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MANAGING SOIL FERTILITY FOR RESTORATION OF NATIVE GRASSLANDS

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ABSTRACT

Fertility of the soil supporting degraded native grassland at Trangie Agricultural Research Centre was either enhanced by addition of fertiliser, reduced by application of sugar, or left untreated. The experiment was repeated on sites where native perennial grasses were either absent or present at relatively low density. After two years, the DM yield of annuals was significantly lower, and DM yield of perennials (if present) significantly higher, in the reduced fertility treatment. If initially present, density of the two major native perennial grasses (*Austrodanthonia caespitosa* and *Enteropogon acicularis*) increased in the reduced fertility treatment but declined in the other two treatments. Basal area of these species tended to decline in all treatments but the decline was least with reduced fertility. Our results support the hypothesis that competition from annual species can limit regeneration of native perennial grasses in semi-arid rangelands and that manipulation of fertility, and consequently the extent of this competition, may be important in facilitating grassland restoration.

INTRODUCTION

Studies in semi-arid rangelands in the United States have shown that the level of plant-available N strongly influences the course of secondary succession (McLendon and Redente 1992, Horn and Redente 1998, Paschke *et al*. 2000). High levels of mineral N reduce the rate of secondary succession and maintain dominance by early seral species in vegetation communities regenerating after disturbance. In contrast, removal of mineral N (e.g. by addition of sucrose) promotes the dominance of late seral, perennial species. In these systems, N appears to be the major factor with P of little consequence (McLendon and Redente 1991). Few, if any, comparable studies have been conducted in the Australian semi-arid zone although results from more mesic temperate grasslands suggest that both P and N may be important determinants of the successional pathway (Morgan 1998, Prober *et al*. 2002).

In this paper we describe a study aimed at determining the influence of soil fertility on vegetation dynamics in semi-arid grassland in central NSW. The objective was to understand the limitations to secondary succession in order to develop appropriate management practices to promote the regeneration of grasslands degraded by the interaction of drought and heavy grazing.

MATERIALS AND METHODS

Study site.

The study was conducted at Trangie Agricultural Research Centre in central western NSW (31˚59′ S, 147˚ 57′ E) on the riverine plain of the Macquarie River. Soils are alluvial red brown earths, typically with sandy clay loam topsoil over blocky structured clay subsoil (S. Mugambi, pers. comm.).

Vegetation was originally a Poplar Box (*Eucalyptus populnea*) woodland association (Beadle 1948) but only a few shade tress now remain and the original perennial grasses, including *Enteropogon acicularis* (curly windmill grass), *Austrodanthonia caespitosa* (wallaby grass), *Chloris truncata* (windmill grass) and *Austrostipa* spp (spear grass), have been mostly replaced by annuals. Depending on the timing of rainfall annual growth may be dominated by winter growing species, particularly *Hordeum leporinum* (barley grass), *Medicago* spp (medics) and *Erodium* spp (crowfoots), or summer growing species such as *Tribulus terrestris* (caltrop) and *Heliotropium europaeum* (heliotrope).

Average annual rainfall is 480 mm (coefficient of variation 41 per cent) with no distinct seasonality.

Treatments

Three fertility levels - high, low and control - were imposed at both 'high perennial' and 'low perennial' sites. Perennial grasses were virtually absent from the 'low perennial' site while a relatively low density of perennial species, mainly *E. acicularis* and *A. caespitosa*, remained within the 'high perennial' site. The high fertility treatment received 120kg/ha of N and 30kg/ha of P annually in four equal applications, applied as 250kg/ha of Granulock 15™ (15% N, 12% P, 7% S) and 180kg/ha of urea (46% N). The low fertility treatment received 1.25kg/m^2 per annum of sucrose (sugar), to promote immobilisation of N, in five equal applications. Neither fertiliser nor sugar was applied to the control treatment. Application commenced on 22nd March 2005 and finished on 1st August 2006. Fertility treatments were applied to 2x2 m plots and were replicated six times at each site.

Measurements

Vegetation measurements were made in the central 1m^2 of each plot in the spring and autumn of 2005 and 2006. Ground cover (mostly annual grasses, legumes and forbs) was estimated visually. The basal diameter of each perennial grass plant was measured to the nearest mm and subsequently used to calculate basal area. However, individual plants were not uniquely identified. The central 1m^2 quadrat in each plot was cut in September 2006. All vegetative material (green and dead) was sorted into perennial grasses and annuals, dried at 80^0 C for 48 hours and weighed.

Rainfall was recorded at the Trangie Agricultural Research Centre's weather station located approximately 4 km from the experimental site.

Statistical analysis

The following mixed model was used to analyse treatment responses for individual sites and times:-
Measured variable ~ Treatment + *Rep* (italics – here and below - used to denote random terms). Analysis focussed on data from the second year of the trial (2006) when treatment effects were most apparent. Variables analysed included dry matter (annuals and perennials), basal area (perennials), ground cover and % green material. Ground cover and % green material were subject to arcsin transformation. Basal area was summed over plants at the plot level prior to square root transformation. This model was also applied to the ratio of perennial plant numbers in spring and autumn 2006. This ratio, reflecting the overall change in perennial plants between the last two observations, has an approximately normal distribution and was constructed for each plot separately.

Changes in basal area and plant numbers of the two dominant perennial species over the two years of the experiment (4 observations) were analysed using the mixed model:-
Measured variable ~ Treatment + Observation + Treatment:Observation + *Rep* + *dev(Observation)* where *dev(Observation)* is a factor variable allowing for random variation in the overall trend.

RESULTS

Seasonal conditions

Apart from the excellent spring of 2005, rainfall tended to be below average throughout the trial period, particularly in the autumn of both 2005 and 2006 and in spring 2006 (Table 1).

Table 1. Monthly rainfall deciles for the trial period.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	6	4	5	2	1	10	4	4	10	10	9	5
2006	5	5	4	3	1	5	8	2	3			

Dry matter

In both 'high perennial' and 'low perennial' sites DM of annuals in September 2006 was significantly reduced in the low fertility treatment, and increased in the high fertility treatment, relative to the control ($P<0.001$ for both sites). In contrast, DM of perennials in the 'high perennial' site was significantly higher in the low fertility treatment ($P<0.05$). Treatment differences in % green material in September 2006 showed similar trends to those for DM of annuals ($P<0.001$ for both sites).

Basal area and ground cover

In the 'high perennial' site basal area of perennials was significantly higher in the low fertility treatment than either the control or high fertility treatments in both March 2006 ($P<0.05$) and September 2006 ($P<0.001$). In contrast, ground cover was significantly lower in the low fertility treatment ($P<0.001$ in March 2006 and $P<0.01$ in September 2006) although treatment means always exceeded 90%. For the 'low perennial' site no comparable analysis of basal area was feasible and ground cover was high in all treatments.

Basal area of *A. caespitosa* declined in all fertility treatments over the two years of the trial ($P<0.001$ for differences among periods) but the decline was least, and average basal area greatest, in the low fertility treatment ($P<0.001$). For *E. acicularis* average basal area was significantly higher in the low fertility treatment ($P<0.01$) but no significant overall downward trend was observed, due to a significant treatment:observation interaction ($P<0.05$). Again, no comparable analysis was feasible for the 'low perennial' site.

Plant density

On the 'high perennial' site the ratio of perennial plant numbers over the last two observations (spring:autumn 2006) was higher than the control in the low fertility treatment, and lower in the high fertility treatment ($P<0.001$). Perennial plant numbers declined (spring:autumn ratio <1.0) in both the control and high fertility treatments but increased in the low fertility treatment. Tends over time for the major perennial species (Figure 1 a & b) indicated a progressive advantage in favour of the low fertility treatment. For both species, the effect of fertility treatment was significant ($P<0.001$) and there was a significant treatment:observation interaction ($P<0.01$). Differences between observations were significant ($P<0.05$) only for *A. caespitosa*. No comparable analysis was feasible for the 'low perennial' site where recruitment was lacking.

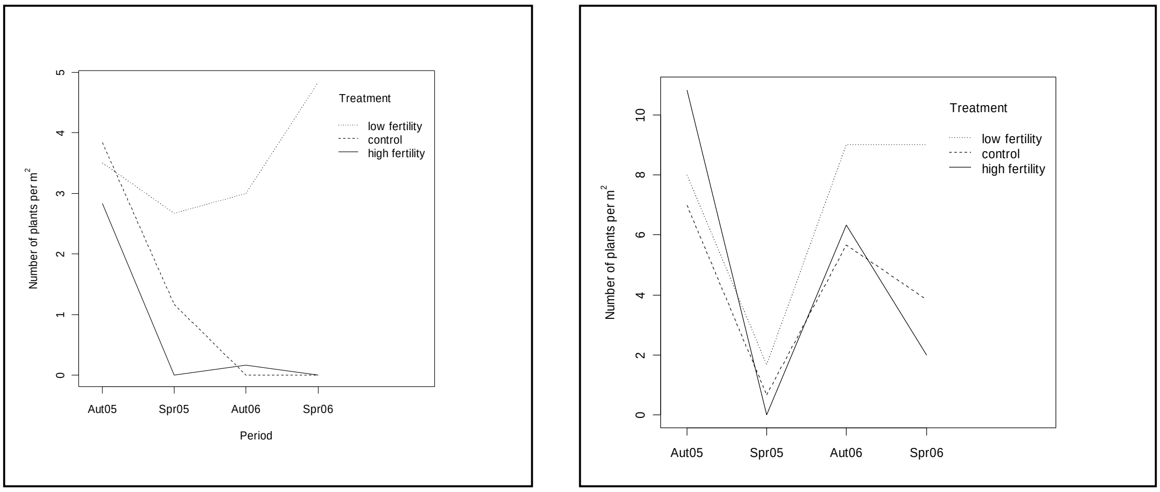
(a) (b)

Figure 1. Changes in density of *A. caespitosa* (a) and *E. acicularis* (b) on the 'high perennial' site.

DISCUSSION AND CONCLUSIONS

Reducing the availability of N by application of sugar markedly reduced the growth of annuals in both the 'low perennial' and 'high perennial' sites. In the 'high perennial' site this facilitated the establishment and growth of native perennial grasses despite dry seasonal conditions that produced an overall trend towards lower basal area of these species. In the 'low perennial' site no recruitment of perennials occurred despite the reduction in annual growth, possibly reflecting a lack of soil seed reserves. Increasing fertility resulted in a marked increase in growth of annuals but reduced the growth of perennials and effectively suppressed their establishment.

For the C4 species *E. acicularis* establishment occurred in all fertility treatments (on the 'high perennials' site) following favourable seasonal conditions in spring (September, October and November) 2005. In contrast, the greatest establishment of the C3 species *A. caespitosa* occurred following above average rainfall in winter (July) 2006.

Robards *et al*. (1978) have argued that the demise of perennial grasses and the establishment of an annual-dominated disclimax community on this site have not produced a decline in livestock productivity. In fact, their estimate of carrying capcity for the disclimax (4 sheep/ha) is considerably higher than for the perennial grassland (2.5 sheep/ha). Their observations, and subsequently those of Michalk and Robards (1993), suggest that the disclimax is stable at this level of stocking.

However, given the experience of recent droughts and expectations of a warmer and drier climate, increased emphasis on restoration of perennial species may be anticipated, particularly in areas with lower annual rainfall than Trangie. Our results suggest that management techniques that achieve a reduction in competitive annual growth through a temporary reduction in fertility may have a role in this process in the semi-arid zone, consistent with findings from community restoration studies in more mesic areas of eastern Australia (e.g. Smallbone *et al*. 2007). Such techniques might include, for example, the direct drilling of (unfertlised) crops into degraded pasture (pasture cropping).

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