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STIMULATION OF GROWTH AND NITROGEN UPTAKE BY SHADING A RUNDOWN GREEN PANIC PASTURE ON BRIGALOW CLAY SOIL

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ABSTRACT

Shading a rundown green panic pasture stimulated greater growth and higher nitrogen (N) concentration of the green panic compared with adjacent plots in full sunlight. The pasture was 16 years-old and located on a grey, brown and red clay Brigalow soil in southern Queensland. The shades ("sarlon" cloth transmitting 37% light) were in place over two growing seasons.

Shade increased uptake of N by the rundown pasture by 5.3 g m^{-2} (≡ 53 kg N ha^{-1}) in the above-ground herbage over the two years; thus giving double the amount of N harvested from the full sun plots. Transfer of N from roots to tops did not appear to explain the result; at the end of the experiment shade roots had lost only 0.55 g N m^{-2} compared to the full sun plots. Soil microbial biomass carbon, and the nitrogen fixing activity of roots measured at the end of the experiment did not differ between treatments. The shade stimulation of N uptake by the grass needs further investigation to understand the mechanisms involved.

INTRODUCTION

Deterioration of old pastures on Brigalow soils is a serious problem in southern Queensland. As pastures age, grass yields and quality decline (Catchpoole 1980; Graham *et al.* 1981) and animal production is reduced (Rudder *et al.* 1982; Robbins *et* *al.* 1986). The problem is due to reduced availability of nitrogen (N) in the soil rather than a decline in total soil N (Robbins 1984). The reasons for reduced availability of nitrogen in soil under old grass pastures and the factors influencing the level of available N are not well understood.

Wong and Wilson (1980) reported increased yield of biomass (tops + roots) and higher N concentration of herbage of infrequently defoliated green panic plants grown under shade compared with full sunlight. Such a response is unexpected in tropical grasses whose photosynthetic capacity and growth usually increases linearly with increased radiation up to full sunlight. The beneficial effect of shade appeared to be associated with increased availability of N from a soil of low to moderate available N status. This interaction of shade with N availability was also found by Eriksen and Whitney (1981) in Hawaii. They found that shade stimulated growth and N uptake by tropical grasses grown without N fertilizer, and that the effect was lost or diminished when 365 kg N ha^{-1} was applied.

The beneficial effects of shading as previously reported by Wong and Wilson (1980) were measured on young green panic plants transplanted into recently ploughed plots as seedlings. It was not known whether a similar response would occur for old, rundown green panic pasture with a large, fully developed root system. If the response was similar, and the mechanism causing the response described, then it may be possible to provide at least a lead towards a practical treatment aimed at improving nitrogen uptake in old grass pasture. Furthermore, the confirmation of a shade stimulation of nitrogen uptake on yet another soil type would support the concept that the effect is widespread and of general importance to the growth of grass under low light conditions: for example, for grass pastures under trees, plantation crops and shrub legumes like leucaena.

This paper reports the effect of shading an old green panic pasture, on a clay Brigalow soil near Munduberra, southern Queensland, on the growth and nitrogen uptake of the grass over two successive growing seasons.

MATERIALS AND METHODS

Site

The experiment was located on the CSIRO Narayen Research Station near Munduberra, south-eastern Queensland (25°42′S, 150°53′E). A 3 ha paddock was chosen from a long-term grazing trial on cleared Brigalow country. The 16 year-old pasture was established in the 1967–68 summer and stocked at *c.* 1 steer ha^{-1}. It was originally sown to green panic, lucerne, glycine and siratro but the legumes disappeared within three years and the pasture became almost pure green panic. No fertilizer N has been applied but 18 kg P ha^{-1} as superphosphate was given each year until 1981 when this was discontinued because no response to phosphorus was evident. The soil is grey, brown and red clay, Ug 5.36 (Northcote 1979). The 0-10 cm layer of the soil has a total N content of *c.* 0.33% (J. S. Russell, *unpublished data*) and soil gravimetric water content at field capacity and wilting point of 0.31 gg^{-1} and 0.18 gg^{-1} respectively.

Pasture

The extent of N-rundown of the green panic was gauged from a comparison of current grass growth and nitrogen concentration with that determined in the first four years of the grazing experiment. The grazing trial included a N fertilizer treatment (100 kg N ha^{-1} yr^{-1}) and the ratio of pasture yields taken in spring and autumn from this treatment to the yields of the nil N paddock used in this experiment had increased from 1.24 for 1969–73 to 1.65 for 1981–85. Nitrogen concentrations in the spring herbage on the nil N paddock had declined from 2.57% averaged over the four years 1968–73 to 1.54% on the full sun plots in 1983–4, and for summer/autumn herbage from 2.07% in 1968–73 to 1.38% in 1983–4.

Treatments

Four replicate areas of apparently uniform green panic were located within the paddock and two adjacent plots of *c*. 2 m × 3 m within each area were fenced to exclude cattle. One plot in each area was selected at random and covered with "Sarlon" shade cloth (37% light transmission) over a wire mesh support 1.5 m off the ground to give a shade treatment. The other plot of each pair was left uncovered as a full sun treatment. The plots were cut on December 1, 1983 when shading commenced, and harvests taken on January 23 and May 8, 1984. The shade was removed over the winter and replaced after a clearing cut on October 1, 1984. Harvests were taken on December 12, 1984, February 2, 1985 and May 3, 1985.

Because of the low sun altitude in April/May some direct light penetrated to the sample quadrat in early morning and late afternoon in the first season. The area of shade cloth in the second season was increased from 3 m × 2 m plus 0.5 m of angled overhang east and west to 5 m × 4 m with 1.2 m of angled overhang. The shade treatment was thus more effective in the second season.

The plots received natural rainfall during the experiment. However, only 36 mm of rain fell from February 1 to March 25, 1985, and to alleviate the extreme water stress which developed, the plots were surface irrigated with 100 mm of water on March 26, and April 2 and 15.

Measurements

The yield of dry matter and N were measured by cutting the herbage to a 10 cm stubble from a fixed quadrat of 1.0 × 0.5 m in the centre of each plot. The remainder of the grass on the plot was then cut to the same height and discarded. The quadrat sample was divided into green panic and weed, and the grass separated into green leaf, green stem, dead leaf and dead stem. Samples were oven dried at 80 °C for 24 hours, weighed, and ground to pass a 1 mm sieve for analysis of nitrogen content after Kjeldahl digestion.

Samples of the 0–7.5, 7.5–15, 15–30 and 30–50 cm layers of soil were taken from each quadrat on May 17, 1985. Six soil cores (4.6 cm diameter) were taken from each quadrat and bulked to give one sample of each soil layer for each plot. The samples were crumbled to pass a 12 mm sieve and subsampled for determination of microbial biomass carbon, NO_3^-–N and NH_4^+–N, surface litter plus crowns, and roots. The NO_3^-–N and NH_4^+–N contents of the soil were also determined on the 0–7.5 cm layer of cores taken at the start of the experiment.

The water content of soil samples was determined by drying samples at 100 °C and of plant samples by drying at 80 °C. The microbial biomass carbon was determined by the chloroform fumigation incubation method of Jenkinson and Powlson (1976). The NO_3^-–N and NH_4^+–N of the soil was determined on 2N KCl extracts after a water pretreatment (Catchpoole and Weier 1980).

Plant crowns were collected by hand from the samples of the 0–7.5 cm layer of soil. Surface litter was recovered by floating the light fraction from the samples sieved to 12 mm. Roots were removed from the 0–7.5 cm layer of soil after extracting crowns and surface litter and from the deeper soil layers by washing the samples through a 2 mm mesh sieve and decanting through a 60 mesh sieve to collect the roots.

Nitrogen fixing activity of the roots was assessed on intact soil-plant cores obtained on April 15, 1985 by placing 12 cm diameter steel tubes over the crown of a green panic plant and driving the tube into the soil to a depth of 16.5 cm. The cores were located immediately adjacent to the sample quadrat and two cores were removed per plot. Soil moisture content was near field capacity at the time of sampling. Nitrogenase activity was assessed using the acetylene reduction assay on the whole cores incubated for 24 hr in a controlled environment room at 30 °C with 14-hour day and 10-hour night (Weier *et al.* 1981).

Environmental parametes were measured between 11 a.m. and 12 noon on the shade and sun plots at each harvest date. Light transmission was measured with a quantum flux meter and for the shade plot averaged 37% of full sunlight over the

TABLE 1

Rainfall and evaporation for the interval between harvests, and soil and leaf (green panic) environmental measurements at the time of harvest for the sun and shade plots.

Harvest date	Rain	Evap.	Soil water content		Leaf water potential		Leaf temperature		Soil temperature 2 cm depth		Soil temperature 13 cm depth	
			Shade	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade	Sun
	(mm)	(mm)	(% oven dry soil)		(MPa)		(°C)		(°C)		(°C)	
Dec. 1, 1983 (clearing cut)			28.2	27.2								
Jan. 23, 1984	228	290	29.7*	24.5	−0.84	−1.02	29.2**	32.5	26.4**	30.9	23.0**	25.4
May 8, 1984	156	606	18.9*	15.8	—	—	19.9*	25.4	16.9**	18.9	16.5	16.8
Oct. 1, 1984 (clearing cut)												
Dec. 3, 1984	172	364	15.8	13.0	—	—	—	—	24.7**	27.7	21.0**	23.8
Feb. 1, 1985	189	408	19.1*	14.2	−1.10*	−1.56	26.0	26.8	24.6**	29.6	23.2**	26.8
May 3, 1985	66	522	22.3*	19.0	−0.92	−1.11	25.3**	28.7	21.2**	27.0	16.2*	17.2
L.S.D. P<0.05 (treatment means within harvests)			2.9		0.27		1.3		0.4		0.8	

Shade and sun means significantly different * $P<0.05$; ** $P<0.01$.

experiment. Soil water content (0–10 cm) was measured on two 2.2 cm cores taken from each quadrat and oven dried at 100 °C. Leaf water potential was measured with a pressure bomb and leaf temperature with an infra-red thermometer. Soil temperature was measured with a metal electronic probe at 2 and 13 cm depths. Rainfall and evaporation during the experiment were recorded at a site 0.5 km distant.

Statistical analysis

Data were subjected to analysis of variance on a split-plot design with shade treatment as the main plot (tested on 3 degrees of freedom) and harvests as sub-plots after testing for equality of variances and correlations between harvests using Box's (1950) test. Plot dry weight and nitrogen yields were transformed to logarithms (base 10) for analysis.

RESULTS

Both years had good spring and early summer rain but were very dry with substantial plant water stress from January to May 1984 and after February in 1985 (Table 1). The latter dry spell was alleviated by irrigating in late March and April. The spot checks at harvest indicated that soil water content and leaf water potentials were slightly lower, and soil and leaf temperatures higher, on the sun compared with the shade plots (Table 1).

The shaded green panic plants grew significantly better than those remaining in the full sun for all harvest periods after the clearing cuts except the harvest on May 8, 1984 (Table 2). N yield per quadrat was generally increased by shade proportionately more than was dry weight yield (Table 2). Shading generally resulted in higher concentrations of N in the plants (Table 3) as well as higher yields of dry matter. The effect of shade was more pronounced in the second year, with the increase in green panic yield of the shaded compared to the full sun plots averaging 160% for dry weight and 179% for N over the three harvests taken. Total N uptake into the tops for the period of shading was equivalent to 98.4 kg N ha^{-1} (shade plots) and 45.6 kg N ha^{-1} (full/sun plots) over the two growing seasons.

TABLE 2

The effect of shade (37% sunlight) during the growing season on the dry weight and nitrogen yield of herbage from a green panic pasture over two seasons.

Harvest date	Dry Weight: Shade	Dry Weight: Sun	Dry Weight: Increment[1]	Nitrogen: Shade	Nitrogen: Sun	Nitrogen: Increment
	($g\ m^{-2}$)			($g\ m^{-2}$)		
December 1, 1983 (clearing cut)	288	308		0.76	0.75	
January 23, 1984	163	120	+35%	0.62	0.41	+51%*
May 8, 1984	110	135	−19%	0.71	0.80	−11%
October 1, 1984 (clearing cut)	13	11		0.24	0.27	
December 3, 1984[2]	135 (80)	110 (46)	+23% (+74%)*	2.00 (1.23)	1.15 (0.54)	+74%* (+130%)**
February 1, 1985	390	148	+163%**	3.99	1.42	+182%**
May 3, 1985	142	41	+247%**	2.52	0.78	+224%**

1. % change due to shade treatment. Treatment difference (log transform) significance: * $P < 0.05$; ** $P < 0.01$.
2. Large dicot weeds present at this harvest; green panic yield shown in brackets.

The irrigation on March 26, 1985 after 7 weeks of drought obviously resulted in a burst of mineralization of soil N because of the high N concentration of the green tissues, with the values of the sun plants higher than those of the shade plants at the

TABLE 3

Effect of shade on the nitrogen concentration (%) of various parts of green panic plants in two successive years. Shade treatment commenced after a clearing cut at the start of each growing season.

Harvest	Green leaf		Green stem		Dead leaf		Dead stem		Weed	
date	Shade	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade	Sun
During treatment										
January 23, 1984	1.32	1.32	0.60	0.58	0.74	0.74	0.38	0.47	—[2]	—
May 8, 1984	2.15	1.99	0.94	0.93	1.20	0.86	0.51	0.39	—	—
December 12, 1984	1.86	1.39	0.81	0.70	—[2]	0.75	—[2]	—	1.53	0.99
February 2, 1985	1.80	1.37	0.66	0.69	1.13	0.66	0.58	0.48	1.39	0.91
May 3, 1985	2.51	3.21	1.14	1.81	1.36	0.99	0.90	0.63	—	—
L.S.D. P = 0.05 (treatment means within harvests)	0.19		0.14		0.18		0.22			
Clearing cuts[1]										
December 1, 1983	1.51	1.47	0.70	0.78	0.80	0.81	0.37	0.32	—	—
October 1, 1984	2.49	2.76	—[2]	—	1.91	2.30	0.57	0.94	—	—

[1] At start of each growing season before shade treatment was commenced.
[2] No sample in harvest.

TABLE 4

Yield and nitrogen per quadrat for material below cutting height sampled on May 17, 1985 at the end of the experiment. Sampled by six (4.7 cm diameter) cores to a depth of 50 cm for each quadrat

	Crowns		Litter		Roots (0-50 cm)	
Attribute	Shade	Sun	Shade	Sun	Shade	Sun
Dry weight ($g\ m^{-2}$)	154 ± 66	196 ± 124	198 ± 40	192 ± 68	1772 ± 96	2002 ± 86
N concentration (%)	0.89 ± 0.05	0.94 ± 0.07	1.28 ± 0.05	1.28 ± 0.01	1.07 ± 0.05	0.98 ± 0.05
N yield ($g\ m^{-2}$)	1.38 ± 0.64	1.80 ± 1.15	2.54 ± 0.53	2.47 ± 0.88	19.13 ± 1.84	19.68 ± 1.24

harvest on May 3, 1985 (Table 3). The green (younger) tissues would have been mainly produced between the date of irrigation and the final harvest. In contrast, the dead leaves and stems would have mainly come from growth prior to the irrigation and their N concentrations were highest for the shade plants, reflecting the effect of shade on stimulation of N uptake. The contrasting response of the green and dead tissues suggests that the mineralization response was probably stronger on the sun plots, which were undoubtedly drier for longer after the harvest of February 1, 1985. The same effect may partly account for the lack of a shade effect in autumn 1984, because only 17 mm rain fell between January 31 and April 6: then 47 mm was received over two days which may have stimulated mineralization of soil N.

The dry weight yield and N content of crowns, litter and roots (Table 4) taken when the experiment finished did not differ significantly (analysis of variance) between shade and full sun treatments. The stratified root samples indicate a tendency for lower dry weight yield and higher N concentrations of roots in the shade plots, e.g. for shade and sun plots, root weights (g m^{-2}) were 626 and 746 (0–7.5 cm), 384 and 370 (7.5–15 cm), 352 and 370 (15–30 cm), and 412 and 516 (30–50 cm) respectively. N concentrations (%) for shade and sun plots were 1.32 and 1.24 (0–7.5 cm), 1.06 and 1.10 (7.5–15 cm), 0.92 and 0.88 (15–30 cm), and 0.85 and 0.66 (30–50 cm) respectively; only the difference at 30–50 cm was statistically significant ($P < 0.05$).

Estimates at the end of the experiment of soil NO_3^-–N and NH_4^+–N, N fixing activity associated with roots, and microbial biomass carbon did not appear to differ between shade and sun plots (Table 5). The higher NO_3^-–N and NH_4^+–N at the end of the experiment probably reflect the extra mineralization which occurred after the irrigation towards the end of the growing season but these values of < 2 ppm and 3 ppm respectively are very small, as mineralization values of 20 ppm or higher are common for this soil after cultivation (V. R. Catchpoole, *unpublished data*).

DISCUSSION

Shading the rundown green panic pasture during the growing season stimulated extra growth of grass through increased N uptake. The effect was larger in the second year when improved shading arrangements were made and when drought in late summer was alleviated by irrigation. N concentrations in tops and roots were also higher for shade than sun material at most harvests; this response for tops is usual (e.g. Fleischer *et al.* 1984; Smith *et al.* 1984) but is not generally accompanied by increased dry matter yield under shade. That the productivity of the unshaded green panic was limited by low availability of soil N was confirmed by the comparison made of current productivity and N concentrations of the herbage with that of the first four years after sowing (see Materials and Methods).

The results from this experiment thus support the hypothesis developed from consideration of the work of Wong and Wilson (1980) and Eriksen and Whitney (1981) that shade increases the availability of soil N for growth of grass. The increased N for top growth did not appear to come from that accumulated in the roots. The roots were a large biomass, equivalent to 17.7 and 20.0 tonnes of dry matter ha^{-1} in the 0–50 cm depth for the shade and sun plots respectively. However, a N balance for the quadrats showed that the shade compared with the sun treatment gained an *extra* 5.28 g N m^{-2} in the tops over the two seasons for a decrease in the roots (0–50 cm) at the final harvest of only 0.55 g N m^{-2}.

The gain in the tops under shade was equivalent to an *extra* 53 kg N ha^{-1} which thus doubled the N uptake by the shaded plants compared to the full sun plants over the two seasons. This increase in available N due to shading was substantial (equivalent to an extra 26.5 kg N ha^{-1} above the base mineralization of 22.8 kg N ha^{-1} yr^{-1} in the full sun plots). Robbins (1984) estimated that only 14 kg ha^{-1} yr^{-1} was mineralized in the soil below a 5 year-old green panic pasture on a black earth soil, although total N in that soil was 0.15% compared to 0.33% in this experiment.

The mode of action of the shade influence on N uptake by the grass was not resolved by the ancillary measurements. Soil NO_3^-–N and NH_4^+–N levels

TABLE 5

Nitrogen status of the surface soil (0–7.5 cm depth) at the start (December 1, 1983) and end (May 17, 1985) of the experiment for the shade and sun plots, and estimates of the nitrogen fixing activity associated with the roots[1] (0–16.5 cm depth) and the microbial biomass carbon (0–7.5 cm depth) at the end of the experiment.

Nitrogen concentration in soil								Root N_2 fixing activity		Microbial biomass	
December 12, 1983				May 17, 1985				April 15, 1985		May 17, 1985	
NO_3^-–N		NH_4^+–N		NO_3^-–N		NH_4^+–N					
Shade	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade	Sun	Shade	Sun
(ppm in oven dry soil)								(mg N m^{-2} day^{-1})		($g m^{-2}$)	
0.20 ± 0.06	0.26 ± 0.06	1.78 ± 0.10	1.78 ± 0.18	1.36 ± 0.07	1.72 ± 0.18	3.12 ± 0.31	2.90 ± 0.50	4.4 ± 0.1	6.6 ± 0.2	79 ± 3	77 ± 1

[1] Nitrogenase activity measured by acetylene reduction.

were low and similar for both sun and shade plots. The spot check on N fixation by rhizosphere organisms (nitrogenase activity) and on soil biomass carbon gave no treatment difference but these factors need to be measured frequently during the season to trace N turnover. The lack of a shade effect on N fixation by rhizosphere organisms is in general agreement with the results of Eriksen and Whitney (1981) and Smith *et al.* (1984). The lower soil temperatures under shade would not be expected to enhance N mineralization or soil biomass degradation which is favoured by higher temperature (Floate 1970). Low soil moisture reduces N release from the soil biomass (Robbins 1984) and in this respect shading, by maintaining slightly higher soil moisture content, may have favoured N release from the soil biomass or uptake of N by surface roots. However, the shade effect in this experiment and in Wong and Wilson (1980) was large when soil water levels were most favourable for growth. In fact the normal N mineralization associated with rewetting after extended dry periods was probably favoured in the sun plots where soil drying was more extreme over a longer period. Physiological injury to the plant under N stress, such as photoinhibition affecting photosynthetic activity (Powles 1984), or damage to other processes affecting root activity and hence N uptake, cannot be discounted. This study has not revealed a specific cause of the shade response; it would appear likely that shading altered the balance of mobilization/immobilization of soil N. Further studies on the effect of shade on rate of mineralization of soil N are warranted.

Agronomically, the results are of considerable interest. The better growth, under trees, of grasses like green panic is probably largely due to this shade effect and not solely, as is often propounded, to "tree-drip" or redistribution of nutrients from deeper soil layers via the tree and subsequent litter fall. Also, the good growth of green panic observed under the leguminous shrub leucaena (G. B. Robbins, *personal communication*) probably includes a component of shade-stimulated N uptake as well as transfer of biologically fixed N from the legume. Under plantation crops the higher N availability may help offset the adverse effect of low light on photosynthetic activity. Importantly, the shade effect has occurred with a number of soils and grass species, and has recently been observed in *Axonopus* and *Stenotaphrum* grown in large pots in a black earth from Lawes, Queensland (P. S. M. Sirisena, *personal communication*). Thus the shade stimulation of N availability may be a general phenomenon and consequently has relevance to the wider problem of understanding the immobilization of nitrogen in the soil in old grass pastures.

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NEW PASTURE PLANT RELEASE

ANNUAL MEDIC

Medicago truncatula Gaertn. var. *truncatula*
(barrel medic)

cv. Parabinga
(Reg. No. B-9a-11)

Origin

Originated from seed designated C.P.I. 98135, collected by E. J. Crawford and B. C. Bull of the South Australian Department of Agriculture in conjunction with the International Centre for Agricultural Research in the Dry Areas, (ICARDA). It occurred on a whitish-brown alkaline clay loam near Fuheus, about 25 km W.N.W. of Amman in Jordan (Anon 1985). The mean annual rainfall of the region is 350 mm at an altitude of 900 m.

Submitted for registration by the South Australian Department of Agriculture and recommended by the South Australian Herbage Plant Liaison Committee. Breeder's seed is being maintained by the Department of Agriculture, South Australia. Registered January, 1986.

Morphological description

Parabinga is morphologically typical of the species *M. truncatula* (Heyn 1963). Its habit is similar to Cyprus barrel medic and slightly more erect than Harbinger strand medic (*M. littoralis*). Leaflets have a pale green blotch edged in brown encompassing the upper midrib region of the leaf surface, surrounded by numerous small white and purple flecks, the latter more prominent on the abaxial surface of the leaflets. Parabinga has clockwise pod coiling and a narrower pod coil range than that of Cyprus viz. 4.75–5.25 *cf.* 3.5–5.25. It is larger podded (about 30%) and larger seeded (about 20%) than Cyprus. It has about 250 000 compared with about 300 000 seeds per kilogram in cultivar Cyprus. Pod spininess is rated as 12 units compared with 10 units in the less spiny cultivar Cyprus, and it has about seven seeds per pod compared with six in cultivar Cyprus (Crawford 1985).

In view of its morphological similarity with other barrel medic cultivars, Parabinga will be certified on a pedigree basis.

Agronomic characters

Parabinga is 2–3 davs earlier flowering than Cyprus barrel medic or Harbinger strand medic at Parafield, S.A. It flowers in about 97 davs after an early May germination in the Parafield environment (Crawford 1985). At Condobolin, N.S.W., Parabinga flowers about one week after Cyprus and two days after Harbinger.

Parabinga, Cyprus and Harbinger have similar initial levels and rates of breakdown of hardseedness, such that in South Australia about 10% of seed is permeable by mid April of the year following its production (Crawford 1985).