Grazing management influences the dynamics of populations of *Stylosanthes hippocampoides* (Oxley fine stem stylo)

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Abstract

This paper describes a study to identify those factors which control the persistence of the subtropical legume *Stylosanthes hippocampoides*, formerly *S. guianensis* cv. Oxley (fine stem stylo). The dynamics of *S. hippocampoides* populations was recorded in permanent quadrats at 2 stocking rates in a grazing study conducted between 1987 and 1992 in south-eastern Queensland.

Density of mature plants fluctuated between 10 and 60 plants/m² during the 5 years with the major contributing factors being variations in seedling recruitment and survival, which, in turn, reflected the size of the soil seed bank and seasonal rainfall. Plant density was consistently higher at the lower stocking rate of 1 beast/1.5 ha compared with 1 beast/1 ha; however, the effect of stocking rate was minor compared with fluctuation due to seasonal variation in rainfall. The maximum life span of the original plants exceeded 5 years, while the survival of seedling cohorts was strongly impacted by seasonal rainfall. Total exclosure from grazing during summer increased the size of the soil seed bank although a precise time period during summer was not identified, while grazing at the lower stocking pressure produced the same outcome.

It was concluded that the large seasonal variation that occurs in *S. hippocampoides* density is driven by large seasonal variation in seedling recruitment, which, in turn, is influenced by the size of the soil seed bank.

Introduction

*Stylosanthes hippocampoides*, formerly *S. guianensis* cv. Oxley (fine stem stylo), is a short-day flowering, subtropical legume, which is well adapted to less fertile, well drained sandy soils of the subcoastal areas of south-eastern Queensland, especially in the Burnett district (Stonard and Bisset 1970; Bowen 1980; Cameron 1987). Oversowing *S. hippocampoides* into native pastures has resulted in substantially greater cattle liveweight gains than from native pasture (Bowen and Rickert 1979; Rickert et al. 1981; Jones and Mannetje 1997).

Large variation in the contribution of *S. hippocampoides* to pasture composition is a feature of these oversown pastures despite the improvement in animal liveweight gain (Stonard and Bisset 1970; Bowen and Rickert 1979). Little is known of the dynamics of populations of this species and Rickert and Prinsen (1981) concluded that studies of individual plant longevity and of soil seed reserves needed to be undertaken to identify those factors which control the persistence of *S. hippocampoides*.

This paper reports a study undertaken to examine the dynamics of *S. hippocampoides* by monitoring seedling recruitment and plant survival in relation to the soil seed bank at 2 stocking rates between 1987 and 1992.

Methods

Grazing experiment

*S. hippocampoides* spread throughout the deep, coarse sand soils derived from granite (acid extractable phosphorus 35 ppm) at Brian Pastures Research Station, Gayndah (25°39’S, 151°45’E) following experimental sowing commencing in 1954. Further sowings of *S. hippocampoides* occurred into cleared *Heteropogon contortus* (black speargrass) pastures between 1954 and
1964 and by 1971 the grass component was predominantly naturalised Melinus minutiflora (red natal grass). In 1971, 3 paddocks each of 3.64 ha were established to evaluate the impact of 3 grazing strategies on animal production between 1971 and 1976 with superphosphate fertiliser (9% phosphorus) applied at a rate of 125 kg/ha annually in December between 1971 and 1974 (Bowen and Rickert 1979; Rickert et al. 1981).

In 1983, the area grazed in the study by Bowen and Rickert (1979) was re-fenced into 4 paddocks each of 3.2 ha. Between 1983 and April 1986, these 4 paddocks were stocked with 2 steers (1 weaner and 1 yearling) so that a weaner went into each paddock and remained there for 2 years. Between May 1986 and April 1987, the paddocks were stocked with 2 yearling steers. From May 1987, 2 paddocks were stocked with 3 steers and the other 2 paddocks with 2 steers, which grazed these paddocks for 12 months to achieve stocking rates of approximately 1 beast/ha and 1 beast/1.5 ha. Steers were replaced annually.

**Plant demography**

In May 1987, approximately 100 individual plants of S. hippocampoides were located in 6 permanently located quadrats, each 1 × 0.5 m, in each of the 4 treatments paddocks. The position of each plant in each quadrat was charted using a grid system whereby each quadrat was divided into 10 grid sections each 25 × 20 cm and individual plants within each grid section were recorded by hand-charting the position of each plant. After this May 1987 recording, further recordings were made at 6-monthly intervals until November 1991 to determine the survival of both the original plants and of subsequently recruited seedlings. In May and November 1992, further recordings were made to determine the further survival of both the May 1987 plants and those plants resulting from seedling recruitment between December 1987 and May 1990.

**Soil seed banks**

The size of the soil seed bank of S. hippocampoides was determined from soil cores collected annually in spring. Each September between 1987 and 1991, 10 samples were collected at random from each paddock. Each sample consisted of 5 individual soil cores, each 5 cm in diameter to a depth of 5 cm. Seed contained in these samples was separated, identified and counted using the technique of Jones and Bunch (1988).

Seed recovered from the soil samples was subjected to germination tests to determine the level of hard-seededness and germination. Where sufficient seed was recovered, 2 replicates each of 50 seeds were tested, although there were as few as 10 seeds per replicate when seeds were scarce. Seed was germinated in a germination cabinet set at 35/20°C for 12 hour day/night temperature with light provided for the 12 hour 35°C period.

**Effects of exclosure on the soil seed bank**

As results from this study reflected the importance of the size of the soil seed bank in determining seedling recruitment, 2 further experiments were conducted to investigate the impact of exclosure from grazing on the soil seed bank. In the first experiment, 4 exclosures, each 2 × 1 m in size, were established in each paddock on November 14–15, 1990 and remained in place until June 1991. Each paddock was divided into 4 quarters to achieve stocking rates of approximately 1 beast/ha and 1 beast/1.5 ha. Steers were replaced annually.

Results from this experiment indicated that seed production was substantially improved by exclosure throughout summer so a second experiment was conducted over the 1991–92 summer to further identify any critical period during summer for seed production. In this second experiment, 1 replicate paddock from each stocking rate treatment was divided into 4 quarters and 2 exclosures, each 2 × 1 m in size, were randomly located in each quarter on November 14, 1991. One of these exclosures remained in place until June 1992. On February 27, 1992, the second exclosure was relocated, again at random, in each of the 4 quarters and remained in place until June 1992. In this way, there were 3 times of exclosure: early summer (November 14–February 27), late summer (February 27–June 22) and all summer (November 14–June 22). In September 1992, 5 random soil
samples were collected from within the exclosed areas in each paddock along with another 5 random samples from the adjacent grazed areas. Each sample constituted 5 individual soil cores, each 5 cm in diameter to a depth of 5 cm.

Soil cores from this exclosure/grazing experiment were processed independently of the earlier seed bank studies. Seed contained in these samples was sieved, separated and aspirated (Jones and Bunch 1988) and the resulting seed/coarse sand samples were weighed. A sub-sample of approximately 10% by weight of these initial samples was separated and used to estimate seed content of the overall sample (B. Fleming, personal communication).

Data analysis

The statistical power of this study, 2 stocking rates × 2 replications, is low such that large differences would be required to achieve statistical significance (Orr and Paton 1993). Treatment differences are characterised using the standard error of the mean derived from the 2 treatment paddocks. The second seed bank exclosure study used only 1 of each treatment paddocks and the standard error of the mean was derived from the 4 replicate exclosure cages. Plant survival was analysed using a proportional hazard survival model (Cox 1972).

Results

Rainfall

Seasonal rainfall varied from below to well above the seasonal mean in different years (Table 1).

<table>
<thead>
<tr>
<th></th>
<th>Summer (Dec-Feb)</th>
<th>Autumn (Mar-May)</th>
<th>Winter (Jun-Aug)</th>
<th>Spring (Sep-Nov)</th>
</tr>
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<tbody>
<tr>
<td>1987</td>
<td>322</td>
<td>90</td>
<td>86</td>
<td>190</td>
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<tr>
<td>1988</td>
<td>107</td>
<td>127</td>
<td>202</td>
<td>78</td>
</tr>
<tr>
<td>1989</td>
<td>302</td>
<td>167</td>
<td>135</td>
<td>176</td>
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<tr>
<td>1990</td>
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<td>309</td>
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<tr>
<td>1991</td>
<td>253</td>
<td>104</td>
<td>34</td>
<td>114</td>
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<tr>
<td>1992</td>
<td>429</td>
<td>219</td>
<td>41</td>
<td>175</td>
</tr>
<tr>
<td>Long-term mean</td>
<td>287</td>
<td>202</td>
<td>105</td>
<td>124</td>
</tr>
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</table>

Changes in plant density

The density of mature plants (i.e., plants > 6 months) fell from 40 plants/m² in May 1987 to 10 plants/m² in May 1988, rose to 40–60 plants/m² between November 1988 and November 1989 and declined to 15 plants/m² in November 1991 with density usually higher at the lighter stocking rate (Figure 1a).

Seedling recruitment

Seedling recruitment was high in both November 1987 and May 1988 but was low between November 1988 and May 1991 at both stocking rates (Figure 1b). Recruitment was high in November 1991 at the light but not at the heavy stocking rate.

Soil seed banks

Soil seed banks were around 2000 seeds/m² in September 1987 but fell to less than 500 seeds/m² between September 1988 and September 1990 at both stocking rates (Figure 1c). The soil seed bank was high in November 1991 at the light but not at the heavy stocking rate.

The proportion of this seed bank falling into the 4 categories (germinable, hard, soft-live and dead) varied between years but not between stocking rate treatments (Figure 2). The proportion of germinable seed varied between 35% in 1987 and 71% in 1990, whereas the proportion of dead seed varied from 8% in 1989 to 40% in 1987.

Relationship between density, recruitment and seed banks

There was a good linear relationship ($R^2 = 0.79$) between the size of the soil seed bank and the resulting seedling recruitment, demonstrating the close links between the size of the seed bank and seedling recruitment, which, in turn, influenced plant density (Figures 1a, 1b and 1c).

Plant survival

Survival of all cohorts declined ($P<0.05$) with time. Of the original May 1987 plants, 20% survived until May 1988 and 5% until November 1992 with no differences between the 2 stocking rates (Figure 3a). Survival of the various seedling
cohorts differed with 60% of the November 1988 cohort surviving after 12 months compared with only 3% for the November 1989 cohort (Figures 3b, 3c, 3d, 3e and 3f). Stocking rate had little effect on survival with exceptions being higher (P<0.05) survival at the lighter stocking rate for the November 1987 cohort and higher (P<0.05) survival at the higher stocking rate for both the May 1989 and November 1989 cohorts.

Effects of exclosure on soil seed banks

Exclosure from grazing over the 1990–91 summer resulted in a substantial increase in the soil seed bank irrespective of stocking rate (Figure 4a). Over the 1991–92 summer, the seed bank at 1 beast/ha was lowest under grazing, intermediate with both early and late exclosure and highest with all summer exclosure (Figure 4b). There was no clear impact of exclosure on the seed bank at 1 beast/1.5 ha, although under grazing it was higher at this stocking rate than at 1 beast/1 ha.

Discussion

This study has improved our understanding of the roles of soil seed bank, seedling recruitment and seasonal rainfall on the large variation in plant density (Figure 1a), seedling recruitment (Figure 1b) and soil seed bank (Figure 1c) of *S. hippocampoides* between May 1987 and November 1991 at 2 stocking rates. (Vertical bars are standard errors of the mean).
Figure 2. Proportions of seed in soil seed bank samples classified as germinable, hard, soft-live and dead in spring between 1987 and 1991. (Data are the mean of 2 stocking rates).

Figure 3. Changes in the survival (number of plants) of *S. hippocampoides* for (a) original (May 1987), (b) November 1987, (c) May 1988, (d) November 1988, (e) May 1989 and (f) November 1989 cohorts between May 1987 and November 1992 at 2 stocking rates. Asterisks indicate that significant (P<0.05) differences in survival occurred.
density, which is a feature of pastures oversown with *S. hippocampoides* as reported by Bowen and Rickert (1979), Rickert and Prinsen (1981), Jones and Mannetje (1997) and Jones et al. (2000). Variation in plant density due to stocking rate was less than the variation between seasons, despite seed banks being consistently lower at heavy compared with light stocking rate.

The mature plant numbers for *S. hippocampoides* recorded in this study (10–60 plants/m²) were lower than the maximum of 146 plants/m² recorded in an oversown native pasture at Narayen Research Station (Jones and Mannetje 1997). However, this 146 plants/m² was recorded only 4 years after sowing and coincided with a very wet summer, after which time density declined to around 4 plants/m² for the following 15 years and then to 3 plants/m². The density of *S. hippocampoides* oversown into *Cenchrus ciliaris* (buffel grass) also at Narayen was consistently less than 10 plants/m² between 1987 and 1996 (Jones et al. 2000).

![Figure 4](image-url)

**Figure 4.** The effects of exclosure during summer on seed banks in the following spring of *S. hippocampoides* grazed at 2 stocking rates (a) in 1991 and (b) in 1992. [Vertical bars are standard errors of the mean derived from 2 replicate paddocks for (a) and 4 replicate exclosure cages for (b)].
The large variation in *S. hippocampoides* density recorded in this study resulted from highly variable seed production (as reflected in soil seed bank data) resulting in variable seedling recruitment and, in turn, variable seedling survival. A similar persistence mechanism has been reported for other introduced legumes. For example, for *Chamaecrista rotundifolia* (Wynn cassia), the pattern of rainfall had a greater impact on demography than stocking rate, because low rainfall both reduced seed set and increased seedling mortality compared with that during higher rainfall years (Jones and Bunch 1995). Similarly, for *Lotononis bainesii* (lotononis), the cycle of seed formation, seed reserves, seedling regeneration and seedling survival was the main contributor to persistence (Pott and Humphreys 1983; Pott *et al.* 1983; Fujita and Humphreys 1992).

Some original *S. hippocampoides* plants in the current study survived for more than 5 years, while at Narayen plants from the original sowing failed to persist for 4 years (Jones *et al.* 2000). The maximum life span for *S. hippocampoides* at Brian Pastures may be similar to the longer-lived *S. scabra* cv. Seca, which has a life span of 8 years (Gardener 1984; Orr 2005). Comparable data on seedling recruitment of *S. hippocampoides* are limited, although recruitment recorded in the current study varied greatly with both years and stocking rate, and was higher than that recorded at Narayen (Jones and Mannetje 1997). These authors recorded similar highly variable recruitment (0–48 seedlings/m²) between 1968 and 1996 with the highest recruitment recorded in 1980 when rainfall was above average. Survival of the different seedling cohorts of *S. hippocampoides* in the current study varied and this most likely reflected the impact of the rainfall pattern on seedling survival. Similar large differences in seedling survival in this environment have been reported for both legumes (Jones *et al.* 2000) and native grass (Orr and Paton 1997).

High densities of *S. hippocampoides* were usually recorded soon after there had been large seedling recruitment so that high densities were associated with a large proportion of seedling plants. This finding is consistent with a similar finding (McIvor and Gardener 1998) for populations of both *S. scabra* cv. Seca and *S. hamata* cv. Verano in northern Queensland.

The size of the soil seed banks of *S. hippocampoides* varied greatly with both year and stocking rate treatment and reached a maximum of 2000 seeds/m² under grazing. At Narayen, seed banks were generally much lower (10–160 seeds/m²), although the 1900 seeds/m² in 1978 and 680 seeds/m² in both 1980 and 1981 were associated with above average rainfall years (Jones and Mannetje 1997). In my study, soil seed banks reached as high as 10 000 seeds/m² under exclosure indicating the potential of *S. hippocampoides* to rapidly produce seed. For example, McIvor *et al.* (1996) quote seed bank ranges of 3000–9000 seeds/m² for Verano and 600–7000 seeds/m² for Seca at a range of sites throughout Queensland.

The substantial increase in seed production with summer exclosure reported here contrasts directly with a substantial reduction in *S. hippocampoides* “density” with summer deferment (Bowen and Rickert 1979), although these authors failed to define their term “density” and quantified density as “shoots/m²”. It is unclear, therefore, exactly how their “density” figures compare with the individual plant densities measured in my study. Nevertheless, the 10 000 seeds/m² from exclosures over the 1990–91 summer compared with only 1000 seeds/m² under grazing indicates that *S. hippocampoides* can produce much higher soil seed yield in the absence of grazing.

Bowen (1980) reported that flowering in *S. hippocampoides* commenced in December and continued until March with the main seed crop being produced during February–March. This suggested that spelling in late summer would give an increase in seed production. My results at 1 beast/ha indicated that resting from grazing during summer improved seed production, but that length of rest was more important than timing. Increasing the length of summer exclosure prevented the consumption by animals of growing points, which, in turn, produced increasing amounts of seed. However, at 1 beast/1.5 ha, grazing was sufficiently lenient to produce seed irrespective of exclosure treatment. This suggests that reducing stocking pressure in summer might be sufficient to produce the necessary increases in seed production, provided rainfall is adequate.

Freshly harvested seed of *S. hippocampoides* contained 90% of hard seed, which softened with extremes of temperature and weather, a process which could take up to 12 months under field conditions (Paton and Robbins 1986). Seed bank samples collected in September in this study contained 12–24% hard seed (it is acknowledged...
that the process of separating seed from soil may influence this proportion of hard seed). This level of hard seed should ensure that seedling establishment will occur throughout the summer, although the large variation in the proportion of dead seed between years suggests that the quality of seed produced is sensitive to seasonal conditions during the period of seed production.

Overall results from the current study suggest that *S. hippocampoides* performs better at Brian Pastures than at Narayen (Jones and Mannetje 1997; Jones et al. 2000). This difference probably reflects the fact that *S. hippocampoides* is better suited to the soil at Brian Pastures than that at Narayen. The soil at Brian Pastures is a deep (> 100 cm) granite-derived sand with high acid-extractable P (35 ppm), whereas the soil at Narayen is a coarse sand derived from granite with a 20–50 cm coarse sand A horizon overlying a dense medium-clay subsoil. Both sites had a history of superphosphate fertiliser application during the 1970s. Rickert and Prinsen (1981) examined the establishment and persistence of *S. hippocampoides* on a range of soil types and concluded that *S. hippocampoides* persisted and spread into native pasture on well drained soils but was not suited to poorly drained soils.

**Implications for grazing management**

This study has demonstrated that plant density varies widely in pastures oversown with *S. hippocampoides*, as a result of highly variable soil seed banks, seedling recruitment and seedling survival. The pattern of rainfall is more influential than stocking rate in determining plant density. While the size of the soil seed bank can be boosted substantially by exclosure from grazing during summer, a reduction in stocking pressure might be sufficient to achieve high seed production if rainfall is adequate. The ensuing larger soil seed bank can substantially boost seedling recruitment and result in a subsequent boost in plant density.

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**References**


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