0.2	0.1	0
Total	<1.0	<1.5	<0.9	<0.4	0.7	<0.1	3.9	1.9	0.1

+Percent basal cover less than 0.1.

In this experiment grazing at a high rate, particularly with sheep substantially increased the proportion of the yearlong green native perennial grasses (particularly D. linkii) in the pasture; few yearlong green perennials and no D. linkii were apparent at the start of the experiment. This result contrasts with the grazing treatments in Experiment 9 where rest-rotational grazing with sheep eliminated A. ramosa and the pasture became dominated by the warm season native perennial B. macra. This difference in the effect of grazing on the species composition was probably related to the higher initial herbage mass and abundance of A. ramosa in Experiment 9. Despite drought conditions the abundance of the yearlong green perennials including D. linkii increased in the high stocking rate treatments. Such conditions were generally unfavourable for seed production and seedling establishment in these species and in more favourable seasons the yearlong green perennials may establish better. Hence, the grazing system outlined in Chapter 11 can be used to reduce the abundance of A. ramosa in a natural pasture while at the same time increasing the abundance of D. linkii.