

Management options in *Heteropogon contortus* grasslands in south-east Queensland: burning, high stocking rate with dry season supplementation and pasture oversowing

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Abstract

This paper reports changes in pasture production and composition and animal production in response to management and development options in a black speargrass (*Heteropogon contortus*) community. The initial study commenced in 1972 in south-east Queensland and measured the effects of tree killing, legume oversowing and pasture replacement at a range of stocking rates. In the second phase (1979–86), reported here, the effects of burning, high stocking rate with dry season supplementation and the timing of grass/legume oversowing were measured. During the study period, summer rainfall was mostly below average.

Burning of native pasture decreased overall yields and decreased cover by >10%. It also led to a decrease in *Aristida* species and an increase in *Glycine* species. Annual liveweight gain was similar to that from unburnt native pasture.

At the high stocking rate, there was no increase in *Aristida* species over the 8 years of the study, but there was an increase in *Bothriochloa decipiens* and a decrease in *Cymbopogon refractus*, both symptoms of pasture decline. Annual liveweight gains per head were maintained at similar levels to those on the burnt and unburnt native pasture by supplementing animals with urea-molasses over the dry season.

Oversowing green panic (*Panicum maximum* cv. Petrie) into old speargrass-siratro (*Macroptilium atropurpureum* cv. Siratro) pastures resulted in very good establishment but establish-

ment was very poor when green panic and siratro were oversown into unimproved speargrass pasture. Some of this failure was due to low rainfall in the season after planting. Even with successful establishment of green panic, there was little benefit to animal production over that from speargrass-siratro pasture.

The implications of each of the different management strategies and development options are discussed in relation to native speargrass and speargrass-siratro pastures.

Introduction

The black speargrass (*Heteropogon contortus*) region covers a total area of approximately 25 M ha in northern Australia (Weston *et al.* 1981) and is located predominantly in areas receiving 650–1000 mm rainfall, on freely draining soils (Tothill 1970). The dynamics of the speargrass community were reviewed by Grice and McIntyre (1995).

In the dry season, pasture quality is low, with protein levels as low as 1% (Christian and Shaw 1951; Shaw and Bisset 1955) and historically, this country was used mostly for cattle breeding, rarely for fattening. Methods developed to overcome this short-coming to improve conception rates and/or allow the possibility of fattening cattle included burning (Shaw 1957; Tothill 1971a), dry season supplementation and pasture oversowing.

Burning is generally done in the late wet-early dry season, when soil moisture is still available, or after the first rains in the late dry-early wet season (Tothill 1971a). It stimulates new growth of high quality feed, allows animals better access to the new growth, can be used to attract animals to previously ungrazed areas (Tothill 1971a) and reduces eucalypt regrowth (Tothill 1971b). A disadvantage of burning is that it removes much of the senesced material (Shaw 1957; Tothill 1971a), thus reducing ground cover and increasing the

risks of soil erosion (McIvor *et al.* 1995). The role of fire in management of pastoral lands in northern Australia is covered extensively in Grice and Slatter (1997). However, while burning was known to enhance germination of speargrass (Tohill 1969) and reduce the occurrence of *Aristida* species, at that time, little was known of the impact of regular burning on pasture production and composition of other species, particularly in south-east Queensland.

Owing to its relative cheapness and ease of provision (Morris 1958), supplementation with non-protein nitrogen and energy (urea-molasses) was used in northern Queensland to reduce weight loss in stock and mortality rates during the dry season. This was achieved through increased intake of the dry material remaining from the previous wet season, resulting in higher animal production (Winks *et al.* 1972; Falvey 1977). In the southern speargrass zone, most research had shown little or no direct benefits to animal performance (Foster and Blight 1984). The normal management strategy was for graziers to turnoff stock in autumn, thus reducing their stocking rate in the dry season, when feed quality was poor and weight losses occurred. With the advent of improved supplementation options, some considered that it might be possible to maintain their stocking rates over the dry season, and maintain animal condition by feeding supplements, *e.g.* silage or hay (Howard 1961) or the cheaper option of urea-molasses. In central Queensland, Shaw and Mannetje (1970) had reported a decrease in speargrass proportion in pastures at increased stocking rates, with an associated increase in unpalatable grasses and forbs. However, in the southern speargrass region, little was known of the impact of maintaining stocking rates over the dry season, when rates were usually reduced, on the potential for overall pasture degradation and/or changes in species composition. The impacts of such a management strategy needed to be assessed.

A third method of improving the quality of dry season pasture was to introduce a legume. This had been done successfully on speargrass country in central Queensland using *Stylosanthes* species (Hacker *et al.* 1982), and in southern Queensland using siratro (*Macroptilium atropurpureum* cv. Siratro) (Mannetje 1967; Lowe 1974; Tohill *et al.* 2008a, 2008b). Further, Tohill *et al.* (2008a) had shown that, with the increases in soil fertility from the legume, there had been an increase in

nitrophilous species such as *Digitaria ciliaris* and *Conyza bonariensis*, suggesting that other more palatable and productive grass species could be introduced into speargrass pasture. However, this raised two questions: should the grass species be sown with the legume, or after a delay when the legume had improved soil fertility; and, what would be the impact on animal production?

The results of an experiment examining the impacts of tree killing, legume oversowing, stocking rate and pasture replacement on pasture production and composition, and animal production, were presented in Tohill *et al.* (2008a; 2008b). This paper examines the impacts of burning, high stocking rate with dry season supplementation, and pasture oversowing on animal and pasture production and composition. Although the experiment was conducted some years ago, most of the findings are still highly relevant. Some 30–70% of producers in northern Australia use supplements (Bortolussi *et al.* 2005a), 80–90% regularly use fire as a management tool (Bortolussi *et al.* 2005b), 30–50% are still using a combination of native and introduced pastures (Bortolussi *et al.* 2005c) for beef production and most see a future for tropical pasture plants (McDonald and Clements 1999).

Materials and methods

Site

The experiment was located on the former CSIRO Narayan Research Station (25° 41' S, 150° 52' E) in south-east Queensland. The original vegetation was grassy eucalypt woodland dominated by silver-leaved ironbark (*Eucalyptus melanophloia*) (Coaldrake *et al.* 1972). The soil is a yellow-red podzolic (paleustalf or albic luvisol), or yellow chromosol (Isbell 1993), derived from granite.

The climate is subhumid subtropical with a mean annual rainfall of approximately 700 mm, which falls predominantly in summer (December – March). Low rainfall and low minimum temperatures (including frosts) severely reduce plant growth in winter. Detailed meteorological information is available in Cook and Russell (1983).

Treatments

The initial experiment was established during 1971–72. In the initial phase (1972–77), the following treatments: tree killing (N), tree killing plus legume oversowing (NS) and pasture replacement, were compared at a number of stocking rates (Tothill *et al.* 2008a). The second phase (1979–86) comprised a set of core treatments from the first phase, but at a reduced number of stocking rates, augmented with the new treatments of burning native pasture (BnN), increased stocking rate with dry season supplementary feeding of cattle on native pasture (SpN), oversowing improved pasture grasses into established native-siratros pastures (P/NS, high soil fertility) and oversowing improved grasses plus siratro into native pastures (PS/N, low soil fertility), at high and low stocking rates. The new treatments and their relationship to previous treatments are given in Table 1. There were 2 replications of each treatment.

In the PS/N and P/NS treatments, 200 kg/ha single superphosphate plus molybdenum at 300 g/ha was applied in conjunction with the initial pasture sowing operations. Subsequently, 100 kg/ha triple superphosphate was applied aerially to the PS/N and P/NS treatments at 3-yearly intervals.

Burning (BnN). In this treatment, cleared native pastures could be burned in only 3 of the 5 years (1979, 1981 and 1982), as there was insufficient fuel load for a successful burn in the other years. Burning was carried out after a reasonable rainfall event (ca. 25 mm) at the end of the dry season. Burning was discontinued after 1983 to allow realistic comparisons of animal production between treatments to be made, without confounding effects of destocking. Prior to the initial

treatment, the pastures had not been burnt for a period of 10 years.

High stocking rate with dry season supplementation (SpN). Generally, the stocking pressure on native pasture would be reduced in the dry season as described above. However, in this trial, the stocking rate on the native pasture control was maintained throughout the year. To test the impacts of increased stocking pressure made possible by increased intake following supplementation on native pastures, the stocking rate on this treatment was increased to 0.67 hd/ha. While this is a large increase, it was set at this level for two reasons. Firstly, supplementation can increase animal intake by up to 30% (Winks *et al.* 1976) without increasing stock numbers. Maintaining stock numbers over the dry season would increase the stocking pressure even further over what was normal. Secondly, at 0.67 hd/ha it was reasonably comparable with the low stocking rate on the improved native pasture (NS_{0.75}). The dry season supplement of urea-molasses was provided *ad libitum* in block form to animals from change-over time (after the May animal weighing) until new season growth commenced, each year from 1979 to 1983 inclusive. The composition (%) of the blocks was: molasses (dried) 54.6, urea 21.7, crude fat 5.5, phosphorus 1.4, calcium 2.2, salt 2.0, sulphur 1.0, plus minor components of copper, zinc, cobalt, manganese, potassium, magnesium and vitamins A and D. It should be noted that the purpose of this treatment was to study the impact of increased stocking rate/pressure on the native pasture, and any subsequent impacts on animal production, not to study the benefits, or otherwise, of urea-molasses supplements. The latter served only to facilitate the maintenance of the higher stocking rate; hence, no measurements were taken of supplement intake.

Table 1. Treatments and stocking rates for the period 1979–86 and their relationship with previous treatments: N = native pasture without trees; NS = native pasture without trees, oversown with siratro; BnN = native pasture burnt annually; SpN = high stocking rate native pasture with dry season supplementation; P/NS = green panic oversown into old NS pasture; PS/N = green panic + siratro oversown into native (N) pasture. Subscripts indicate the stocking rate in hd/ha.

Old treatment	N _{0.18}	N _{0.29}	N _{0.41}	NS _{0.41}	NS _{0.75}	NS _{0.93}
New treatment	PS/N _{0.75}	BnN _{0.41}	N _{0.41}	P/NS _{0.75}	NS _{0.75}	NS _{1.11}
	PS/N _{1.11}			P/NS _{1.11}		
	SpN _{0.67}					

Effect of fertility status on the establishment of oversown grass. In January 1979, pastures on these treatments were oversown with green panic (*Panicum maximum* cv. Petrie) at a seeding rate of 2 kg/ha. Green panic was chosen as it had shown better establishment than buffel grass in preliminary findings of Cook and Dolby (1981). For the PS/N treatment, siratro was included in the mixture at 4 kg/ha. To enhance seed setting by siratro and green panic, the oversown treatments were spelled for 6 weeks from mid-March to early May each year until 1983. Animals were grazed in an adjacent laneway of native pasture during this period, so that the overall stocking rate on these treatments was effectively some 10% lower than the nominal rate indicated in Table 1. While this could have advantaged live-weight gain in these treatments compared with others, the lack of access to a legume during this period would have been a disadvantage.

Stocking rates. Stocking rates were based on locally derived levels for black speargrass pastures in the area and from the trial experiences of Mannetje and Butler (1991) and Tothill *et al.* (2008a; 2008b) at Narayen. All treatments were set-stocked with mostly Belmont Red steers. Animals were introduced as weaners at 6–8 months of age (170–220 kg) and remained on the trial for 2 years, with the older 2 or 3 animals in each paddock being removed each year. Paddock sizes varied from 5.6 to 9.6 ha so that 4 or 5 animals made up each treatment.

Measurements

Animals were weighed at 5 strategic times during the year. The times selected were those that, based on the previous 5 years of information, coincided with times of significant change in the rate of liveweight change, *i.e.*, late dry season-early wet season and late wet season-early dry season.

Pasture composition, pasture presentation yields and pasture species frequency were estimated using the procedures outlined in the BOTANAL package (Tothill *et al.* 1992), annually at the end of the main pasture growing season (March–April). Pasture composition was determined using the dry-weight rank method (Mannetje and Haydock 1963), adjusted for quadrat weight (Jones and Hargreaves 1979) with species apportioned into green and dry. Presentation

yield was determined using the visual estimation technique of Haydock and Shaw (1975). Animal intake was calculated from animal live weight and rate of gain using the formula of Minson and McDonald (1987). Intake was apportioned into green and dry components based on preliminary diet selection studies by R. McLean (personal communication). Utilisation (%) was calculated by expressing the estimated annual intake as a proportion of total growth (end of season presentation yield + estimated intake in the growing season). It was assumed that all growth from the previous growing season decomposed by the end of the current season. A visual estimate of ground cover was done simultaneously with pasture estimates, on the basis of projected foliar and/or litter cover within each quadrat.

Temperature data were recorded daily at the official weather station for Narayen, located 3–4 km north-west of the experimental site. Rainfall was recorded daily at the experimental site.

Statistical analyses

The data analysed for pasture yields were green and total (green + dead) dry matter yields of speargrass, siratro, other grasses and forbs and total green dry matter yields. For pasture composition, except for total values, the same parameters were analysed as for pasture production.

Animal liveweight gains were analysed using ANOVA on an annual and seasonal basis using data for individual animals, with initial live weight as a covariant. Different management/feeding strategies such as burning or high stocking rate with supplementation were designed to reduce the dry season protein deficiency and increase energy intake. An alternative feeding strategy was to provide protein by way of a legume; hence, for analysis of animal production, the NS treatment stocked at 0.75 hd/ha (Tothill *et al.* 2008b) was included as a comparison with N, BnN and SpN.

The analyses were carried out using GENSTAT © 1980 Lawes Agricultural Trust (Rothamstead Experimental Station) using a completely randomised design with 2 replications.

Results

Climate

Rainfall over the experimental period was below average (Figure 1), and considerably less than in the first phase of the experiment (Tothill *et al.* 2008a). Only 3 out of 8 years had above median annual (691 mm) or spring–summer (488 mm) rainfall, and 5 of the 8 years had spring–summer rainfall below decile 3 (401 mm), based on long-term (1885–1998) records.

Mean monthly minimum temperatures ranged from 6.6°C in July to 19.3°C in January, while mean monthly maximum temperatures ranged from 19.6°C to 32.2°C, and grass minimum temperatures from 2.7°C to 17.3°C. There was an average of 27 frosts per year, with the highest number of heavy frosts (grass minimum < -2.2°C) occurring in the winter of the very dry year 1982, with none in the following winter, when rainfall was well above average.

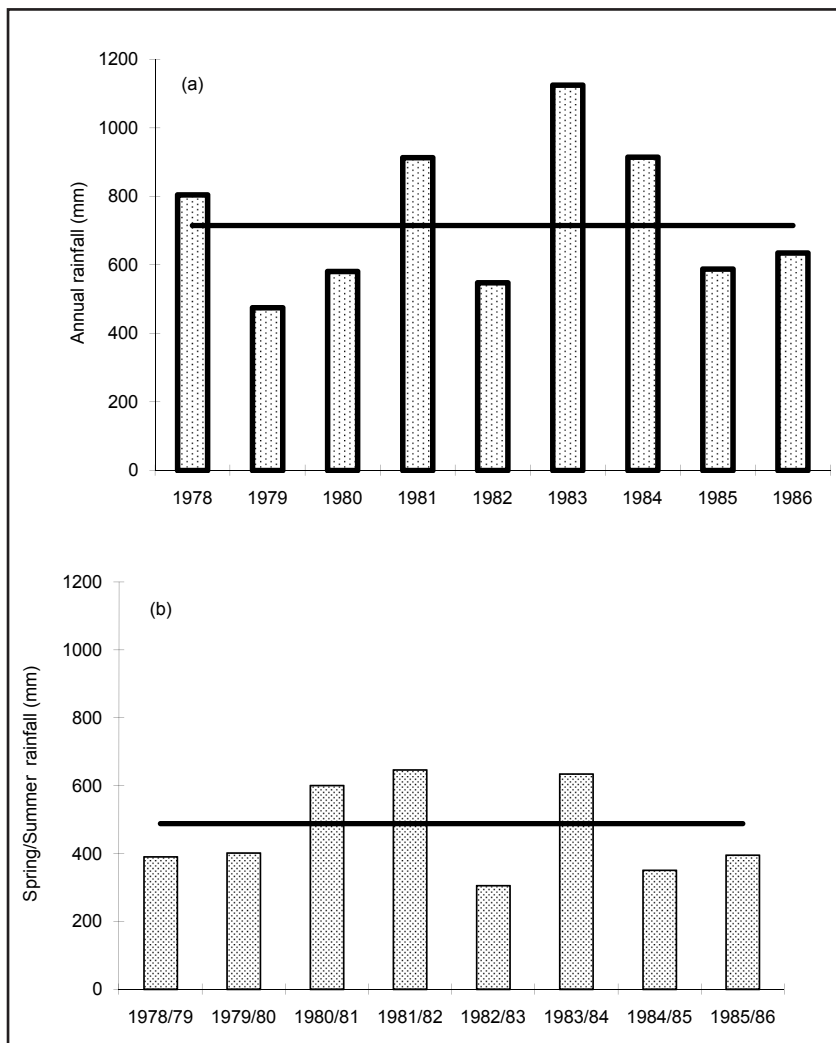


Figure 1. Actual (bars) rainfall during the study period (1979–1986) and long-term median rainfall (line): (a) annual; (b) spring–summer (October–March).

Pasture yield and composition

Effect of burning and high stocking rate plus supplementation (BnN vs SpN vs N). Total green presentation yields were lower in the burnt treatment (BnN) than the unburnt (N) treatment every year, though these differences were significant ($P < 0.05$) in 1985 only (Figure 2a). Total green yields in the SpN treatment were intermediate between BnN and N treatments in every year except the first.

Speargrass yields were similar for BnN, SpN and N treatments in every year except 1984, when the yield in BnN was significantly greater ($P < 0.01$) than those in SpN and N (Figure 2a). However, the frequency of speargrass decreased over time in the N treatment, while remaining constant in BnN and SpN (Table 2). With burning, and the increased stocking rate in SpN, there was a significant reduction in the 'other grass' component in 5 of the 8 years (from 1982 onwards) and in the overall mean (Figure 2a). These differences were evident in the first year also, although the differences were not significant.

There was considerable difference between treatments in the species contributing most to the 'other grass' component (Figure 2b). Erect wiregrass (*Aristida* spp.) and *Sporobolus elongatus* were less ($P < 0.05$) in treatment BnN, while *Bothriochloa decipiens* was greater ($P < 0.05$) in treatments SpN and N and *Cymbopogon refractus* was greater ($P < 0.05$) in treatment N.

Yields of forbs were generally reduced with burning (Figure 2a), though yield was significantly different ($P < 0.05$) from that in treatment N in only 2 out of 8 years (1983 and 1985) and in SpN in 1983 only. There was a large proportional increase ($P < 0.05$) of *Glycine* spp. with burning and a lesser increase ($P > 0.05$) in treatment SpN when compared with treatment N. *Aster subulatus* and *Conyza bonariensis* were reduced in BnN compared with SpN and N.

Cover was substantially reduced with burning (BnN) and increased stocking rate (SpN) (Table 2). The differences between N and BnN were significant ($P < 0.05$) for the 8-year mean and 3 of the individual years. Similarly, differences between N and SpN were significant ($P < 0.05$) for the 8-year mean and 2 of the individual years. Estimated utilisation rates averaged 21, 27 and 38% in the N, BnN and SpN treatments, respectively,

with values up to 50% in some years in the SpN treatment.

Effect of fertility status on the establishment of oversown grass. Establishment of green panic in the low fertility (PS/N) treatment was very poor (Table 3). This may have been exacerbated by the relatively unfavourable climatic conditions following sowing. In the high fertility treatment (P/NS), green panic increased in yield and frequency until the very dry period of 1982–83 and declined and remained low in the years after that.

As the green panic was not oversown until January 1979 and there was very little of it in the pastures until 1980, the first 2 years have been omitted from treatment comparisons of green yield and percent composition. Total green yield was significantly greater ($P < 0.05$) overall for the 6 years 1981 to 1986 in treatment P/NS than in NS or PS/N (Figure 3a). When compared at the equivalent stocking rate of 0.75 hd/ha, sub-treatment P/NS_{0.75} generally produced higher yields than NS_{0.75} and PS/N_{0.75} (Figure 3a). Results were similar at a higher stocking rate of 1.11 hd/ha. Overall, the low stocking rate had significantly higher ($P < 0.01$) green yield than the high stocking rate, but this effect was stronger in treatments NS and P/NS in the early years (Figure 3a), and lessened with time. Yields of speargrass were significantly lower ($P < 0.05$) in the high stocking rate than the low rate in most treatments in most years, and when averaged over the 6 years.

Although the yields of speargrass in the PS/N treatment were similar to those in the NS and P/NS treatments, owing to the lack of green panic and/or siratro, it represented a higher proportion of the total yield (Figure 3b). Siratro yield and frequency declined in the P/NS and PS/N treatments over the 6-year period (Table 3), while other grasses and forbs fluctuated with seasons. The proportion of green panic declined at the high stocking rate, but remained relatively constant at the low stocking rate (Figure 3b).

Animal production

Burning, high stocking rate plus supplementation and legume (BnN vs SpN vs N and NS). Annual liveweight gain (LWG) per head was quite variable between treatments with no difference overall. Gains/ha from the NS treatment at 0.75 hd/ha (NS_{0.75}) were significantly higher ($P < 0.05$)

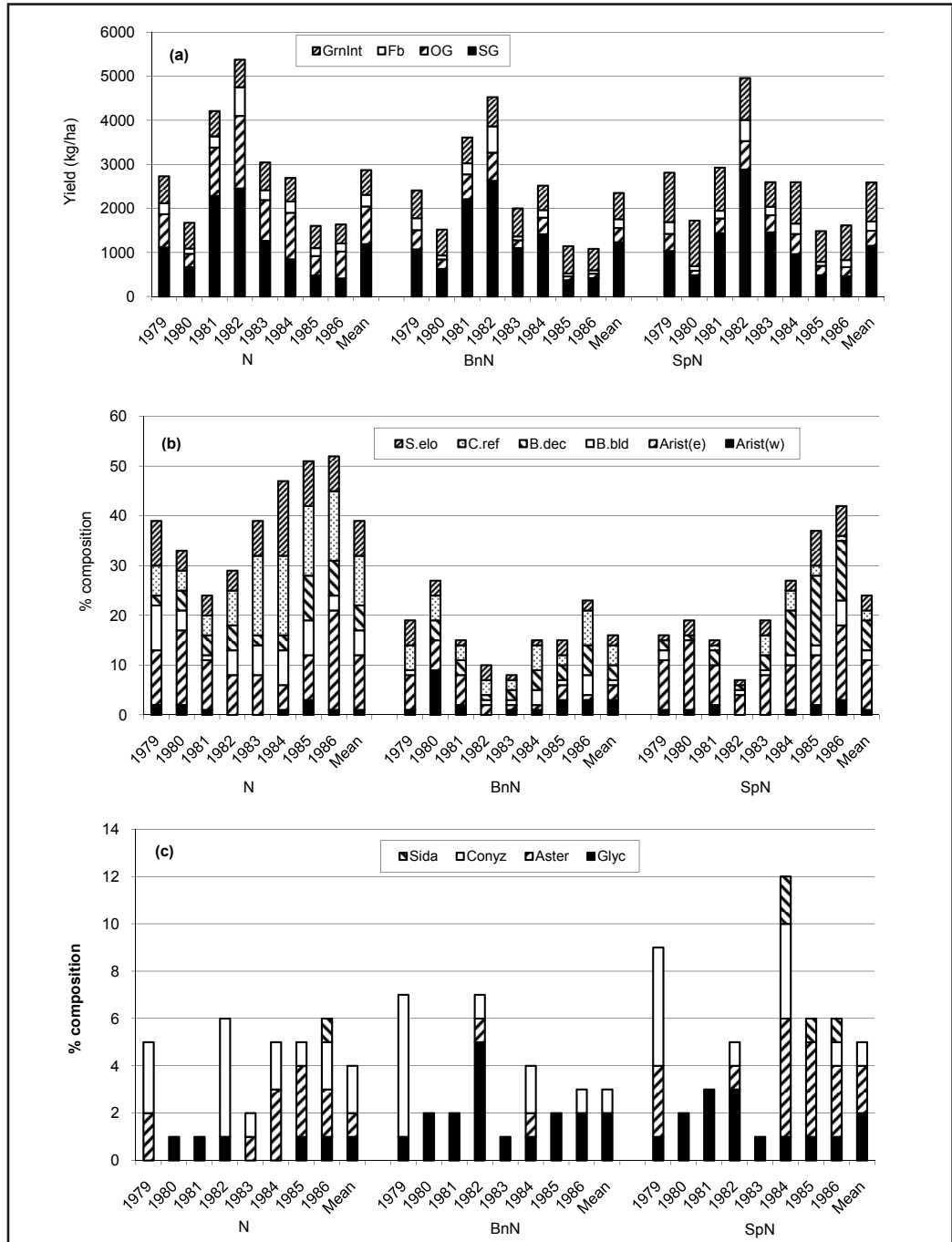


Figure 2. Effects of late dry season burning and high stocking rate with dry season urea-molasses supplementation on pasture yield and composition, 1979-86, for each year and overall mean. (a) Green yield and estimated intake of green material over the growing season for individual years by treatments: N = native pasture control; BnN = native pasture burnt; SpN = high stocking rate native pasture plus supplementation, for speargrass (SG), other grasses (OG) and forbs (Fb), plus green intake (GrnInt); (b) proportion of total yield of individual other grass species - weeping *Aristida* spp. (*Arist(w)*), erect *Aristida* spp. (*Arist(e)*), *Bothriochloa bladhii* (*B.bl*), *B. decipiens* (*B.dec*), *Cymbopogon refractus* (*C.ref*) and *Sporobolus elongatus* (*S.elo*); (c) proportion of total yield of individual forb species - *Glycine* spp. (*Glyc*), *Aster subulatus* (*Aster*), *Conyza* spp. (*Conyz*) and *Sida* spp. (*Sida*).

Table 2. Frequency of occurrence of speargrass and cover for native pasture control (N), burnt native pasture (BnN) and high stocking rate native pasture with dry season supplementation (SpN) for 1979–86. Values in the same row for each group (frequency of occurrence and cover) followed by a different letter are significantly ($P < 0.05$) different.

Treatment	Frequency			Cover		
	N	BnN	SpN	N	BnN	SpN
		(%)			(%)	
1979	88	91	90	77	68	66
1980	87	95	96	73	66	64
1981	94	94	98	85a	77ab	71b
1982	84a	94ab	98b	92a	73b	86ab
1983	75a	96b	94b	83a	50b	71ab
1984	72a	96b	93b	80	77	71
1985	71a	97b	90b	69a	53b	54b
1986	71a	95b	90b	76	70	69
Mean	80	94	93	79a	67b	69b

Table 3. Total presentation yield, composition and frequency of occurrence of green panic in autumn each year, oversown into native (PS/N) and native-siratiro (P/NS) pastures, and for the siratiro in these pastures. Values are the mean of 2 stocking rates. (tr = trace).

Year	Low fertility (PS/N)			High fertility (P/NS)		
	Yield	Comp.	Freq.	Yield	Comp.	Freq.
	(kg/ha)	(% DM)	(%)	(kg/ha)	(% DM)	(%)
Green panic						
1979	6	0.2	5	11	0.6	7
1981	tr	tr	tr	440	9.8	35
1982	tr	tr	tr	1340	18.0	43
1983	1	0.1	1	740	17.3	17
1984	tr	tr	1	270	11.5	34
1985	tr	tr	tr	120	9.2	14
1986	tr	tr	tr	850	14.9	18
Siratiro						
1979	33	1.2	15	263	15	92
1981	25	1	6	730	15	84
1982	83	2	18	1485	21	94
1983	16	0.5	5	220	7	60
1984	7	0.3	5	135	6	55
1985	1	0.1	1	45	4	27
1986	1	0.1	1	173	7	48

than from the other treatments in most years (Table 4). After the very dry year in 1982–83, LWGs per head and per hectare were lower in all 4 treatments than in the previous 5 years. There was no significant difference in LWG between the N and BnN treatments.

Overall, treatments produced similar LWGs in the different seasons. The only significant differences were in LWG/ha in spring–summer, when SpN and NS produced higher gains than N and BnN (Table 4).

Oversowing grass into pasture. Annual LWGs per head and per hectare were generally higher on the old siratiro-based pastures (NS and P/NS) than on the newly oversown pastures (PS/N) (Table 5). Despite the benefits of the oversown green panic, LWG from the P/NS treatment was significantly better ($P < 0.05$) than from the NS treatment in 1980–81 only.

LWG/head was higher at the lower stocking rate (0.75 vs 1.11 hd/ha) in all years, but significantly higher ($P < 0.01$) in only 2 years. Conversely, LWG/ha was lower at the low stocking

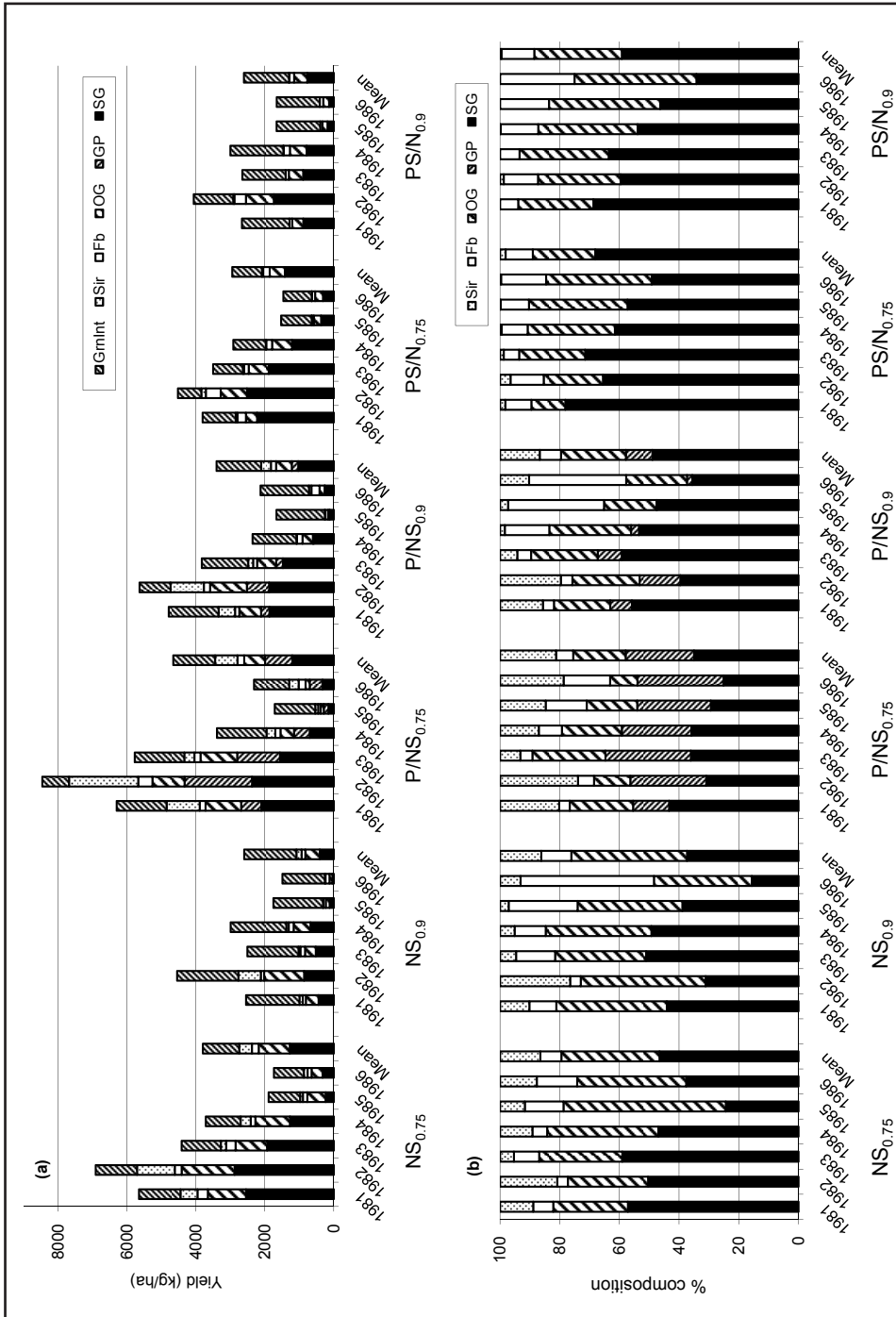


Figure 3. Effects of soil fertility status on establishment of green panic and siratro for each treatment for individual years: (a) green yield and estimated intake of green material over the growing season for main pasture components: speargrass (SG), green panic (GP), other grasses (OG), forbs (Fb) and siratro (Sir), plus green intake (GrMint); (b) proportion of total yield of main pasture components of speargrass, green panic, other grasses, forbs and siratro.

Table 4. A comparison of annual and seasonal animal liveweight gains from different feeding/management systems: N – cleared native pastures; BnN – native pastures burnt annually; SpN – native pastures at a high stocking rate with animals supplemented with urea-molasses in the dry season; NS – native pastures plus siratro. Values within the same year and group followed by different letters are significantly different ($P < 0.05$).

Treatments	Liveweight gains							
	N	BnN	SpN	NS	N	BnN	SpN	NS
Stocking rate (hd/ha)	0.41	0.41	0.67	0.75	0.41	0.41	0.67	0.75
No. animals	8	8	10	8	8	8	10	8
<i>Annual</i>			(kg/ha)			(kg/hd)		
1978–79	54.7b	63.4b	105.6a	95.0a	133.4y	154.8xy	160.0x	126.6y
1979–80	60.5b	60.2b	88.4b	121.0a	147.6y	146.8y	134.0y	161.4x
1980–81	55.5c	59.4c	92.2b	130.9a	135.3y	144.9y	138.2y	174.5x
1981–82	51.1b	57.1b	62.6b	106.1a	124.8x	139.4x	94.9y	141.5x
1982–83	52.1b	52.9b	68.4b	101.8a	127.0x	129.0x	103.6y	135.8x
1983–84	45.4b	42.6b	49.9b	98.3a	110.8xy	103.9y	75.6y	131.1x
1984–85	40.3b	52.8b	54.6b	84.8a	98.4xy	128.9x	82.8y	113.0x
1985–86	30.1b	33.1b	52.4ab	77.6a	73.4y	80.7xy	79.4xy	103.5x
Mean	48.7b	52.1b	71.8b	101.9a	118.8	128.6	108.6	135.9
<i>Seasonal averages 1978–83</i>								
Winter	-8.2	-7.8	-12.7	-5.4	-20.0	-18.9	-17.6	-7.2
Spr–Sum	57.7b	60.3b	93.3a	102.4a	140.7	147.1	126.8	136.5
Autumn	5.3	6.0	10.1	14.0	13.0	14.8	13.7	18.7

rate in all 6 years, but significantly so ($P < 0.05$) in only 3 years.

Discussion

This study has demonstrated the benefits of a number of management options for speargrass pastures in south-east Queensland. While burning of native pasture decreased *Aristida* species and overall yields, and decreased cover by $>10\%$, annual liveweight gain was similar to that from unburnt pasture. At the high stocking rate, supplementing animals over the dry season with urea-molasses maintained annual liveweight gain per head. Although there was no increase in *Aristida* species over the 8 years, there was an increase in other species symptomatic of pasture decline. Oversewing green panic into old speargrass-siratro pastures resulted in successful establishment, but oversewing green panic plus siratro into native pasture was a complete failure. Even with the successful establishment of green panic, there was little benefit to animal production over that from speargrass-siratro pasture.

Climate

While rainfall was well below the long-term average, when compared with records for the more recent 30-year period (1969–98), rainfall during the experimental period (1979–86) was closer to normal, with 4 out of 8 years below median annual (633 mm) and 5 years below median spring–summer (414 mm) rainfall, and only 2 spring–summers below decile 3 (382 mm).

Burning native pasture

Owing to the dry conditions that prevailed for much of the experimental period, burning could be carried out in spring of 1978, 1981 and 1982 only. The burn of 1978 was the first for more than 10 years. The lower green yield on the burnt treatment than on the unburnt treatment does not support the generally held view that burning promotes growth; however, the yield estimates were taken some 6 months after burning. Burning reduced the yield and composition of wiregrass (erect *Aristida* spp.), as had been reported by Orr *et al.* (1997). This contrasts with the findings of Orr (2004), but different taxonomic units were used in that study and what we referred to as ‘erect *Aristida*’ was similar to

Table 5. Effects of oversowing green panic into native pasture systems on annual animal liveweight gains averaged over stocking rates of 0.75 and 1.11 hd/ha: NS – native pasture plus siratro; P/NS – green panic oversown into old NS pastures; PS/N – green panic and siratro oversown into cleared native pasture. Stocking rate comparisons (LSR – 0.75 hd/ha; HSR – 1.11 hd/ha) are averaged over treatments. Values within the same year and group followed by different letters are significantly different ($P < 0.05$). Note: the P/NS and PS/N treatments were rested for 6 weeks (March–May) each year until 1983, and cattle grazed adjacent native pasture only during this period.

Treatment	Annual liveweight gains									
	NS	P/NS	PS/N	NS	P/NS	PS/N	LSR	HSR	LSR	HSR
No. animals	18	18	18	18	18	18	24	30	24	30
		(kg/ha)			(kg/hd)		(kg/ha)		(kg/hd)	
1980–81	147.7b	171.3a	110.8c	158.2y	180.0x	116.8z	116.7	129.8	156.9	146.3
1981–82	136.2a	120.4ab	99.4b	142.5x	127.9xy	106.1y	96.3n	141.0m	129.5	121.6
1982–83	124.6a	136.9a	84.5b	131.5x	147.8x	90.7y	98.7n	132.0m	132.8	113.8
1983–84	114.3	119.6	108.5	130.7	132.7	116.9	104.9	123.2	141.3p	106.2q
1984–85	100.1ab	114.4a	85.0b	106.2xy	126.7x	90.6y	90.9	108.7	122.3p	93.7q
1985–86	88.9	95.3	81.5	95.0	98.9	87.0	71.5n	105.6m	96.2	91.0
Mean	118.6ab	126.3a	95.1b	127.4xy	135.7x	101.4y	96.5	123.4	129.8	112.1

what they referred to as ‘coarse *Aristida*’. Both Tothill (1969) and Orr *et al.* (1997) indicated that speargrass was enhanced by burning, whereas we found that the frequency of speargrass was maintained under burning and decreased without burning, even though actual yields were similar on the 2 treatments. This might have been a reflection of a lack of speargrass recruitment in N pastures (Orr *et al.* 2004) and insufficient spelling of the BnN pastures after burning. Orr and Paton (1997) indicated that greater benefits were obtained if pastures were spelled for 4–6 months after burning, or grazed at half the stocking rate. Burning reduced the overall proportion of other grasses and forbs, and also changed the species composition. While *Bothriochloa decipiens* and *Cymbopogon refractus* increased in the unburnt pasture, these species remained constant in the burnt pasture. Similarly, *Glycine* spp. became the predominant forb species in the burnt treatment, whereas *Aster subulatus* and *Conyza bonariensis* were the predominant species in the unburnt treatment (Figure 2c).

The small differences in liveweight gain (10 kg/hd, 3 kg/ha) between the burnt and unburnt treatments, even in the years following the burns, support the findings of Ash *et al.* (1982), who reported increases of only 8 kg/hd from burning, but contrasts with the 40 kg/hd reported by some commercial producers (Grice and Slatter 1997). Winter (1987) reported substantial increases in liveweight gain from burning pastures in the Northern Territory, but in that case, only half the

paddock was burnt. This may well explain the differences between commercial and research results. In most research experiments, the whole area is burnt. While burning improves pasture quality and accessibility to green leaf, it reduces available dry matter, which can then lead to feed shortages later in the year, particularly in the dry season (Anderson and Pressland 1987). Burning only part of a paddock alleviates this problem and could explain the higher benefits observed by Winter (1987) and commercial producers.

Before pastures are burned, a range of issues need to be considered. While there may be substantial benefits, *e.g.* reduction of woody weeds, reduction of some *Aristida* species and alleviation of patch grazing (Grice and Slatter 1997) and some benefits in animal production, fire also reduces ground cover, which can lead to increased erosion (McIvor *et al.* 1995) and can impact adversely on biodiversity (Grice and Slatter 1997).

High stocking rates plus dry season supplementary feeding with urea-molasses

At the time of this experiment, supplementary feeding was changing from an aid to survival in drought times to a more general use of routinely supplementing during the winter–spring season. In north Queensland on speargrass pastures, Winks *et al.* (1976) reported that supplementing weaners with urea-molasses supplements during the dry season increased feed intake by about

30%. This effectively increased stocking pressure by a corresponding amount. If graziers kept animals during the dry season that would otherwise be turned off, this would increase stocking pressure even further. Our study increased stocking rate by 60% in an attempt to simulate this increased grazing pressure on speargrass pasture, and to make the pressure comparable with that on the speargrass-siratro pasture. However, after 8 years at the increased stocking rate, there were only limited signs of pasture deterioration (*i.e.*, decreased speargrass, increased erect *Aristida* spp.) occurring. The most noticeable changes were the decrease in biomass and ground cover, reflecting the increased consumption with the higher stocking rate. In terms of pasture composition, there was an increase in *Bothriochloa decipiens* and a decrease in *Cymbopogon refractus*, both indicators of heavy grazing. However, the proportion of wiregrass (erect *Aristida* spp.) remained virtually the same in the high stocking rate treatment (SpN) and the native pasture control treatment (N). While the lack of change in pasture composition at this high stocking rate is somewhat difficult to explain, it is in agreement with the findings of Orr *et al.* (2001) in central Queensland. They experienced an even drier period than those in this trial, which suggests that adverse climatic conditions may limit the opportunity for differences between treatments to emerge.

In north Queensland, deficiency in rumen degradable protein is the major factor limiting animal intake during the dry season and responses to feeding urea-based supplements occur (Winks *et al.* 1979). However, in central and southern Queensland, benefits to urea-molasses supplements have been inconclusive (Graham *et al.* 1983; Foster and Blight 1984). While we did not have direct comparisons, our results suggest benefits to urea-molasses supplements occurred in some years. Animals in the high stocking rate (plus dry season supplement) treatment (SpN) had similar liveweight gains/head to those on the low stocking rate native pasture control treatment (N) but, in most years, gained significantly less than those in the native-siratro treatment (NS) at a similar stocking rate. However, in the first year, when pasture yields were similar in all 3 treatments, liveweight gain was significantly higher in the SpN treatment than in the N or NS treatments. Further, liveweight gain during the following 4 years, when supplement was supplied,

was only 20% lower than that in the NS treatment while pasture yields were 40% lower, but in the 3 years after supplementation ceased, liveweight gain was 30% lower, while pasture yields were only 30% lower. Since there was ample pasture available in the N and NS treatments (*i.e.*, available dry matter was non-limiting), this suggests that both poor pasture quality (low digestibility/slow rate of digestion/low digestible energy) and low rumen degradable nitrogen limit animal intake in southern Queensland during the dry period in winter-spring and the primary limiting one will vary between years and situations.

Introducing an improved grass into improved native pasture

The observed increase in annual nitrophilous grasses in native pastures, which had been improved by the introduction of siratro (Tothill *et al.* 2008a), indicated that a suitable ecological niche for the introduction of a desirable improved grass existed. Green panic had been found to be an easily established and self-regenerating perennial grass of good forage value. This study tested 2 options: a 1-stage process, where the grass and legume (green panic and siratro) were oversown simultaneously into an unimproved native pasture (PS/N), with the hope that the legume would establish and boost soil fertility; and oversowing the grass into existing native-siratro pastures (P/NS), representing a potential 2-stage process, where legume oversowing would improve both quality of the available pasture and soil fertility in the initial phase, followed some years later by oversowing an improved grass.

Sowing green panic into the native-siratro pasture resulted in good establishment, with green panic reaching 18% of the pasture presentation yield in 1982. This contrasted with the poor result in the 1-stage process, where it contributed <1%. While below-average rainfall may have substantially contributed to this, it is clear that the higher soil fertility of the previously oversown treatment significantly affected the establishment and persistence of green panic. This difference was then enhanced by the pasture spelling procedure, which led to a higher level of siratro in the P/NS treatment than in the NS (Figure 3). However, both siratro and green panic decreased over time in both treatments. McDonald *et al.* (1998) reported similar differences in establishment of

oversown digit grass (*Digitaria eriantha* cv. Premier) and sabi grass (*Urochloa mosambicensis* cv. Nixon) on sites of high and low fertility at the same location. However, in that sowing, the 2 species continued to increase in frequency over time. It should be noted these 2 species are not recommended for planting on granite soils, owing to their potential to become dominant but unproductive.

LWG was some 30% higher in the old siratro treatments (NS and P/NS) than in the treatment where grass and siratro were oversown into native pasture at the commencement of this study (PS/N), and was similar to that reported by MacLeod and McIntyre (1997) from speargrass-mixed legume pastures, and from speargrass-fine stem stylo (*Stylosanthes guianensis* var. *intermedia*) pastures reported by Bowen and Rickert (1979). Care needs to be taken in interpreting the LWG from these treatments, because the P/NS and PS/N treatments were rested for approximately 6 weeks (mid-March to early May) each year until 1983. The overall effect of this strategy on liveweight gains on these treatments is not clear. While it would provide an advantage over the NS treatment, owing to the stocking rate being some 10% lower, these animals grazed native pasture during the rest period and hence had no access to a legume. As quality of native pasture declines at this time, the benefit of the legume in the diet is significant. In fact, the difference in LWG between the P/NS and the PS/N treatments was far greater than the differences between the P/NS and the NS treatments, suggesting that the lack of legume for the whole year had a far greater impact on LWG than the resting. Nevertheless, the need for a rest period to enhance establishment means alternative pasture has to be available for animals, and hence is an added cost to the process.

Conclusions

Burning can provide substantial benefits in reduction of some *Aristida* species, particularly in good seasons when recruitment of speargrass will be best. However, burning pasture on the whole paddock might reduce animal performance. Burning only half a paddock could minimise this effect by providing forage for stock while pastures regrew, but this hypothesis needs testing. Introduction of a high quality grass into a speargrass

pasture will have a much greater chance of success if preceded by the introduction of a productive legume, but appears to have little beneficial effect on LWG. Hence, if pasture improvement is being considered, it seems more beneficial to animal production to oversow legumes into additional unimproved speargrass areas, rather than to sow improved grass species into already developed speargrass-siratro pastures.

Acknowledgements

The authors thank Messrs G. Tipman and W. Messer for expert technical assistance, Messrs D. Crane, G. Gericke and F. Hockmuth for stock handling and weighing, and the staff of the Narayan Research Station for general maintenance. We extend our appreciation to Dr D. Ratcliff for invaluable statistical advice in the analysis of these data, and to Mr J.N.G. Hargreaves for his input into the redesign of this experiment and his meticulous input into data capture and storage. The project received funding support from the Australian Meat and Livestock Research and Development Corporation (now Meat and Livestock Australia) and fertiliser was supplied by Consolidated Fertilisers.

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(Received for publication September 3, 2008; accepted September 26, 2009)