Section 3 PRELIMINARY EVALUATION OF THE RESPONSE TO FERTILITY AND THE RELATIVE GRAZING VALUE OF SOME NATIVE PERENNIAL GRASSES

CHAPTER 5

Experiment 3A Effects of fertility on the herbage mass of some native perennial grasses

Native and natural pastures dominated by warm season perennial grasses are generally regarded as unproductive (Roe et al. 1959; Cook et al. 1976) but the application of superphosphate to these pastures can increase productivity depending on the response from cool season annual naturalized legumes (Lodge and Roberts 1979) or white clover (Robinson and Lazenby 1976). Probably because the view expressed by Donald (1970) that native grasses lack the potential to respond to improved fertility has been widely accepted, the responses of native and naturalized grasses to increased P, S and N levels is not well documented. In pot cultures B. macra (Cook et al. 1976), Themeda australis, Poa labillardieri (Groves et al. 1973), D. racemosa (Robinson 1976), D. linkii and D. richardsonii (Harradine and Whalley 1978) have demonstrated positive herbage mass responses to increased fertility. Herbage mass responses have been obtained in the field from Danthonia spp. fertilized with superphosphate (Davies et al. 1934) and from Poa spp. supplied with N (Fisher 1974). If the ecology of native and natural pastures of the study area is to be understood a greater knowledge of how individual species react to varying fertility conditions is required, particularly about which components of herbage mass may be increased.

This experiment compared the herbage mass of six warm season native perennial grasses and Paspalum dilatatum at five levels of applied P, S and N in pots. The herbage mass of eight native perennial grasses growing in fertilized and unfertilized natural pastures is also presented.

A. Methods

Glasshouse

This experiment used the surface horizon (0-10 cm) of a coarse, sandy textured grey-brown podzolic soil from a site, previously described by Holford and Gleeson (1976) at "Tilmunda", 24 km north of Bendemeer, New South Wales. The available P, soil sulphate S and soil nitrate N were estimated by the methods shown in Appendix 1. Results were as follows:

Available P (ppm)	Sulphate S (ppm)	Nitrate N (ppm)
5.0	2.9	3.6

The species used were the warm season native perennial grasses C. truncata, E. leptostachya, B. macra, D. sericeum, S. elongatus, and A. ramosa, and, the commercially available warm season species P. dilatatum. Seeds of these species were sown on 11 October 1976 in 15 cm diameter plastic pots lined with polythene bags and containing 2800 g of air-dried soil.

Three replications of the following treatments were applied at sowing; P was applied in solution as sodium dihydrogen phosphate at five rates equivalent to 0, 10, 25, 60 and 90 kg P ha^{-1}; S was applied as sodium sulphate at five rates equivalent to 0, 10, 25, 40 and 60 kg S ha^{-1}; and N was applied as ammonium nitrate at five rates equivalent to 0, 10, 50, 100 and 150 kg N ha^{-1}. In addition 40 kg S ha^{-1} and 100 kg N ha^{-1}; 60 kg P ha^{-1} and 100 kg N ha^{-1}; and 60 kg P ha^{-1} and 40 kg S ha^{-1}, were applied to each of the P, S and N treatments respectively. An initial basal nutrient solution (kg ha^{-1}) of each of the following was added; KCl, 58.7; $MgCl_2.6H_2O$, 5.45; $CaCl_2$, 30.4; H_3BO_3, 0.79; $ZnCl_2$, 1.59; $MnCl_2.4H_2O$, 2.55; $Na_2MoO_4.2H_2O$, 0.25; $CuCl_2.2H_2O$, 1.78; $Co(NO_3)_2.6H_2O$, 0.1; and Fe EDTA, 1.5.

Pots were thinned to five plants in each and watered daily to field capacity with deionised water. Over the experimental period glasshouse temperature ranged daily between a mean minimum of 18°C and a mean maximum of 26°C.

Plants were harvested when all plants of each species were flowering, eight weeks after sowing. The harvested plants were sorted into vegetative material and inflorescence. Each portion was dried in a forced

draught dehydrator at 80°C for 48 hours and weighed.

Field

This study was undertaken on the fertilized natural pasture (Study area site 1) and the unfertilized (Study area 2) natural pasture described in Experiment 1. At both sites soil pH was determined as described in Appendix 3 and the available P, sulphate S and nitrate N in the top 10 cm were determined as described in Appendix 1.

At each site six individual plant samples of each species were harvested at ground level on 23 March 1977, from exclosures that had been in position for six weeks. Plants were selected to represent the range in plant size encountered at each site. The species sampled were; C. truncata, E. leptostachya, B. macra, D. sericeum, S. elongatus, A. ramosa, D. linkii and S. scabra. The harvested material was hand sorted into green leaf, green stem and leaf sheath bases, dead leaf, dead stem, and inflorescence. Each portion was dried for 48 hours at 80°C in a forced draught dehydrator and weighed.

The dry weight data from the glasshouse experiment were analysed by conventional analysis of variance. As there was a large species x nutrient (P, S, N) interaction significant nutrient responses for each of the species were assessed in terms of the linear and quadratic components of the yield curve and the fitted lines shown in the figures are these least squares regressions. For each species growing at the two field sites significant differences in the mean herbage masses were assessed by independent 't' tests.

B. Results

Glasshouse

The application of P and S significantly increased ($P < 0.001$) the herbage mass of all of the species. The maximum herbage masses of P. dilatatum and C. truncata were highest ($P < 0.01$) and that of A. ramosa lowest in response to applied P (Fig. 5.1a). Herbage masses of C. truncata, D. sericeum and A. ramosa increased linearly over the range of P applied, whilst those of P. dilatatum, B. macra and S. elongatus increased up to

approximately 25 kg ha^{-1} of applied P. With added S, P. dilatatum also had the highest herbage masses (Fig. 5.1b) and the masses of C. truncata, B. macra and D. sericeum were at least twice those of E. leptostachya. However, in all species 90 percent of maximum herbage mass was obtained by the application of around 10 kg S ha^{-1}. Applied N increased the herbage mass of all species except S. elongatus and A. ramosa (Fig. 5.1c) and at all levels of applied N the masses of P. dilatatum were at least 20 percent higher than those of C. truncata, B. macra and D. sericeum. Herbage masses of P. dilatatum, C. truncata, B. macra and E. leptostachya were near maximum with the application of 50 kg N ha^{-1}, but those of D. sericeum increased over the range of N applied.

When P was not applied herbage mass was low and all species were severely stunted, also most of the E. leptostachya, D. sericeum, B. macra, A. ramosa and S. elongatus plants although satisfactorily establishing, failed to survive until harvest. Without added sulphur the herbage mass of P. dilatatum was significantly higher ($P < 0.05$) than that of the other species and all plants except those of P. dilatatum were stunted and chlorotic. In these treatments all E. leptostachya plants and the majority of those of B. macra, A. ramosa, S. elongatus and D. sericeum, although establishing successfully, failed to survive. Without added N severe stunting and chlorosis was observed in all species except A. ramosa and all plants survived. The herbage masses of P. dilatatum, C. truncata and B. macra in the absence of added N were twice those of D. sericeum, A. ramosa and E. leptostachya. At the highest rate of applied N there was a 5-10 percent plant mortality in B. macra, D. sericeum, S. elongatus and A. ramosa.

Field

The P, S and N levels of the soil at the fertilized site were higher than those at the unfertilized site (Appendix 1), although the soil moisture and temperature (Appendix 5A and B) at the two field sites were similar. As growing conditions were similar at both study areas the past application of superphosphate may have significantly increased the total vegetative herbage mass of individual plants of S. elongatus, C. truncata, A. ramosa, D. linkii ($P < 0.01$) and B. macra ($P < 0.05$) (Table 5.1), but it did not alter the herbage mass of dead plant material in any of these species. At the fertilized site the green leaf mass of all species except

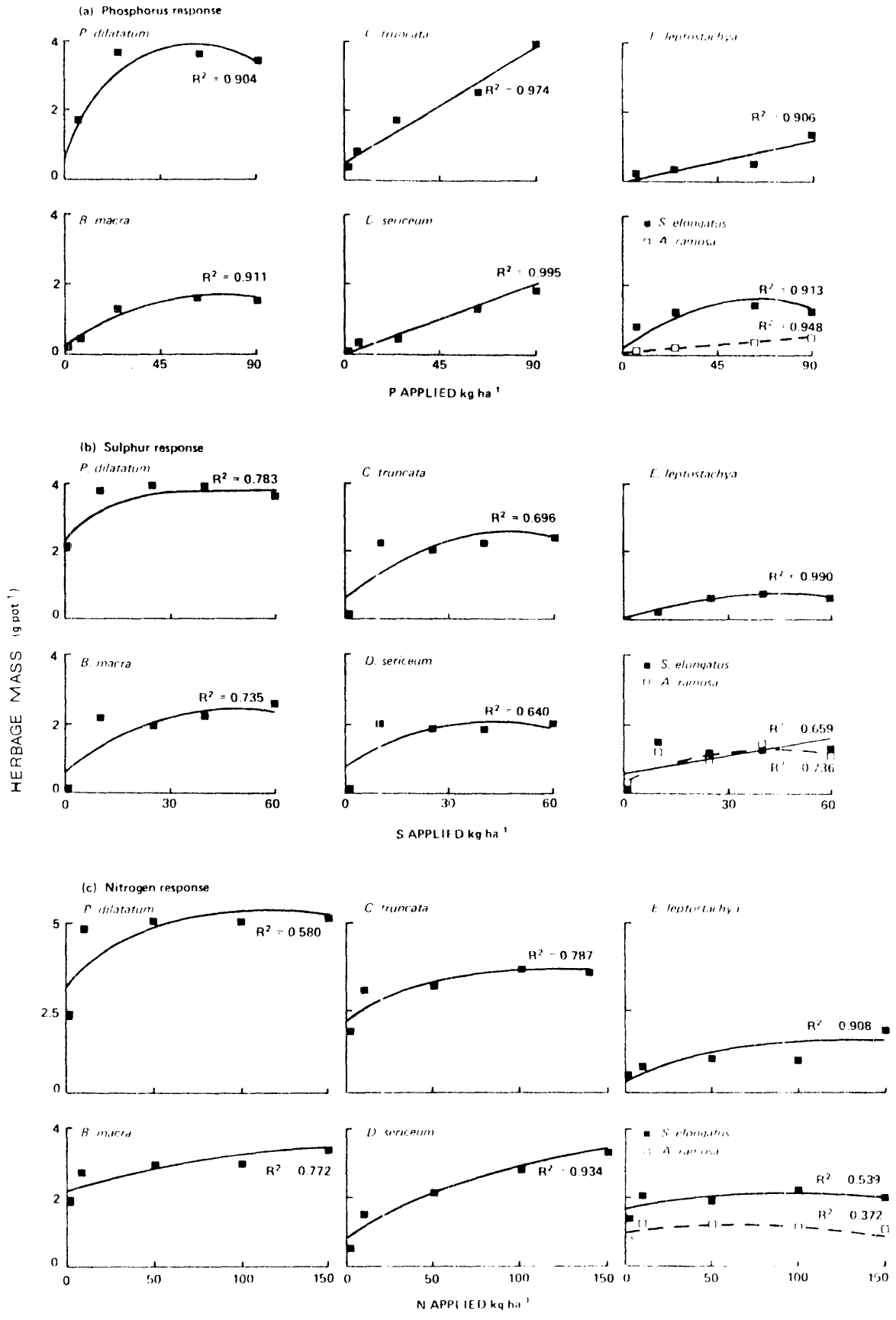

Figure 5.1 The herbage mass ($gpot^{-1}$) of seven perennial grasses at five rates of (a) applied P; (b) applied S, and (c) applied N.

D. sericeum and S. scabra and the green stem masses of all species except D. sericeum, S. scabra and E. leptostachya were significantly higher than those at the unfertilized site.

C. Discussion

Contrary to the view expressed by Donald (1970) that native species lack potential to respond to improved fertility levels, the application of either P, S or N positively increased the herbage mass of all the native grass species, except S. elongatus and A. ramosa. In the field the past application of superphosphate increased the green leaf mass of individual plants of all species except D. sericeum and S. scabra.

Because the amount of dead material in the species growing at the two field sites was not significantly affected by fertilizer history, green leaf mass rather than total plant herbage mass may be a more sensitive indicator of plant response to fertility. Furthermore, Roe et al. (1959) found that this portion of native pasture was highly correlated with animal production. While the field results are not conclusive they demonstrate a probable effect of fertilizer on the herbage mass of native grasses and the glasshouse data indicate that some native grasses respond well to P, S and N and that there are marked differences between species.

The plant mortalities that occurred in the pots with no added P or S appear to be related to the high level of N applied in those treatments, rather than the low levels of P or S. Harradine and Whalley (1978) found that seedlings of A. ramosa and D. linkii did not survive at high rates of N when P was not applied, and survival increased with the application of P. With high rates of applied N, plant deaths have also been reported for B. macra plants growing in pots (Robinson 1976). These seedling and mature plant mortalities indicate that these species of native grasses may be susceptible to large imbalances in the levels of P, S and N.

Changes in species composition with fertilizer application (e.g. Davies et al. 1934) and with localized changes in soil fertility produced by grazing (Whalley et al. 1978) could reflect important differences in species requirements for P, S and N. In a native or natural pasture B. macra is able to grow and persist under low fertility conditions. However, it may

Table 5.1. The green leaf, green stem and total vegetative yield of eight native perennial grasses growing in fertilized (F+) (study area site 1) and unfertilized (Fo) (Study area 2) natural pasture. Fertilized pasture received 150 kg superphosphate ha^{-1} annually over the previous 10 years.

	Dry matter production (g $plant^{-1}$)								
	Green leaf			Green stem			Total		
	F+	Fo	Response	F+	Fo	Response	F+	Fo	Response
C. truncata	1.13 ± 0.47[1]	0.50 ± 0.28	*	0.54 ± 0.26	0.12 ± 0.18	*	2.00 ± 0.65	1.09 ± 0.46	**
E. leptostachya	1.36 ± 0.73	0.53 ± 0.35	*	1.18 ± 0.67	0.74 ± 1.25	ns	3.30 ± 1.50	0.39 ± 0.37	ns
B. macra	4.30 ± 1.74	1.58 ± 0.95	***	6.57 ± 2.40	1.31 ± 0.97	***	16.67 ± 7.14	10.11 ± 6.81	*
D. sericeum	1.56 ± 0.72	0.85 ± 0.51	ns	1.82 ± 0.88	0.91 ± 0.73	ns	4.66 ± 2.91	2.62 ± 0.67	ns
S. elongatus	3.51 ± 2.14	0.77 ± 0.65	**	4.84 ± 2.48	1.05 ± 0.40	**	8.79 ± 4.61	6.78 ± 2.92	**
A. ramosa	3.59 ± 2.05	0.31 ± 0.20	**	20.02 ±12.02	8.15 ± 2.04	*	31.02 ±13.90	10.50 ± 3.56	**
D. linkii	0.38 ± 0.30	0.10 ± 0.04	*	0.27 ± 0.17	0.05 ± 0.05	**	0.82 ± 0.46	0.39 ± 0.38	**
S. scabra	2.93 ± 2.24	1.26 ± 0.99	ns	1.68 ± 1.42	0.25 ± 0.14	ns	8.44 ± 6.21	5.64 ± 2.95	ns

[1]Mean and standard deviation of 6 estimates.

ns Not significant
* P = 0.05
** P = 0.01
*** P = 0.001

be a productive and efficient species as it occurs across a wide range of fertility (Whalley et al. 1978) and in pot culture (Cook et al. 1975) and field studies (Moodie 1934a) its herbage masses have been shown to increase with fertility. Conversely, A. ramosa is widely regarded as an unproductive species of low fertility sites (Harradine 1976). The abundance of this species decreases with superphosphate application (Moodie 1934a; Berman 1954) and in pot culture and field experiments, Harradine (1976) found that applied N depressed the growth of A. ramosa. Similarly, in field experiments Robinson and Lazenby (1976) showed that the relative abundance of S. elongatus and Eragrostis spp. decreased with superphosphate application.

In the glasshouse the maximum herbage masses of the native perennial grasses with P, S and N applied, were from 15 to 75 percent lower than those of P. dilatatum. Within the native grasses there were significant herbage mass differences; B. macra, C. truncata and D. sericeum produced up to twice as much dry matter as either A. ramosa, S. elongatus or E. leptostachya. Therefore, the herbage mass response to applied fertilizer of native and natural pastures would depend on the species composition.

Experiment 3B The role of plant mass, basal area and density in assessing the herbage mass response to fertility of some native perennial grasses

This experiment further reports on the mechanisms that the individual plants of some native perennial grasses may use to achieve a change in mass. The way in which these mechanisms may affect the apparent responsiveness of some species to fertility, depending on how herbage mass estimates of green leaf masses are compared was also investigated. To demonstrate these effects the herbage mass and basal area estimates from the nitrogen (N) treatments of the glasshouse experiment (Experiment 3A) and similar field data, together with plant density estimates are presented.

A. Methods

Glasshouse

The plants used in this experiment were from the N treatments of Experiment 3A. After the first harvest, eight weeks after sowing, the N

treatments (0, 10, 50, 100 and 150 kg N ha^{-1}) were reapplied and the plants allowed to regrow. The species used were the warm season native perennial grasses: C. truncata, E. leptostachya, B. macra, D. sericeum, S. elongatus, and A. ramosa and the commercially available warm season species P. dilatatum.

The plants were clipped to ground level 10 weeks after nitrogen was reapplied. The basal area of each plant was estimated by the UOG method described in Experiment 1. The harvested material was hand sorted into green leaf, green stem plus leaf sheaths, dead material and inflorescence. Each portion was dried in a forced draught dehydrator at 80°C for 48 hours and weighed.

Field

At two sites, a fertilized (Study area 1, site 1) and an unfertilized (Study area 2) natural pasture described in Experiments 1 and 3A, 20 individual plants of the native perennial grass species; C. truncata, E. leptostachya, B. macra, D. sericeum, S. elongatus, A. ramosa, D. linkii and S. scabra were clipped at ground level in April 1978.

The plants were selected to represent the range in plant size at each site and their basal area determined by the UOG method described in Experiment 1. The harvested plant material was hand-sorted into green leaf, green stem plus leaf sheaths, dead leaf, dead stem and inflorescence. These portions were dried at 80°C for 48 hours and then weighed. Plant density (number of plants per unit area) was estimated for each of the above species in 20 randomly located one m^2 quadrats at each site.

The herbage mass data (g $plant^{-1}$ and g cm^{-2} of plant basal area) and the plant basal area data from the glasshouse experiment were analysed by conventional analysis of variance. Significant N responses were assessed in terms of the linear and quadratic components of the yield and basal area curves and the fitted lines shown in the figures are these least squares regressions. For each species growing at the two field sites significant differences in the mean green leaf herbage mass, mean plant basal area and the mean plant density were assessed by independent 't' tests. Significant effects of site on the regression coefficient relating

green leaf mass and plant basal area were determined by the method of Snedecor and Cochran (1969).

B. Results

Glasshouse

Applied N significantly increased ($P < 0.01$) the green leaf mass per plant of all the species (Fig. 5.2). With green leaf mass expressed as a function of plant basal area (Fig. 5.2) the application of N also significantly increased the green leaf mass per unit area of all species ($P < 0.01$), with the exception of *C. truncata*.

At high levels of applied N the basal area of *C. truncata* was significantly higher ($P < 0.001$) than that of other species (Fig. 5.3). Nitrogen at the higher levels also significantly increased the basal areas of most species ($P < 0.05$), the exceptions were *B. macra* and *A. ramosa*.

Field

Soil moisture and temperature conditions at the two field sites were similar (Appendix 5A and 5B), though the P, S and N levels of the soils at the fertilized site were higher than those at the unfertilized site (Appendix 1). Long term fertilizer application significantly increased the mean green leaf mass per plant of all the species (Table 5.2), except *S. scabra* and *D. sericeum*. The basal areas of *C. truncata* and *D. linkii* plants growing at the fertilized site (Table 5.2) were significantly higher ($P < 0.05$) than those at the unfertilized site, but for all other species there was no significant effect of past fertilizer history on the mean basal area. The mean densities of plants of *A. ramosa*, *D. sericeum* and *C. truncata*, growing at the unfertilized site were significantly higher than those at the fertilized site, while the mean plant density of *E. leptostachya* plants was significantly higher ($P < 0.01$) at the fertilized site.

The regression coefficients showing the rate at which green leaf mass changed as plant basal area increased (Table 5.3) were significantly higher ($P < 0.01$) for fertilized *B. macra* and *A. ramosa* plants than for those growing at the unfertilized site. For all other species these

Table 5.2. The mean green leaf mass and mean plant basal area of 20 selected plants covering a range of sizes for eight native perennial grasses growing in fertilized (Study area 1 site 1) and unfertilized (Study area 2) natural pasture, together with the mean plant density of each of the species.

Fertilized pasture received 150 kg superphosphate per ha annually over the previous 10 years.

Species	Mean green leaf mass (g plant^{-1})			Mean plant basal area (cm^2)			Mean plant density (m^2)		
	Fertilized	Unfertilized	Response to change in fertility	Fertilized	Unfertilized	Response to change in fertility	Fertilized	Unfertilized	Response to change in fertility
C. truncata	1.20±0.14	0.48±0.05[+]	**	15.93±1.52	10.14±1.10	*	3.60±0.85	8.67±2.87	*
E. leptostachya	1.11±0.17	0.66±0.09	*	3.20±0.61	5.86±1.09	ns	9.25±2.21	2.37±0.87	**
B. macra	1.18±0.18	0.39±0.06	***	6.42±1.21	8.52±1.66	ns	4.10±0.79	6.45±1.95	ns
D. sericeum	0.40±0.06	0.32±0.06	ns	8.91±1.34	9.31±1.00	ns	2.10±0.16	12.05±3.37	**
S. elongatus	1.17±0.21	0.51±0.10	**	5.03±0.92	3.33±0.51	ns	1.80±0.85	1.30±0.28	ns
A. ramosa	0.17±0.19	0.07±0.01	**	8.48±1.62	8.56±0.68	ns	1.60±0.62	8.90±3.47	*
D. linkii	0.39±0.08	0.10±0.02	**	1.74±0.45	0.47±0.07	*	5.40±2.66	4.95±1.56	ns
S. scabra	0.84±0.16	0.73±0.17	ns	6.47±1.31	4.49±0.64	ns	9.30±1.49	6.35±1.34	ns

[+] Mean and standard error of 20 estimates

ns Not significant

* $P < 0.05$

** $P < 0.01$

*** $P < 0.001$

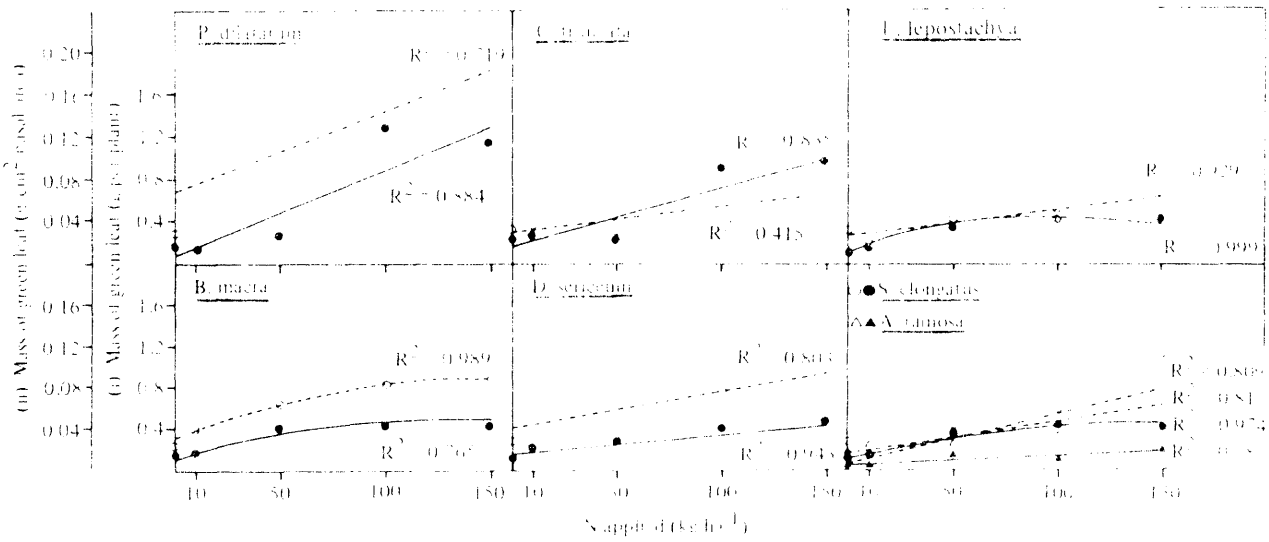

Figure 5.2 The effect of five rates of applied N on the green leaf mass of seven warm season grasses with herbage mass expressed as (i) gmplant^{-1}●——●, and (ii) g cm^{-2} of plant basal area○----○.

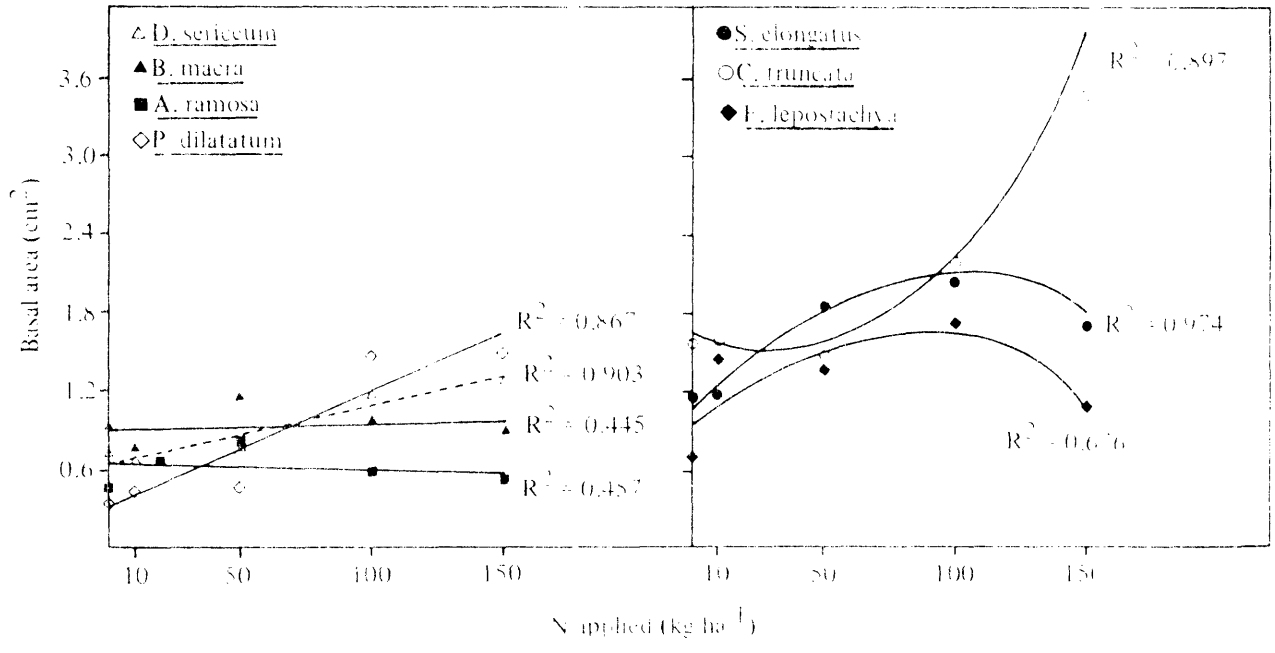

Figure 5.3 The effect of five rates of applied N on the basal area per plant of seven warm season grasses.

regression coefficients were not significantly different between the two Study areas.

C. Discussion

With increased fertility the green leaf mass per plant of all species increased in the glasshouse experiment, and in the field those of C. truncata, B. macra, D. sericeum, S. elongatus, A. ramosa and D. linkii increased when fertilizer was applied. These herbage mass increases were attained in one of three ways: (i) both basal area and leaf mass per unit basal area increased; (ii) basal area but not leaf mass per unit basal area increased; or (iii) leaf mass per unit basal area but not basal area increased. For the species studied the mechanisms used to increase plant herbage mass can be summarised as follows:

(i)	(ii)	(iii)
E. leptostachya	C. truncata	A. ramosa
D. sericeum (glasshouse only)	D. linkii	B. macra
S. elongatus		
S. scabra (field only)		
P. dilatatum (glasshouse only)		

While the basal areas of individual A. ramosa and B. macra plants were not significantly higher at the higher fertility site, their masses per unit basal area were higher at the fertilized site than at the unfertilized site. Hence, increased green leaf herbage mass per plant in these species was achieved by increasing leaf mass, but not basal area. Conversely, although the basal area of C. truncata and D. linkii plants was greater at the higher fertility site, the green leaf mass per unit of plant basal area was not affected. In these two species increased herbage mass per plant resulted from increased plant basal area and not increased leaf mass per unit basal area. For the other species studied, increased green leaf mass per plant was achieved by individual plants increasing both leaf mass and basal area. These data indicate that different native perennial grasses have different mechanisms of increasing herbage mass per plant in response to fertility and management. Similarly, past fertilizer history and management had a different effect on the plant density of the grasses studied. Care should therefore be taken when selecting an appropriate

Table 5.3. The regression equation relating the green leaf mass (y) and plant basal area (x) of eight native perennial grasses growing in fertilized and unfertilized sites. Standard errors are given in parentheses.

Species	Regression equation: Fertilized site	r	Unfertilized site	r	Effect of fertility on regression coefficient
C. truncata	y = 0.02(0.02)x + 0.88(0.13)	0.63+	y = 0.02(0.01)x + 0.34(0.23)	0.60	ns
E. leptostachya	y = 0.06(0.02)x + 0.20(0.07)	0.66	y = 0.04(0.01)x + 0.07(0.07)	0.70	ns
B. macra	y = 0.12(0.02)x + 0.41(0.18)	0.79	y = 0.02(0.01)x + 0.18(0.10)	0.51	**
D. sericeum	y = 0.015(0.010)x + 0.62(0.09)	0.67	y = 0.03(0.02)x + 0.82(0.14)	0.58	ns
S. elongatus	y = 0.17(0.04)x + 0.33(0.24)	0.72	y = 0.10(0.04)x + 0.17(0.16)	0.50	ns
A. ramosa	y = 0.06(0.02)x + 0.16(0.26)	0.55	y = 0.004(0.004)x + 0.05(0.02)	0.53	**
D. linkii	y = 0.17(0.02)x + 0.10(0.04)	0.93	y = 0.22(0.04)x - 0.01(0.02)	0.77	ns
S. scabra	y = 0.11(0.01)x + 0.11(0.11)	0.90	y = 0.14(0.03)x - 0.13(0.16)	0.88	ns

+ $p = 0.05$ $r = 0.44$

ns Not significant

** $P < 0.01$

method of measuring and comparing the herbage response of individual species in the field. If mass per unit basal area was used to monitor the response of species to management, as suggested in Experiment 1, it would underestimate the herbage mass response of individual species such as C. truncata and D. linkii and would not indicate the effects of fertility on plant density. Similarly, plant responses to increased fertility should not be assessed solely by changes in plant basal area as this method would unfavourably bias the responsiveness of species such as A. ramosa and B. macra. Plant density estimates may also give a biased assessment of response. Any method of assessing the effect of fertility or management on the herbage mass of individual species growing in the field should therefore take into consideration not only the different mechanisms by which individual plants may increase their herbage mass, but also plant density.

Mean total herbage and green leaf mass estimates in kg ha^{-1}, calculated from equation (1) Experiment 1 for each of the species studied were as follows:

Species	Total herbage mass (kg ha^{-1})		Green leaf herbage mass (kg ha^{-1})	
	Fertilized	Unfertilized	Fertilized	Unfertilized
C. truncata	54	52	43	42
E. leptostachya	153	33	103	16
B. macra	466	286	48	25
D. sericeum	122	497	8	38
S. elongatus	86	39	21	7
A. ramosa	344	664	3	6
D. linkii	38	13	21	5
S. scabra	213	228	78	46
Total	1476	1812	325	185

Again, these data clearly indicate the importance of the different mechanisms that plants may use to change the herbage mass of individual species in the field in response to management. While individual plants of C. truncata, E. leptostachya, B. macra, S. elongatus, A. ramosa and D. linkii

had significantly higher green leaf masses at the higher fertility site, when differences in plant density were taken into consideration the only species that had higher estimated herbage masses at the fertilized site were E. leptostachya, B. macra, S. elongatus and D. linkii. Similarly, although B. macra and A. ramosa, and C. truncata and D. linkii plants growing at the fertilized site had significantly higher mean green leaf masses per unit basal area, and mean basal areas, respectively these differences had little effect on the estimated herbage mass of these species. The effect of plant density on herbage mass was reflected in the higher herbage mass of D. sericeum and A. ramosa plants at the unfertilized site where these species had a high plant density. The total herbage mass esimtates at each site compared favourably with preliminary data from clipped quadrats (Experiment 1) and are in agreement with herbage mass estimates determined in other grasslands dominated by warm season native perennial grasses (e.g. Biddiscombe et al. 1956; Groves 1965; Fisher 1974).

CHAPTER 6

The studies described in this Chapter were designed to obtain preliminary data on the seasonal growth, crude protein and in-vitro digestibility of eight of the dominant perennial grasses in the region.

Experiment 4A. Seasonal changes in the herbage mass of eight native perennial grasses.

A. Materials and Methods

The herbage mass of eight native perennial grasses was estimated at regular intervals from three sites within two grazed natural pastures in the study area. The grasses selected for study were the warm season native perennial grasses A. ramosa, B. macra, D. sericeum, S. elongatus, C. truncata, and E. leptostachya and the yearlong green perennial grasses S. scabra and D. linkii.

Three natural pasture sites were studied; sites (1) and (2) were a poorly developed sheep camp and a non-sheep camp respectively in a fertilized pasture (Study area 1) and the third was an unfertilized natural pasture (Study area 2). These Study areas were described previously in Experiment 1. Further descriptions are given in Plates 6.1, 6.2 and 6.3 and Appendices 1, 5A and 5B. Both pastures were stocked at two sheep ha^{-1} throughout the experimental period. The basal cover of the dominant native grasses and of bare ground (Table 6.1) was estimated at each of the sites in February 1979 from 5000 points (Tidmarsh and Havenga 1955) using a single wheel-point apparatus (von Broemsben 1966).

Twelve individual plants of each of the selected grasses were clipped at ground level on 20 occasions from March 1976 to March 1978 for sites (1) and (2) at Study area 1. Similar samples were collected on ten occasions from February 1977 to March 1978 at Study area 2. Six of the individual plants of each species were collected from inside 1 m^2 exclosures and six from outside. The exclosures were moved after each sampling and no individual plant was harvested more than once during the experiment.

Plate 6.1 The fertilized non stock camp site (Study area 1 site 1) near Barraba.

Plate 6.2 The fertilized stock camp site (Study area 1 site 2).

Plate 6.3 The unfertilized site (Study area 2) near Manilla.

Table 6.1. Mean basal cover (%) of the major native perennial grasses at the three sites selected for study.

	Study Area 1		Study Area 2
	Site 1	Site 2	
	% Mean basal cover		
A. ramosa	5.3	5.6	5.7
B. macra	2.1	7.8	7.7
D. sericeum	1.4	1.2	5.4
S. elongatus	2.8	2.0	1.5
E. leptostachya	5.7	1.9	1.9
C. truncata	4.9	1.2	4.2
S. scabra	2.8	3.5	2.7
D. linkii	2.8	0.9	1.5
Other species	2.2	1.8	2.3
Bare ground	70.0	74.1	67.1

The six plant samples of each species from outside the exclosures were bulked before hand-sorting into green leaf blades, green stems plus leaf sheaths, dead stems and inflorescence, while the plants from inside were sorted individually. These portions were dried for 48 hours at $80^{o}C$ in a forced draught dehydrator and weighed. As a basis for comparing the mass of plants of different sizes and species, the basal area of each plant harvested from the exclosures was estimated using the UOH method outlined in Experiment 1 and the weights of the portions were expressed as herbage mass of plant basal area. The number of plants per unit area (density) of the eight species were counted in 20 randomly located 1 m^2 quadrats at each of the Study areas in November 1977. Estimates of the herbage mass per unit area of each species were calculated using equation (1) given in Experiment 1.

Significant differences in the mass of each species between sites (1) and (2) at Study area 1 were assessed by independent 't' tests. For comparisons between all three sites the least significant difference ($P < 0.05$) between the mean mass of each species was calculated. Despite differences in soil fertility (Appendix 1) the green leaf masses of the eight native perennial grasses (mg cm^{-2} of plant basal area) were significantly

different between sites on only 2 occasions and so the data presented in Fig. 6.1 were averaged over all sites. For each harvest date the total herbage mass of individual plants harvested from exclosed and grazed areas were compared by independent 't' tests. These differences were not significant on any occasion and so only data for plants harvested from the exclosures have been presented.

In order to assess seasonal trends herbage mass data for December, March, June and September-October of each year were chosen to represent summer, autumn, winter and spring, respectively. For each of the species the differences between green leaf, green stem and total vegetative herbage mass per unit basal area were tested for significance.

B. Results

The eight grasses tested fall into three groups with respect to the green leaf mass per unit basal area throughout the year (Fig. 6.1). The first group consisted of A. ramosa, B. macra, D. sericeum and S. elongatus (group 1). These species carried little green leaf throughout the winter and the amount of green leaf during the summer period was related to the summer rainfall. Each of these species produced the most green leaf following the heavy rain at Study areas (1) and (2) in January, 1978 (Fig. 6.1). The proportion of the total biomass represented by green leaf was lowest for A. ramosa, with S. elongatus being the most leafy of this group (Table 6.2). These four species are all warm season native perennial grasses.

C. truncata and E. leptostachya showed considerably less seasonal variation in amount of leaf per unit basal area (Fig. 6.1). The main difference between these two species and those of group 1 was the greater winter production of green leaf, particularly in 1977 with the higher late autumn and winter rainfall (Fig. 6.1). Green leaf represented a greater percentage of the total herbage mass throughout the year compared with the above four species (Table 6.2).

The final group (group 3) S. scabra and D. linkii, had the least seasonal variation in green leaf mass per unit basal area. The winter production of these two species was less affected by winter rainfall than the

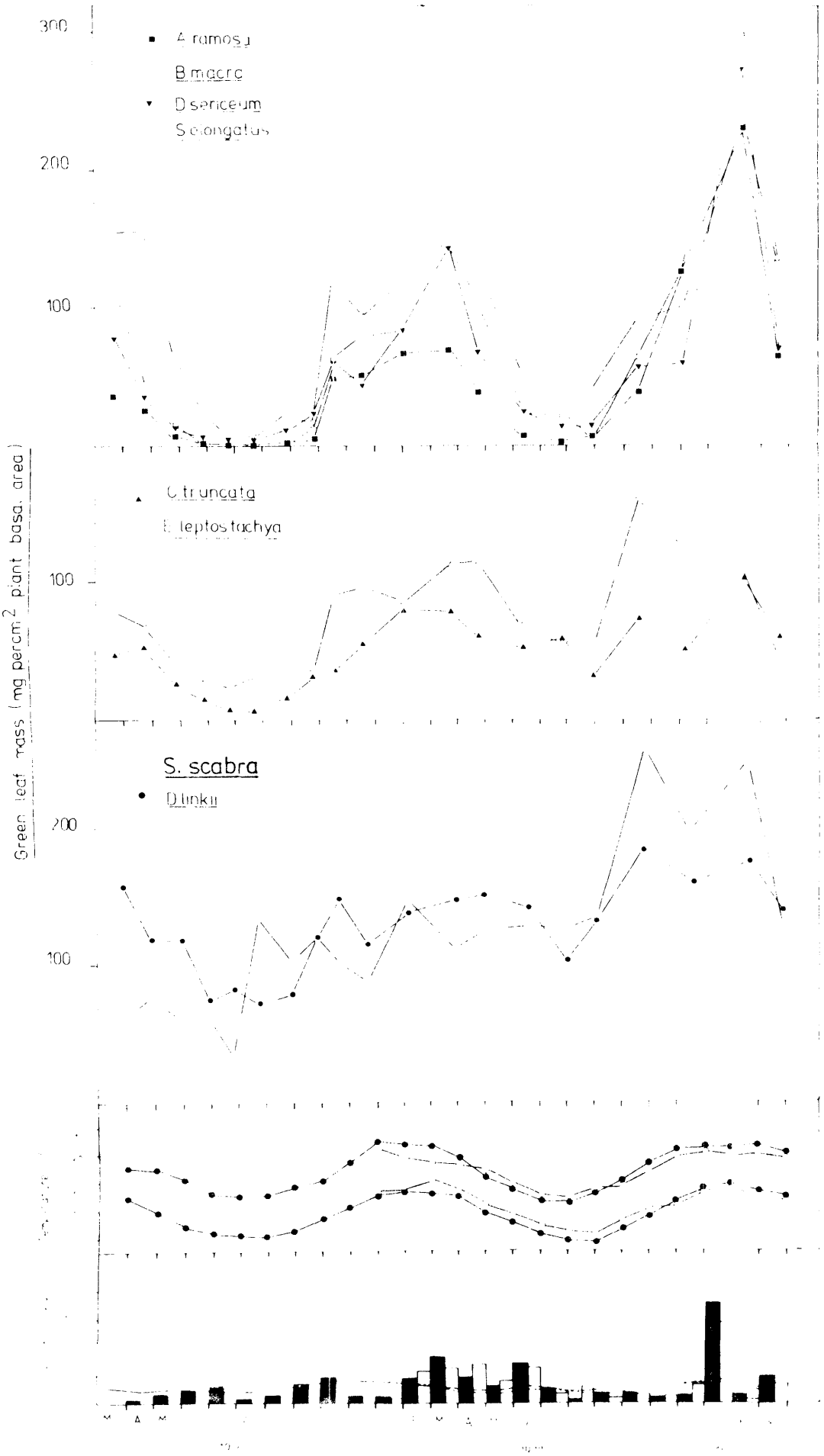

Figure 6.1 The green leaf mass per unit basal area of eight native perennial grasses averaged over the three sites together with the mean maximum and minimum ambient temperatures (^{o}C) at Study areas 1 (●) and 2 (○) and the monthly rainfall at Study areas 1 (■) and 2 (□). The long term average monthly rainfall at Barraba (—) and Manilla (- - -) are also shown.

Table 6.2. Green leaf herbage mass expressed as a percentage of the total vegetative herbage mass for eight species of native perennial grasses. Herbage mass data (mg cm^{-2} plant basal area) meaned over the three sites were used to represent each season.

	Green leaf (%)			
	Summer	Autumn	Winter	Spring
Aristida ramosa	4.5	4.4	0.3	1.0
Bothriochloa macra	7.2	16.4	1.6	3.4
Dichanthium sericeum	7.8	19.0	4.3	5.8
Sporobolus elongatus	16.6	33.3	10.4	8.5
Chloris truncata	54.0	57.0	46.8	41.3
Eragrostis leptostachya	41.3	32.3	24.8	28.3
Stipa scabra	21.9	30.9	28.6	26.1
Danthonia linkii	30.1	38.2	41.8	40.0

two species in group 2 (Fig. 6.1) although their green leaf percentage was somewhat less than that of C. truncata and E. leptostachya in summer and autumn (Table 6.2). However, S. scabra produced consistently more herbage mass of green leaf per unit basal area than D. linkii.

In all species except A. ramosa and S. scabra, the green stem mass was higher in autumn, when plants were flowering, than in any other season (Table 6.3). In all seasons, A. ramosa plants had much higher amounts of green stem than plants of the other species and contributed at least 60% of the total green herbage mass per hectare. The extended flowering period of S. scabra during summer and autumn was reflected in the similar green stem mass values for these periods.

Dead leaf and stem comprised over 75% of the total herbage mass of B. macra, D. sericeum, S. elongatus, C. truncata and E. leptostachya in both summer and winter. All of the warm season grasses generally had from two to six times more dead herbage than green in all seasons except autumn (Table 6.3).

Table 6.3. The estimated herbage mass (kg ha^{-1}) of eight native perennial grasses, meaned over three pasture sites.

	Herbage mass (kg ha^{-1})								
	Aristida ramosa	*Bothriochloa macra*	*Dichanthium sericeum*	*Sporobolus elongatus*	*Chloris truncata*	*Eragrostis leptostachya*	*Stipa scabra*	*Danthonia linkii*	Total
Green leaf									
Summer	49	70	51	40	26	39	97	14	386
Autumn	46	117	44	77	40	28	110	34	496
Winter	6	21	13	33	44	32	166	41	351
Spring	14	22	19	14	42	54	133	31	383
Green stem									
Summer	557	44	36	11	2	13	68	4	735
Autumn	620	180	48	99	10	27	58	8	1050
Winter	1009	96	22	68	4	11	34	5	1249
Spring	959	10	7	17	9	19	36	20	1077
Total dead									
Summer	483	872	522	232	21	44	406	32	2612
Autumn	426	490	152	37	21	36	184	50	1396
Winter	561	1034	267	214	46	102	380	50	2659
Spring	851	846	254	303	51	139	353	31	2774
Total vegetative									
Summer	1089	986	609	283	49	96	571	50	3733
Autumn	1092	787	244	213	71	91	352	92	2942
Winter	1576	1151	302	315	94	145	580	96	4259
Spring	1824	878	280	334	102	212	522	82	4234

Experiment 4B. Seasonal changes in the crude protein content and in-vitro digestibility of eight native perennial grasses.

A. Materials and Methods

Portions of five of the six individual plant samples collected from the exclosures at each of the sampling dates in Experiment 4A were bulked to give green leaf, green stem, dead leaf and dead stem samples. The remaining sample was ground as a composite whole-plant sample. Samples from December, March, June and September-October of each year were used to determine the crude protein levels representative of summer, autumn, winter and spring, respectively.

Each of the dried samples was ground to pass through a 1 mm sieve and analysed in duplicate for total nitrogen (N_{tot}) content by the method of Williams and Twine (1967) and the percentage of crude protein was estimated as $N_{tot} \times 6.25$.

The in-vitro organic matter digestibility (OMD) of the ground samples was determined as described by Alexander and McGowan (1961), except that the incubation period was increased from 2 to 3 days. Samples were analysed in triplicate and determinations were repeated if results differed by more than five units.

B. Results

In winter and spring the green leaf crude protein of the warm season grasses ranged from 6% to 12%, while that of D. linkii and S. scabra ranged from 8% to 17%, in winter and spring (Fig. 6.2). A. ramosa consistently had the lowest values and E. leptostachya had the highest values. Green leaf crude protein percentages of all species decreased in December 1976 when rainfall was low (Fig. 6.1). Crude protein content of green stem was higher in later summer and autumn when most species were flowering, except for those of A. ramosa and S. scabra which generally had high proportions of green stem throughout the year. Dead leaf and stem crude proteins were less than 6% in all cases.

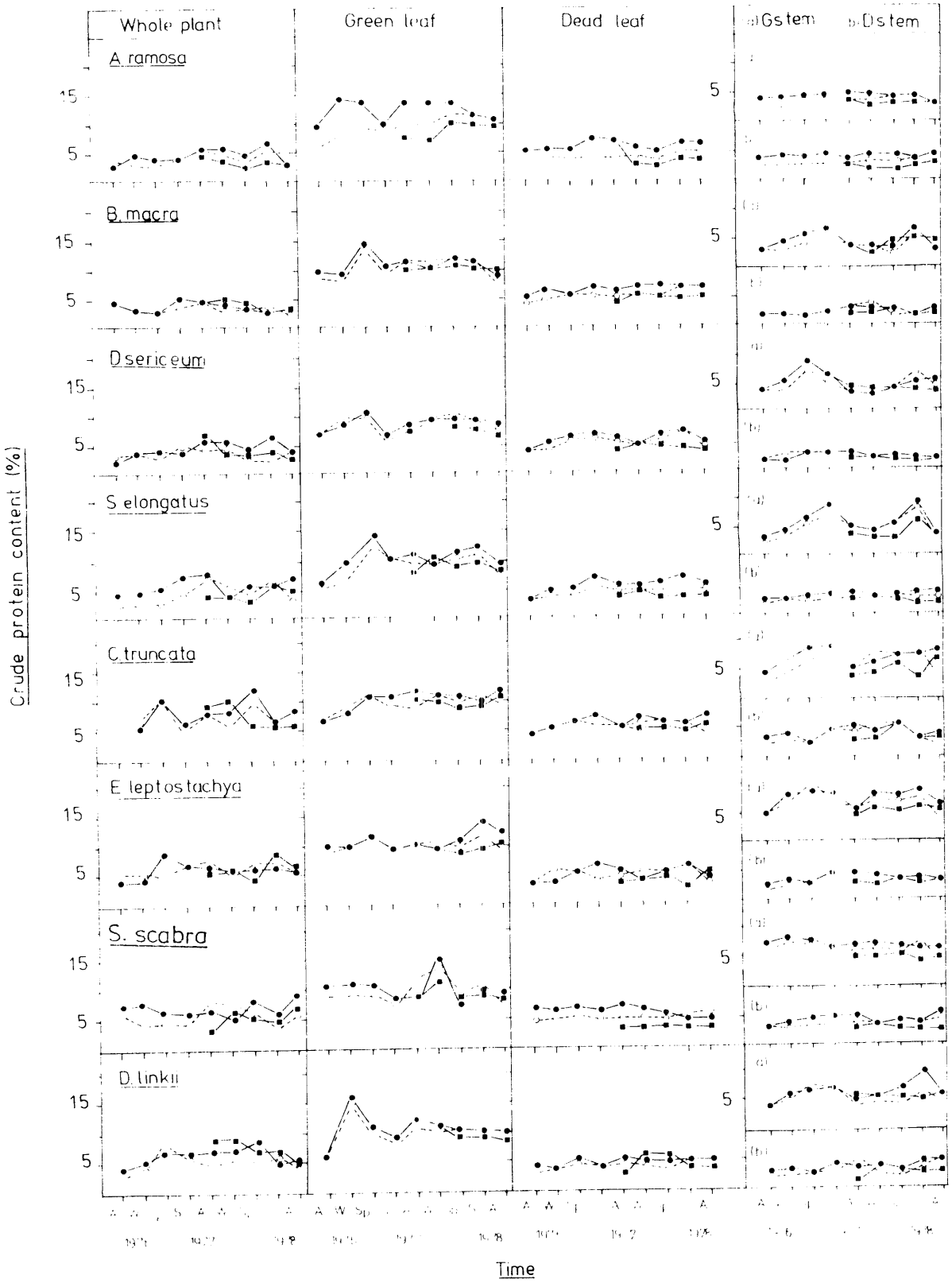

Figure 6.2 The crude protein content of the green and dead leaf and stem portions of the eight grasses studied at Study area 1, sites 1 (●) and 2 (○) and Study area 2 (■).

The digestibility of the two leafiest warm season perennial grasses (E. leptostachya and C. truncata) remained above 60% for most of the experimental period (Fig. 6.3) while that of the other four warm season species tended to decrease more in the autumn and winter. Sufficient green leaf material for analysis was not available for A. ramosa, B. macra and D. sericeum in winter in 1977. At each of the three sites the digestibilities of D. linkii green leaf material was generally higher than 60% in all seasons, but those of S. scabra green leaf were always less than 60%.

Green stem digestibilities ranged from 25% for A. ramosa in autumn to 60% for D. sericeum and D. linkii in spring and E. leptostachya and S. scabra in winter and spring (Fig. 6.3). Digestibilities of B. macra and S. elongatus stems were also around 60% in spring. Dead leaf generally varied from 30% to 55% digestibility and in most species the digestibilities were higher in spring than in autumn and winter. Dead stem digestibilities ranged from 20% to 40% in most species and were often higher in spring and autumn than in summer and winter.

C. General Discussion of Experiments 4A and 4B and Conclusions

These preliminary data indicate that the warm season native perennial grass, A. ramosa is an undesirable pasture species. Its herbage mass is composed mainly of coarse, green stems that have crude protein contents of less than 5% and digestibilities lower than 55%. The three-awned seed of A. ramosa also causes contamination of wool and sheep carcases (Lodge and Hamilton 1981) resulting in widespread production losses. Of the other warm season grasses C. truncata and E. leptostachya produce some green forage in autumn and winter, when low temperatures severely limit the green forage production of A. ramosa, B. macra, D. sericeum and S. elongatus, which restricts their potential usefulness. The preliminary results indicate that D. linkii and S. scabra are potentially desirable species for grazing because of the amount of green leaf and high crude protein content. However, the real value of S. scabra is limited as it is confined to light textured soils (Beadle 1948), its seeds contaminate wool (Cornish and Beale 1974) and it has a low digestibility.

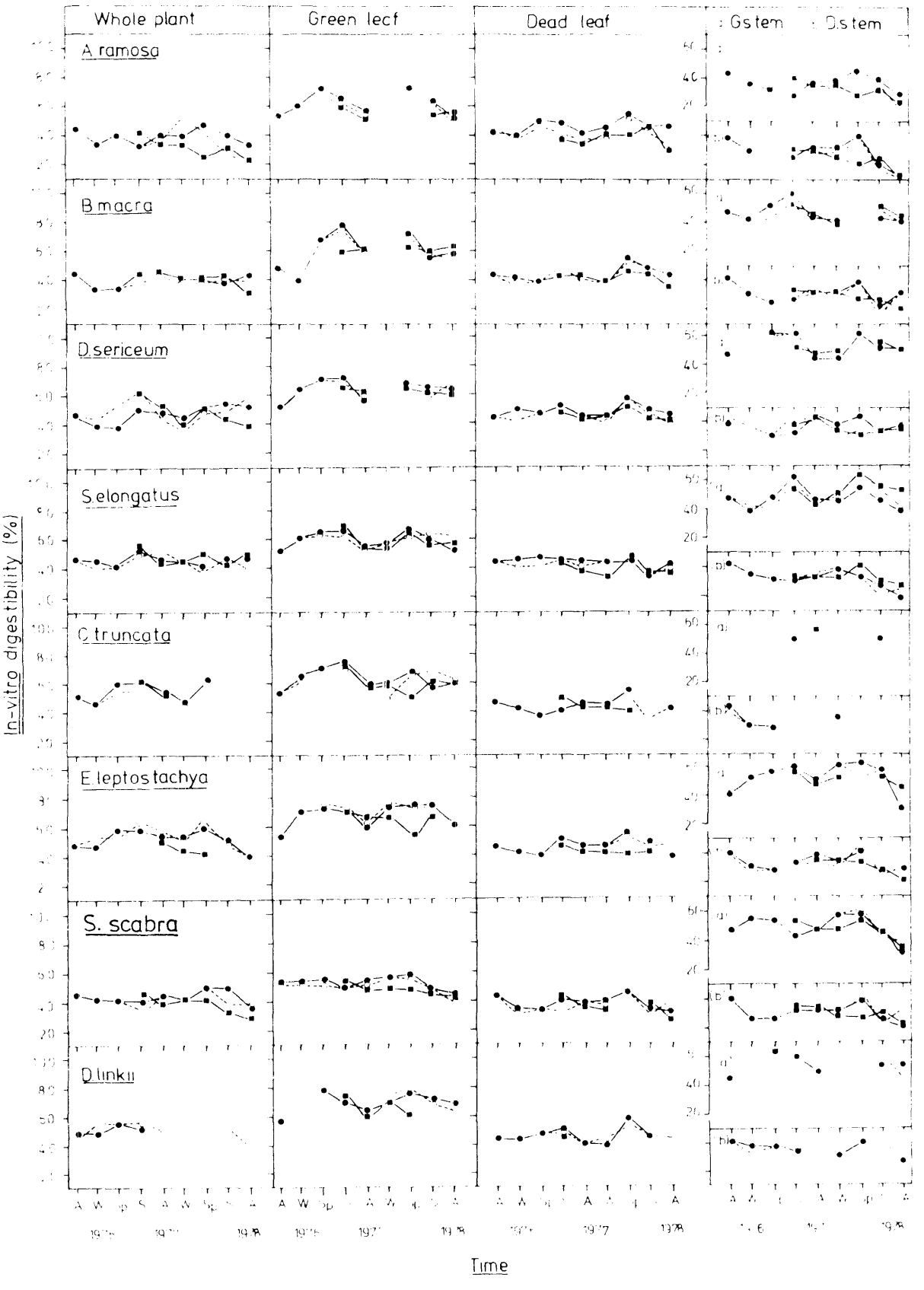

Figure 6.3 The in-vitro digestibility of the green and dead leaf and stem portions of the eight grasses studied at Study area 1, sites 1 (●) and 2 (○) and Study area 2 (■).

These preliminary rankings of grazing value need to be confirmed by diet selection and animal production studies in this environment. In a more arid environment, for example, diet selection studies (Leigh and Mulham 1966) indicated that at most times of the year Danthonia caespitosa plants are more acceptable to sheep than S. scabra.

In winter and spring the green leaf mass of the warm season grasses tended to be lowest when the mean daily temperature was below 10°C. These seasonal differences are consistent with the optimum temperatures for growth of warm season and yearlong green native perennial grasses determined in other environments (Groves 1965; Hodgkinson and Quinn 1976; Hagon and Groves 1977).

The high abundance of warm season native perennial grasses in the native and natural pastures of the Northern Slopes (Williams 1979) and their low green leaf availability in winter and spring, are factors which limit animal production from these pastures in this region. Similar temperature limitations to the production of green forage in warm season native perennial grasses have been noted in other environments by Roe (1947), Biddiscombe et al. (1956), Roe et al. (1959) and Whittet (1966). Hence, in pastures dominated by warm season native perennial grasses the low amount of green leaf in winter is an inherent characteristic of the dominant species and cannot simply be overcome by fertilizer application. However, the application of fertilizer may change the species composition of the native perennial grasses (e.g. Whalley et al. 1978) which in some situations may partially overcome the problem. Naturalized cool season annual legumes present in these pastures may respond to fertilizer application, although their production is confined to a short period in spring (Lodge and Roberts 1979). Also at higher elevations, around 700 m, on the Northern Slopes, white clover (Trifolium repens cv. Haifa), woolly pod vetch (Vicia dasycarpa cv Namoi) and lucerne (Medicago sativa cv Hunter River) oversown into fertilized natural pasture improved the winter and spring production of ungrazed plots (Archer 1981). However, the introduction of these legumes into native and natural pastures on the lower slopes, where summers are hotter and drier, has not proved practical.

The crude protein content of the whole plant samples of A. ramosa, B. macra and D. sericeum varied little between seasons, probably because of the large amounts of dead material at most times of the year. Begg and Freney (1960) showed that the crude protein content of whole plants of

grazed, unfertilized native grasses varied seasonally, being lowest when growth was restricted by low temperature and low soil moisture or when plants had matured. In the present study seasonal variations in temperature and rainfall had little effect on the crude protein content of whole plants. Crude protein content of whole plants is of little importance, however, in assessing the nutritional value of species as both sheep and cattle may exhibit considerable preference when grazing (e.g. Hardison et al. 1954; Meyer et al. 1957). Although there were differences between the digestibilities of the plant components of different species, these differences may not be important when there are large differences between the seasonal growth rhythms of the individual species. Higher annual livestock production could be expected from species which have a long period of growth (e.g. D. linkii) because young highly digestible plant material would be present for a longer period than in species which have a shorter growing season (e.g. warm season native perennial grasses).

In these studies a low stocking rate (2 sheep ha^{-1}) had no significant effect on the mass of total herbage harvested per plant from the grazed and exclosed areas. However, at most sampling dates individual plants collected from the exclosures were observed to have a higher amount of green leaf than those harvested from the grazed areas. This reflects the low utilization of pastures dominated by warm season grasses, and at low stocking rate the accumulation of dead herbage. The pastures studied were typical of unmanaged and understocked pastures on the Northern Slopes and although there is little evidence of change in the botanical composition of these pastures at low stocking rate (Lodge and Roberts 1979) there are nevertheless valuable species such as D. linkii present.

For the three sites studied the total green leaf herbage mass of the eight dominant species ranged from around 300 kg ha^{-1} in winter to 500 kg ha^{-1} in autumn and although the total green (leaf and stem) was often as high as 1500 kg ha^{-1}, the main component was coarse stems of A. ramosa that have a low crude protein content and low digestibility. Additional green forage would be provided in these pastures by other native perennial grasses, annual legumes and grasses and annual and perennial herbaceous weeds. However, to substantially increase the carrying capacity of these pastures management schemes need to be formulated to increase the abundance of species such as D. linkii that have high amounts of green leaf. Future management of native

and natural pastures in the study area should aim at increasing the abundance of species such as D. linkii and discouraging species such as A. ramosa and the establishment of persistent and productive legumes.

Section 4 FACTORS AFFECTING FLOWERING, SEED GERMINATION AND SEEDLING EMERGENCE AND SURVIVAL

CHAPTER 7

THE FLOWERING PHENOLOGY OF EIGHT NATIVE PERENNIAL GRASSES

Experiment 5

The flowering phenology of A. ramosa, B. macra, D. sericeum, S. elongatus, E. leptostachya, C. truncata, S. scabra and D. linkii was studied under field conditions at Study area 1 site 1 and Study area 2.

A. Materials and Methods

Ten one m^2 exclosures at Study area 1 site 1 and Study area 2 described in Experiments 1 and 4A, and Appendices 1, 5A and 5B were used to observe flowering phenology. At both of the Study areas the stage of inflorescence development of plants of the above eight species were scored, at the end of each month from April 1976 to March 1978 at Study area 1 and from December 1976 to March 1978 at Study area 2 using the following system:

Score	Stage of inflorescence development
1	Anthesis, early seed set
2	Seed set, immature
3	Seed set, mature
4	Seed mature commencing to fall from inflorescence
5	Seed fall from inflorescence completed.

Plants in exclosures were scored until June 1977 when observations commenced on marked plants. From this time on the number of inflorescences and their stage of development were recorded on each of six marked plants of each species at both of the Study areas. The percentage of inflorescences at each stage of development were then calculated.

B. Results

All species at Study area 1 site 1 were flowering in autumn 1976 (Table 5.1). Although soil moisture was adequate in spring 1976 at Study area 1 site 1 (Appendix 5A) the inflorescences of all species did not

emerge until the average minimum temperature was about 15°C and the actual minimum temperature exceeded 5°C (Appendix 5B). Most species were flowering at both sites by November or December 1976, except for S. elongatus growing at Study area 2 and B. macra at both sites. For B. macra, in particular, inflorescences only emerged after a period of adequate soil moisture in summer when average minimum ambient temperatures were around 15°C. In 1977 rainfall was below average in spring and early summer (Appendix 5A) and at these times flowering was not observed in any of the species, except A. ramosa. The appearance of inflorescences of this species was recorded in December 1977 at Study area 1 site 1 and November 1977 for Study area 2, under harsh environmental conditions, indicating the xerophytic nature of A. ramosa. With adequate soil moisture in January 1978 (Appendix 5A) inflorescences had emerged on all species.

Species such as A. ramosa, B. macra, D. sericeum, S. elongatus and E. leptostachya exhibited only one main flowering period that commenced in late spring and summer (Table 5.1). However, in C. truncata, S. scabra and D. linkii plants the appearance of inflorescences in late spring or early summer may be followed by another flowering period in March provided summer rainfall has been adequate and the mean minimum temperature exceeds 15°C (Appendix 5B). In March 1977 after adequate spring and summer rainfall this phenomenon was observed for D. linkii and C. truncata plants growing at both Study areas and for S. scabra plants at Study area 1 site 1, but was not observed the following year after dry conditions in spring and early summer.

In 1976 seed fall was completed by the end of May for D. linkii and S. scabra plants and by the end of June for all of the other species except A. ramosa, B. macra and E. leptostachya. Of these three species E. leptostachya retained seed in the inflorescences for long periods and the inflorescence tended to separate from the stem, rather than the individual seeds separating from the inflorescence. Seed fall in 1977 was completed by the end of July in D. sericeum, C. truncata and S. scabra plants growing at both sites and in B. macra plants growing at Study area 2.

C. Discussion

Inflorescences of all species emerged when adequate soil moisture was available and the average minimum ambient temperature exceeded 15°C.

Table 7.1 The flowering phenology of eight native perennial grasses at Study area 1 site 1 from April 1976 to March 1978 and at Study area 2 from December 1976 to March 1978. A (+) indicates the predominant flowering state. Flowering stages (1-5) were; (1) anthesis, (2) seed set, immature, (3) seed mature, (4) seed fall commenced, (5) seed fall completed.

Stage of Flowering																																									
		Study area 1																								Study area 2															
		1976									1977												1978			1977													1978		
		Predominant stage															Actual percentage									Predominant stage							Actual percentage								
Species	Flowering Stage	A	M	Jun	J	A	S	O	N	D	Jan	F	M	A	M	Jun	J	A	S	O	N	D	Jan	F	M	D	Jan	F	M	A	M	Jun	J	A	S	O	N	D	Jan	F	M
A. ramosa	(1)									+												10	26	4	5	+											3	17	44	15	1
	(2)										+												14	55	3		+												7	2	30
	(3)	+										+	+	+										15				+	+												
	(4)		+												+	+	4	4						26	21					+	+	+	26	6	2	2				80	
	(5)			+	+	+	+	+	+								96	96	100	100	100	90	60		71								80	94	98	98	95	85	49	3	69
B. macra	(1)											+											14	23	2		+	+												40	
	(2)												+											50					+											25	
	(3)	+												+	+									8	18					+	+									10	
	(4)		+													+								19	25							+	3							15	5
	(5)			+	+	+	+	+	+	+	+						100	100	100	100	100	100	86		55	+							97	100	100	100	100	100	100	10	95
D. sericeum	(1)									+	+												67	8	10											10			14	2	
	(2)											+												26		+	+												16	14	
	(3)	+											+	+										43	6			+	+											40	2
	(4)		+												+	+								4	9					+	+	+								14	10
	(5)			+	+	+	+	+	+								100	100	100	100	100	100	33	19	75								100	100	100	90	100	100	70	50	88
S. elongatus	(1)									+													6	23	6			+	+										14	10	
	(2)										+	+	+										6	33	2					+										70	
	(3)	+												+	+										32						+	+									45
	(4)		+													+	6							44	4								25							10	38
	(5)			+	+	+	+	+	+								94	100	100	100	100	100	88		56	+	+						75	100	100	100	100	100	86	10	17
C. truncata	(1)									+													25	20	10															43	
	(2)										+		+										15	20	20	+														17	
	(3)	+										+		+										40	9		+		+	+										40	
	(4)		+												+	+								20	25			+			+	+									
	(5)			+	+	+	+	+	+								100	100	100	100	100	100	60		36								100	100	100	100	100	100	100		100
E. leptostachya	(1)								+														74	14	2	+										7			67	6	8
	(2)									+													22	2	2		+	+											8	40	4
	(3)	+	+	+	+	+					+	+	+	+	+	+								82					+	+	+	+								44	88
	(4)						+	+									20								76								44							10	
	(5)																80	100	100	100	100	100	4	2	30								56	100	100	93	100	100	25		
S. scabra	(1)								+														40		3										25	30			62		
	(2)												+										10	8												2					
	(3)									+				+										42		+										2				42	
	(4)	+									+				+	+								22			+	+	+	+	+	+				6	2				
	(5)		+	+	+	+	+	+				+					100	100	100	100	100	100	50	28	97								100	100	75	60	98	100	38	58	100
D. linkii	(1)								+														10	36	4															20	
	(2)									+			+										4	20		+														40	
	(3)										+			+										10			+		+	+											
	(4)	+										+			+	+	26	12						34				+			+	+	50	12	6					20	
	(5)		+	+	+	+	+	+									74	88	100	100	100	100	86		96								50	88	94	100	100	100	100	20	100

These conditions were essential for the appearance of B. macra inflorescences and the importance of both temperature and moisture on the yield of the head-stem component of this species has also been shown by Cook et al. (1976) in pot culture.

In all species the emergence of inflorescences and the length of the flowering period appeared to be controlled by general growth conditions rather than by any specific factor such as daylength. Similar observations have been made for plants of B. macra (Cook et al. 1976) and A. ramosa (Harradine 1976) and in these two species, as well as D. sericeum, anthesis was observed to occur at any time of the year in the glasshouse (Ledge unpublished data). However, in a more arid environment, Williams (1961, 1971) suggested that the regular onset of flower initiation in spring flowering species such as S. scabra and Danthonia caespitosa may be attributed in part to changes in daylength. In contrast with the present study Williams (1971) noted that S. scabra and D. caespitosa have only one flowering period, but found that C. truncata may have two flowering periods if summer rainfall was adequate.

CHAPTER 8

SEED DORMANCY

Experiment 6

Seed dormancy is the failure of otherwise viable seed to recommence development immediately when supplied with water and oxygen at temperatures recognised as normally favourable for plant growth (Villiers 1972). In seed plants, dormancy is considered biologically advantageous in adapting the growth cycle of a plant to seasonal and adverse variations in environmental conditions. Seed dormancy may also have some significance in the manipulation of species composition as it may inhibit the germination of fresh seed (e.g. Mott 1972; Hagon 1976) or extend the storage period of germinable seed in the soil.

As dormancy may be an important factor controlling germination, experiments were conducted to investigate the length of the dormant state of some native grass seeds and the effects of light and the lemma, palea and glumes on germination.

A. Materials and Methods

Fully mature dispersal units of A. ramosa, B. macra, D. sericeum, S. elongatus, E. leptostachya, C. truncata, S. scabra and D. linkii were collected during April 1978 from Study area 1 site 1 and stored in paper bags at room temperature (12-27^{o}C). Dispersal units of A. ramosa, B. macra, D. sericeum, E. leptostachya, C. truncata, S. scabra and D. linkii are generally enclosed by structures, but those of S. elongatus are often naked caryopses.

To determine the length of dormancy the germination of each sample was tested at 14-day intervals from collection until units were 12-months old. Awns were removed from S. scabra units before use. The germination tests were conducted on 25 dispersal units of each species placed in four sterile plastic petri dishes containing filter paper moistened with distilled water. Temperature was maintained constant at 25^{o}C and irradiance was between 6.5 and 7.5 watts m^{-2}. After seven days germination was recorded if the radicle length exceeded the seed diameter and a plumule had emerged. The number of dispersal units of S. scabra was limited and for this species germination tests were conducted for only

20 weeks.

The effect of light on germination was determined by additional tests in the light and dark at 25°C, 20 and 40 weeks after collecting units; germinated seeds were counted after seven days. The effects of the structures enclosing the caryopses were determined on fresh seed and seed 12 months-old by testing dispersal units and naked caryopses under the above light and temperature conditions. Germination tests were conducted on four replicates of 25 dispersal units or naked caryopses of each species. Caryopses were obtained by gently rubbing units between corrugated rubber sheets. As the number of dispersal units of S. scabra was limited units that were 24 months old were used instead of those 12 months old. The results were analysed by standard statistical methods after transforming germination percentages to arcsin values.

At the end of the experiment viability of the seed samples used in this investigation was determined by a standard Tetrazolium test (Table 8.1) and the percentage of empty florets in the seed lots was also recorded.

Table 8.1. The percentage viability and the percentage of empty florets in the seed lots used in Experiment 6.

Species	% Viability	% Empty florets
A. ramosa	97	1
B. macra	98	9
D. sericeum	86	12
S. elongatus	82	0
E. leptostachya	85	4
C. truncata	88	8
S. scabra	78	2
D. linkii	100	17

B. Results

With time there were significant differences ($P < 0.001$) in the percentage germination of some species (Table 8.2). The germination percentage of A. ramosa, B. macra and S. elongatus tended to increase with time (Table 8.2), but that of D. sericeum, in particular, was relatively stable over the period. Initially, germination percentages were low in S. scabra and D. linkii but increased 8-16 weeks after units were collected. The initial germination percentages of A. ramosa, B. macra and S. elongatus were significantly lower ($P < 0.001$) than those at 14, 12 and 36 weeks, respectively after units were harvested.

Germination was significantly lower ($P < 0.001$) in the dark than in the light for whole dispersal units of B. macra, S. elongatus and E. leptostachya 20 weeks after collection (Table 8.3) and for the S. elongatus and E. leptostachya units 40 weeks after harvest. At both times E. leptostachya units failed to germinate and S. elongatus units had either nil or very low germination percentages in the dark.

Removal of the glumes and lemma and palea significantly increased ($P < 0.001$) the germination percentage of freshly harvested units of A. ramosa, B. macra, D. sericeum, C. truncata and S. scabra (Table 8.4). After storage for 54 weeks the germination of the caryopses of only two species, D. sericeum and D. linkii, were significantly higher than those of the whole dispersal units.

C. Discussion

No significant trends in time could be detected for the germination of whole dispersal units of D. sericeum, E. leptostachya and C. truncata. In D. sericeum, C. truncata and D. linkii the germination of units that were shed 12 months previously was inhibited by the lemma and palea and in these species these structures may have a long term role in dormancy. However, after the same period of storage, removal of the lemma and palea of E. leptostachya units did not significantly increase germination and in this species a longer period of storage or storage under different temperature regimes may be required to overcome physiological dormancy.

Table 8.2. Percentage germination of whole dispersal units of eight native perennial grasses at time intervals up to 12 months after unit collection. The arcsin transformations of the values are given in parentheses.

	Germination percentage								
	Number of weeks from unit harvest								
	2	8	16	24	32	40	48	52	LSD (P=0.001)
A. ramosa	28 (37.0)	32 (34.5)	55 (47.9)	62 (51.9)	68 (55.6)	66 (54.3)	60 (50.8)	75 (60.0)	(23.2)
B. macra	22 (28.0)	43 (41.0)	43 (41.0)	49 (44.4)	68 (55.6)	64 (53.1)	64 (53.1)	66 (54.3)	(17.5)
D. sericeum	25 (30.0)	24 (29.3)	19 (25.8)	18 (25.1)	32 (34.5)	27 (31.3)	16 (23.6)	31 (33.8)	(15.7)
S. elongatus	7 (15.3)	1 (5.7)	6 (14.2)	21 (27.3)	18 (25.1)	43 (41.0)	42 (40.4)	37 (40.0)	(20.7)
E. leptostachya	21 (27.3)	17 (24.4)	33 (35.1)	35 (36.3)	12 (20.3)	10 (18.4)	15 (22.8)	52 (46.2)	(35.2)
C. truncata	19 (25.8)	13 (21.1)	19 (25.8)	9 (17.5)	9 (17.5)	19 (25.8)	45 (42.1)	38 (38.1)	(18.3)
S. scabra	1 (5.7)	21 (27.3)	32 (34.5)	-	-	-	-	-	(19.5)
D. linkii	1 (5.7)	3 (10.0)	13 (21.1)	16 (23.6)	13 (21.1)	14 (22.0)	28 (32.0)	19 (25.8)	(14.9)

Two mechanisms of dormancy were apparent in the species studied. After varying storage periods the germination percentage of dispersal units of A. ramosa, B. macra, S. elongatus, S. scabra and D. linkii increased, indicating a breakdown of dormancy. In other grass species this loss of dormancy with time has been attributed to an increase in the biosynthesis of gibberellic acid in the caryopsis (Simpson 1965; Mott 1974) or loss of inhibitors from the lemma and palea (Hagon 1976). As the removal of the lemma and palea from freshly harvested units of A. ramosa, B. macra, D. sericeum, C. truncata and S. scabra significantly increased germination, these structures may have an equally important role in the germination of fresh seed of these species as the level of growth promoters or inhibitors in the caryopsis. In this study the exact nature of the physiological role of the lemma and palea in dormancy was not investigated, but they may contain inhibitors (Hagon 1976) or may either mechanically restrict germination, reduce oxygen transport to the embryo (Mott 1974), reduce imbibition or prevent the leaching of an inhibitor. Removal of the lemma and palea from fresh dispersal units of S. elongatus, E. leptostachya and D. linkii did not increase germination and in these species dormancy may involve an after ripening requirement of the embryo, related to either promoter (gibberellic acid) or inhibitor levels in the caryopsis.

A further mechanism for regulating germination appeared to operate in B. macra (20 weeks after harvest), S. elongatus and E. leptostachya, in that dispersal units of these species appeared to have an obligate light requirement for germination. However, dormancy in dispersal units of these species may be reduced further in the soil (Tothill 1977) and so in the field the apparent light requirement of these species may not affect their germination.

The main flowering period of native grasses in the study area commences in late spring and early summer (Experiment 5). Hagon (1976) proposed that seed dormancy would limit the germination of freshly fallen seed even if suitable temperature and moisture conditions occurred. However, this would only occur if dormancy in fresh seed was complete and its germination percentage was zero. In this study either freshly harvested seed or seed that had been collected two weeks previously showed some germination, indicating that some field germination of fresh seed would occur in these species if temperature and soil moisture conditions were

Table 8.3. Effect of light on the germination of eight native perennial grasses, 20 and 40 weeks after units were collected. The arcsin transformations of the data are given in parentheses.

	Germination %				
	Number of weeks from seed harvest				
	20		LSD	40	LSD
Light regime	Light	Dark	(P=0.001)	Light	Dark (P=0.001)
A. ramosa	81(64.2)	75(60.0)	(10.5)	66(54.3)	67(54.9) (10.8)
B. macra	60(50.8)	2(8.1)		64(53.1)	58(49.6)
D. sericeum	16(23.6)	12(20.3)		27(31.3)	19(25.8)
S. elongatus	6(14.2)	0(0)		43(41.0)	1(5.7)
E. leptostachya	11(19.4)	0(0)		7(15.3)	0(0)
C. truncata	18(25.1)	9(17.5)		17(24.3)	8(16.4)
S. scabra	25(30.0)	12(20.3)		-	-
D. linkii	25(30.0)	22(28.0)		24(29.3)	24(29.3)

Table 8.4. Percentage germination of whole dispersal units and caryopses of eight native perennial grasses for freshly harvested units and units stored for 54 weeks. The arcsin transformations of the data are given in parentheses.

	Germination %					
	Time from seed harvest					
	0 weeks			54 weeks		
	Dispersal unit	Caryopsis	LSD (P=0.001)	Dispersal unit	Caryopsis	LSD (P=0.001)
A. ramosa	22 (28.0)	63 (52.5)	(11.9)	72 (58.1)	72 (58.1)	(10.8)
B. macra	42 (40.4)	83 (65.7)		70 (56.8)	74 (59.3)	
D. sericeum	41 (39.8)	78 (62.0)		38 (38.1)	73 (58.7)	
S. elongatus	22 (28.0)	26 (30.7)		36 (36.9)	44 (41.6)	
E. leptostachya	26 (30.7)	23 (28.7)		26 (30.7)	40 (39.2)	
C. truncata	9 (17.5)	75 (60.0)		57 (49.0)	71 (57.4)	
S. scabra	2 (8.1)	54 (47.3)		16 (23.6)	13 (21.1)	
D. linkii	0 (0)	1 (5.7)		25 (30.0)	88 (69.7)	

suitable. The dormancy of whole dispersal units in the soil may also break down more rapidly than those studied under laboratory conditions (Tothill 1977) and this may further reduce the dormancy period of some species in the field. Therefore, the primary role of dormancy in the survival of these species seems to be to extend the period of germination. In a native or natural pasture this would ensure that not all of the seeds would germinate with the first occurrence of suitable rainfall and that at each successive rainfall event germinable seed would be available until the next seed fall. In this context long-term dormancy mechanisms may have an important role in that the longer the time from seed fall to the germination of the last viable seed, the more likely it would be that the right combination of weather and freedom from competition could occur for successful germination and establishment.

The successful use of native perennial grasses in either natural or artificial seeding of rangelands (Breakwell 1923; Hormay 1970) or in the colonisation of erosion areas (Cameron 1961) would depend on readily germinable seed. Satisfactory germination could perhaps be obtained by sowing carefully threshed caryopses of A. ramosa, B. macra, D. sericeum, C. truncata and S. scabra, or whole dispersal units of A. ramosa and B. macra that had been stored for 2-3 months or S. elongatus stored for 9 months. For a high level of germination D. linkii units would have to be stored for at least 3 months (Hagon 1976) and the lemma and palea removed.

CHAPTER 9

THE EFFECT OF TEMPERATURE ON THE GERMINATION OF EIGHT NATIVE PERENNIAL GRASSES

Experiment 7

The wide range of seasonal temperatures in the study area (Table 1.2; Appendix 5B) indicate that germination may be partially controlled by temperature. Accordingly the temperature response curves of germination for A. ramosa, B. nacra, D. sericeum, S. elongatus, E. leptostachya, C. truncata, S. scabra and D. linkii were determined.

A. Materials and Methods

Fully mature dispersal units of the abovementioned grasses were collected around Tamworth during March 1977 and stored in paper bags at room temperature (12-27°C). The effects of temperature on germination were determined with 22 month old non-dormant caryopses. Fifty caryopses of each species, except D. sericeum, were placed onto germination pads in small trays and moistened with tap water. Caryopses were obtained by gently rubbing units between corrugated sheets of rubber. There was a high proportion of empty florets in D. sericeum and only 25 seeds per tray were available for this species.

For each species thirty-six trays (9 temperatures x 4 replicates) were placed in moist sand on a temperature gradient plate (Larsen 1971) across which temperature varied evenly from 4°C to 47°C. The trays were placed in transverse rows perpendicular to the temperature gradient along rows of 5° temperature increments from 5°C to 45°C with four replicates of each species in each row. The temperature of each row, as measured by thermocouples, varied by ± 0.5°C over the tray width. Each of the trays were covered with a semi-circular shaped piece of Perspex and the whole plate was covered with a Perspex lid. Over the experimental period natural light (laboratory) was incident on the plate. Pads were kept moist by the addition of distilled water when necessary and counts of germination were taken at 24 hour intervals for 14 days. Germination was recorded when the radicle exceeded the small diameter of the caryopsis and a plumule had emerged. Total germination at all temperatures was analysed after

transforming germination percentages to arcsin values.

The germination rate index for each species was calculated as the sum of the quotients of the number of seeds germinating each day divided by the time in days from placing the seeds onto the moist pads (Maguire 1962).

The viability of the seed samples used in this investigation was determined at the end of these experiments by a standard Tetrazolium test. For each species percent viability was as follows: A. ramosa 100; B. macra 92; D. sericeum 92; S. elongatus 88; E. leptostachya 80; C. truncata 90; S. scabra 84 and D. linkii 95.

B. Results

At temperatures between 20-35°C for A. ramosa; 15-35°C for D. sericeum and C. truncata; 20-25°C for E. leptostachya; 20-30°C for B. macra and S. elongatus and 15-25°C for D. linkii and S. scabra (Table 9.1) germination was significantly higher ($P < 0.001$) than for the other temperatures. The preference of D. linkii and S. scabra for lower temperatures and of A. ramosa for higher temperatures is demonstrated both by their optimum temperatures and their broader optimum temperature range (Table 9.1). To obtain between species comparisons with such a wide range of maximum germination percentages the data in Table 9.2 were calculated for each temperature as a percentage of maximum germination. At 15°C the germination of D. linkii, S. scabra and C. truncata was significantly higher ($P < 0.001$) than that of most other species, and at 10°C D. linkii was the only species with a high relative germination percentage. Conversely, at 35°C the germination of A. ramosa, C. truncata, B. macra and D. sericeum was comparatively higher than that of all other species, and A. ramosa was the only species that had a high relative germination percentage at 40°C. Over the range of 15-35°C the germination of C. truncata and D. sericeum was always greater than 50%, indicating a marked plasticity in the temperature response curves for germination of these species.

There was little variation in the germination rate index (Fig. 9.1) of E. leptostachya, D. linkii and S. scabra between 20-30°C; B. macra and D. sericeum between 20-35°C; C. truncata between 15-35°C and A. ramosa

Table 9.1. Percentage germination of non-dormant caryopses of eight native perennial grasses at temperatures varying from 5°C to 45°C. The arcsin transformations of the values are given in parentheses.

	Germination percentage									
	Temperature °C									LSD
	5	10	15	20	25	30	35	40	45	(P=0.001)
A. ramosa	0 (0)	0 (0)	19 (25.8)	67 (54.9)	71 (57.4)	73 (58.7)	73 (58.7)	47 (43.4)	0 (0)	(6.2)
B. macra	0 (0)	0 (0)	17 (23.7)	53 (46.8)	61 (51.1)	49 (44.1)	36 (36.8)	10 (17.6)	0 (0)	(6.6)
D. sericeum	0 (0)	0 (0)	27 (31.3)	54 (47.3)	49 (44.4)	47 (43.3)	44 (41.4)	5 (11.1)	0 (0)	(14.2)
S. elongatus	0 (0)	0 (0)	2 (6.1)	26 (30.5)	38 (37.5)	37 (37.4)	12 (19.6)	2 (6.1)	0 (0)	(5.8)
E. leptostachya	0 (0)	0 (0)	0 (0)	13 (21.1)	7 (15.3)	5 (12.9)	2 (6.1)	0 (0)	0 (0)	(6.9)
C. truncata	0 (0)	0 (0)	46 (42.4)	57 (48.8)	57 (48.8)	57 (48.8)	43 (40.5)	8 (12.6)	0 (0)	(9.9)
S. scabra	0 (0)	4 (11.5)	74 (59.3)	81 (64.2)	72 (58.1)	61 (51.3)	34 (33.6)	0 (0)	0 (0)	(5.5)
D. linkii	0 (0)	76 (60.5)	98 (85.4)	97 (82.9)	99 (87.1)	75 (60.3)	38 (37.5)	0 (0)	0 (0)	(13.3)

between 20-40°C. The germination rate of S. elongatus varied only slightly between 25-30°C with a maximum at 30°C.

Table 9.2. The germination of each species at temperatures below 20°C and above 30°C, expressed as a percentage of the maximum germination for each of the species. The arcsin transformation of the data are given in parentheses.

	Germination percentage					
	Temperature °C					
	5	10	15	35	40	45
A. ramosa	0 (0)	0 (0)	26 (30.7)	99 (84.3)	64 (53.1)	0 (0)
B. macra	0 (0)	0 (0)	27 (31.5)	60 (50.8)	16 (23.6)	0 (0)
D. sericeum	0 (0)	0 (0)	57 (49.0)	67 (54.9)	9 (17.5)	0 (0)
S. elongatus	0 (0)	0 (0)	4 (11.5)	43 (41.0)	4 (11.5)	0 (0)
E. leptostachya	0 (0)	0 (0)	0 (0)	16 (23.6)	0 (0)	0 (0)
C. truncata	0 (0)	0 (0)	80 (63.4)	75 (60.0)	13 (21.1)	0 (0)
S. scabra	0 (0)	5 (12.9)	91 (72.5)	42 (40.4)	0 (0)	0 (0)
D. linkii	0 (0)	77 (61.3)	93 (81.9)	39 (38.7)	0 (0)	0 (0)
L.S.D. (P = 0.001)			(42.1)	(40.7)		

C. Discussion

Of the grasses tested D. linkii and S. scabra are yearlong green species which have lower optimum growth temperatures than the other species which are warm season perennials; for example, the optimum growth temperature for D. caespitosa is about 25/20°C (Hodgkinson and Quinn 1976), whereas the growth of B. macra increases linearly from 23/17°C to 31/25°C (Cook et al. 1976).

The temperature response curves indicated that the optimum temperatures for germination in most of these species were within the range of 20-30°C. Outside this range the germination percentages of D. linkii and S. scabra were higher at lower temperatures and those of the warm season grasses A. ramosa and D. sericeum improved at higher temperatures.

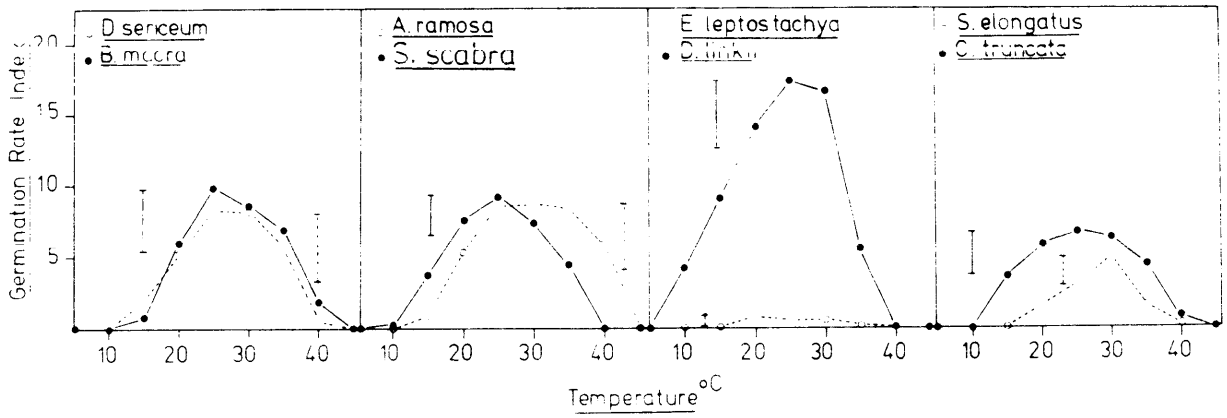

Figure 9.1 Germination rate index of eight native perennial grasses at temperatures varying from 5°C to 45°C. For each species the least significant difference between temperatures ($P < 0.001$) is indicated by an error bar.

However, at the lower temperatures the rate of germination of D. linkii and S. scabra was significantly below the maximum of 25°C, and adequate moisture conditions may be required for 7-10 days to achieve high germination percentages. Similar temperature response curves for germination have been shown for D. linkii and A. ramosa by Harradine (1976); for B. macra by Moore (1958) and for B. macra, D. sericeum and D. linkii by Watt and Whalley (1982). The curves determined by Watt and Whalley (1982) for seed collected at Inverell were essentially similar except that B. macra had a narrower range than D. sericeum and the latter had a wider range than in the present study. However, Hagon (1976) found that the germination percentage of Danthoria spp. and Stipa bigeniculata was not significantly affected by a temperature range of 15/5°C-35/25°C, but at 30°C the germination capacity of B. macra was significantly lowered. This suggests that the temperature response curves for germination may vary within species and within ecotypes of the different species. Also, alternating temperatures may more realistically represent the germination range compared with constant temperatures.

These results suggest that maximum germination from natural seedfalls or artificial sowings of D. linkii and S. scabra would occur from late autumn through to early spring and that high soil temperatures in summer (Appendix 5B) might restrict the germination of these yearlong green species. For the warm season native perennial grasses germination would be highest between late spring and early autumn and low temperatures in winter might limit the germination of these species. With adequate soil moisture D. linkii might germinate in mid-winter and A. ramosa in mid-summer.