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Pasture Renovation Techniques of *Digitaria decumbens* and *Lotononis bainesii* Mixture

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Abstract
Pasture renovation techniques were evaluated in *Digitaria decumbens* and *Lotononis bainesii* mixture, at Mt. Cotton, southeast Queensland, where lotononis remained in trace proportions. Cultivation involving chisel ploughing or disc harrowing was ineffective in a renovation technique study, presumably due to deep seed burial, but a mow-and-remove treatment and a burning enhanced seedling recruitment of lotononis were effective. Vegetative regrowth of nodal buds was enhanced by a mow-leave, the burning and the mow-remove treatments. A herbicide (Glyphosphate) treatment did not contribute to suppression of associated grass and it appeared to have killed all lotononis and volunteer species but not *Digitaria decumbens*, A short-duration heavy grazing experiment indicated that in December or January heavy grazing was more successful than in March, May, or September, whereas nil grazing increased soil seed reserves significantly. It is concluded that the success of pasture renovation by the creation of a "gap" and subsequent seedling recruitment requires a favourable combination of soil seed reserve increment and favourable conditions for seeding recruitment.

Discipline: Grassland
Additional key words: biomass control, gap creation, heavy grazing, seedling recruitment, soil seed reserves

Introduction

Lotononis (*Lotononis bainesii* cv. Miles) is a subtropical pasture legume which is valued for its superior nutritive value, ready acceptability by livestock, cold tolerance, and adaptation to infertile soils. Pangola grass (*Digitaria decumbens*) is a low growing, creeping tropical grass, which combines well with lotononis in low coastal heath soils of subtropical Australia. Since lotononis behaves as a short-lived plant with a mean half-life of 4.2 months when associated with pangola grass at Mt. Cotton, southeast Queensland[3,15], persistence in plant yield was achieved by the manipulation of grazing pressure to enhance the cycle of plant replacement by seedlings[5]. Survival of seedlings was considered to be enhanced by the maintenance of grazing pressure after emergence, since the plant developed a buried crown under the full sun-light condition in the glasshouse. In the field, plant growth of associated *Digitaria decumbens* prevented the buried crown development of lotononis[4].

Reduction of grass dominance or of the amount of residual grass by mowing, heavy grazing and burning was essential to the seedling recruitment from soil seed reserves for *Stylosanthes humilis* and Siratro[6,7], and control of competition with grass by herbicide application enhanced Siratro seedling growth and persistence[2]. The "gap" (small bareground) creation by renovation techniques or heavy grazing would be favourable to seedling emergence, to the development of an underground crown, and to subsequent seedling survival of lotononis[16]. It may also enhance hardseededness breakdown by increasing soil surface temperature[14].

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Table 1. Effects of various pasture renovation techniques on seedling and nodal bud density of lotononis at Mt. Cotton, Queensland, Australia

Date 1984	Treatments[1)]						
	Mow-leave	Mow-remove	Burn	Chisel	Disc	Spray	Control
	Seedling density (/m²)						
15 Oct	0.0	0.0	0.1	0.0	0.0	0.0	0.0
22 Oct	0.0	0.4	1.2	0.0	0.0	0.0	0.1
27 Oct	0.1	0.6	1.3	0.0	0.0	0.0	0.2
5 Nov	0.0	0.6	1.4	0.1	0.0	0.0	0.0
19 Nov	0.0	0.8	1.7	0.0	0.0	0.0	0.0
26 Nov	0.0	1.3	1.9	0.0	0.0	0.0	0.0
3 Dec	0.1	0.9	1.9	0.0	0.0	0.0	0.0
10 Dec	0.0	1.4	2.4	0.0	0.0	0.0	0.0
	Nodal bud density (/m²)						
15 Oct	4.6	2.2	3.4	0.4	0.1	0.0	0.1
22 Oct	3.7	1.8	3.1	0.3	0.3	0.0	0.1

1): Mow-leave: Mowing and cut pasture left on the sword, Mow-remove: Mowing and pasture removed, Burn: Mowing and burning, Chisel: Chisel ploughing, Disc: Disc harrowing, Spray: Herbicide spraying, Control: No disturbance.

Table 2. Dry matter presentation of the associated grass, lotononis and volunteer species in March 1985 at Mt. Cotton

Components	Treatments[1)]						
	Mow-leave	Mow-remove	Burn	Chisel	Disc	Spray	Control
	Dry matter presentation (kg/ha)						
Grass	6,620ab[2)]	6,860ab	6,350b	10,780a	8,990ab	9,320ab	8,160ab
Lotononis	610ab	1,220a	870ab	110b	270b	0b	100b
Volunteers	130	130	420	340	480	0	140

1): Abbreviations: Refer to Table 1.
2): Values followed by different letters differ significantly at $p=0.05$ by the Tukey's range test.

A series of field studies were carried out at Mt. Cotton, Queensland from 1984 to 1987 to examine renovation techniques and heavy grazing, measuring plant regrowth and seedling regeneration of lotononis.

Renovation techniques

Table 1 shows the effects of the pasture renovation techniques. Vegetative regrowth of nodal buds was apparently enhanced by the mow-leave, the burning and the mow-remove (cut-pasture-remove) treatments as compared with other treatments at 15 days after the treatment (15 October) (Table 1), but the difference was not highly significant. Only the burning and the mow-remove treatments led to some seedling emergence, albeit at a low level, and this was superior to the burning treatment.

The mow-leave, the burning and the mow-remove treatments enhanced dry matter yield of lotononis significantly ($p<0.01$) and reduced associated grass yield as compared with other treatments in March 1985 (Table 2). Hence the burning, the mowing and the mow-remove treatments enhanced seedling regeneration and lotononis growth, while the other treatments did not contribute to successful lotononis renovation.

Short-duration heavy grazing

The condition of the pasture following heavy grazing (Table 3) reflected a lower level of litter accumulation in the Dec- and Sep-grazing treatments; in the subsequent year, the May-grazing treatment accumulated more litter than the other treatments. Least residual stubble was present in the Sep-treatments. Some bare ground was evident but the treatment differences were not significant.

The initial response of seedling recruitment occurred only in the December 1985 treatment (Table 4), but subsequent seedling recruitment events occurred in all the treatments, as was noted in the counts made on 25 June 1986 (Table 5) and 2 April 1987 (Table 6); on the latter occasion, the Jan. 1986 treatment showed a significantly higher density of seedling than the mean of the other treatments by partitioning. Density of nodal roots (Tables 4, 5, 6) was usually negatively correlated with density of seedlings, and was highest in the control treatment. These compensating trends between seedling recruitment and vegetative perennation tended to equilibrate seed head density in a period favourable to flowering (Table 4 for November–December 1985 flowering). The pattern of flowering is shown in more detail in Fig. 1 for the period October to December 1986; vegetative survival in the May-, Sep- and Dec-grazing treatments was poor and reflected in reduced flower density.

Errors associated with the measurement of the soil seed bank at the end of the experiment (Table 6)

Table 3. Dry matter stubble, litter presentation and bare ground percentage after short-duration heavy grazing in two experimental years at Mt. Cotton

Treatments		May	Sep.	Dec.	Jan.	Mar.	Mean
Litter (kg/ha)							
1985/86		2,162	1,404	734	3,179	2,766	2,049
1986/87		5,290	2,669	2,180	2,616	3,406	3,232
	Mean	3,726	2,037	1,457	2,898	3,086	2,641
Stubble (kg/ha)							
1985/86		2,740	129	1,706	1,238	785	1,319
1986/87		708	387	981	705	1,205	797
	Mean	1,724	258	1,344	972	995	1,058
Bare ground (%)							
1985/86		10.6	13.3	20.0	0.0	0.0	8.8
1986/87		0.0	0.0	0.0	0.0	8.7	1.7
	Mean	5.3	6.7	10.0	0.0	4.4	5.3

Table 4. Effects of short-duration heavy grazing on seedling emergence and nodal-root density of lotononis measured at 33–54 days after individual grazings at Mt. Cotton

Short-duration heavy grazing period	Seedling density (/m²)	Nodal-root density (/m²)	Seed head density[1)] (/m²)	Seed head density[2)] (/m²)
May 1985	0.0	16.7	73	95
Sep. 1985	0.0	27.1	59	140
Dec. 1985	31.5	3.3	125	N.A.
Jan. 1986	3.5	5.6	N.A.	N.A.
Control	0.0[3)]	21.5[3)]	148	218
LSD ($p = 0.05$)	n.s.	15.2	N.A.	N.A.

1): Measured on 19, 21, 23, 24 and 26 November 1985 for control, May-, Sep- and Dec-treatments, respectively.

2): Measured on 9 December 1985.

3): Measured on 19 November 1985.

Table 5. Effects of the short-duration heavy grazing on seedling and nodal-root density of lotononis measured on 25 June 1986 at Mt. Cotton

Short-duration heavy grazing period	Seedling density (/m²)	Nodal-root density (/m²)	Seed germination (%)
May 1985	0.4	2.9	25.1[1]
Sep. 1985	11.5	6.0	77.2[1]
Dec. 1985	21.7	0.0	14.8[2]
Jan. 1986	9.0	7.9	N.A.
Mar. 1986	10.4	5.6	N.A.
Control	19.2	10.2	21.8[2]

1): Harvested on 9 December 1985. 2): Harvested on 29 November 1985.

Table 6. Effects of the short-duration heavy grazing on seedling and nodal-root density of lotononis measured on 2 April 1987 at Mt. Cotton

Short-duration heavy grazing period	Seedling density (/m²)	Nodal-root density (/m²)	Seed head density[1] (/m²)	Seed germination[2] (%)	Soil seed reserves[3] (/m²)
May 1985	1.7	7.7	36.3	36.0	4,010
Sep. 1985	2.9	7.9	11.3	N.A.	6,000
Dec. 1985	8.3	5.8	2.7	70.0	8,760
Jan. 1986	116.0	1.3	58.5	52.5	10,200
Control	13.3	17.5	68.1	50.5	25,270
LSD ($p = 0.05$)	n.s.	7.3	41.9	6.1	12,970

1): Measured on 7 December 1986. 2): Tested on seeds collected on 29 October 1986.
3): Measured on 18 April 1986.

precluded significant treatment differences, but the control treatment showed a high value of 25,270 seeds/m², which was compared to approximate values of 9,000–10,000/m² for the Dec- and Jan-grazing treatments, and 4,000–6,000 seeds/m² for the less successful May- and Sep-grazings. Germinability of the seed collected in both the 1985 and 1986 seasons varied inexplicably among the treatments from 15 to 77% (Tables 5 and 6).

Discussion

1) Control of biomass through renovation techniques

Litter may favourably affect seedling germination, but excess litter amounts may cause delay of emergence and seedling suspension above the ground[8]. In pangola grass pastures which were grazed continuously at medium-heavy stocking rates in southeast Queensland, litter level was highest in spring and lowest in late autumn since decomposition of litter increased in summer[1]. At Mt. Cotton, litter levels in pangola-dominated pasture was 730–5,290 kg/ha in 1985/86 and 1986/87 (Table 3), which was much higher than that of both Bruce and Ebersohn's range of 810–2,090 kg/ha[1]. The comparatively much higher litter level although lesser stubble in 1986/87 may be associated with plant death and desiccation because of the prolonged drought in 1986. Litter amount was reflected in bareground or "gap" creation in 1985/86 but not in 1986/87.

Residual grass control by the burning and the mowing treatments was reflected in the reduction in associated grass biomass, which apparently reduced competition from the companion grass, and increased lotononis yield (Table 2). In the heavy-grazing experiment, the Jan-grazing treatment increased lotononis yield and reduced pangola grass presentation compared with the control in August 1986 (data not presented). This treatment also increased seedling recruitment, notably in April 1987 (Table 6), but reduced nodal root density significantly (Tables 5 and 6). This may be associated with higher susceptibility

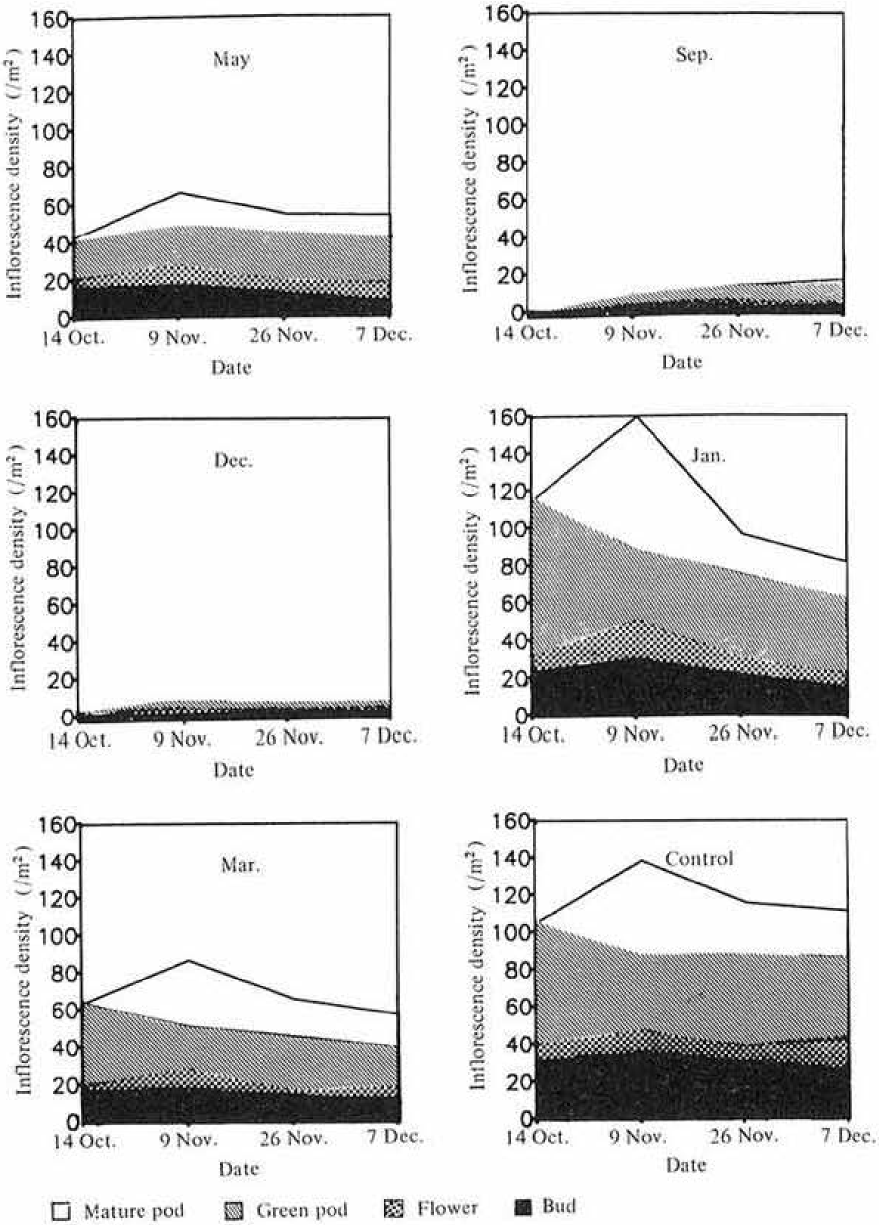

Fig. 1. Effects of short-duration heavy grazing in different times on inflorescence development of lotononis during the main flowering phase in 1986 at Mt. Cotton
May, Sep., Dec. and Jan., Mar.: Heavy grazing time in 1985 and 1986, respectively.
Control: No grazing.

of plants to treading damage in the summer time, but no supporting evidence is available.

Cultivation by the chisel ploughing and the disc harrowing enhanced pangola growth in terms of dry matter at 6 months after the treatment, but decreased lotononis (Table 1), which is in accord with the Middleton's results[9], where the population of *Kazungula setaria* increased or remained at the same level. The chisel ploughing and the disc harrowing treatments caused a fairly rough soil ripping as noted by Middleton[9]. The nil seedling emergence (Table 1) indicated inappropriate renovation methods for lotononis, in which emergence took place from shallow soil as shown in Fujita and Humphreys[4], and Mott et al.[13] also noted this as a possible cause for non-response in germination in *Stylosanthes* spp.

The herbicide (Glyphosphate) treatment appears to have killed all lotononis and volunteer species but not pangola grass; paraquat may be more appropriate to control pangola grass grown with Glyphosphate-susceptible lotononis.

2) Seedling recruitment and the "gap" creation

In terms of biomass control and "gap" creation, heavy grazing or managed fire would be common management practices in farming systems. Miller[11] reported a successful establishment of *S. humilis* without cultivation on native pastures at Katherine, Northern Territory in Australia by heavy grazing and two separate burning treatments associated with favourable rainfall.

In the renovation techniques, the burning treatment had about 1.7 times lotononis emergence relative to the mow-remove treatment (Table 1). The nil lotononis recruitment by the mow-leave treatment may be due to competition for light, as applied also to the other treatments.

On the other hand, grass and/or litter presentation may favour seedling emergence through an improved moisture environment where rainfall is limited, and fire may create unfavourable environmental conditions for seedling germination[12].

The higher density of lotononis seedlings in the burnt plots than in the mow-remove plots (Table 1) may be attributed to less competition rather than to moisture stress at the soil surface, since the onset of emergence occurred after a seasonal rainfall of 107 mm in October 1984 followed by subsequent rainfalls of 94 and 97 mm in November and December, respectively. Subsequently, the pasture was gradually covered by pangola grass and lotononis regrowth.

3) Effects of pasture disturbance on seed production

Pasture disturbance by renovation techniques may cause changes in pathways of persistence in short-lived legumes and subsequent reproductive behaviour, which would have an influence on the soil seed bank.

A short-duration heavy grazing equivalent to 21 sheep/ha together with mowing at the early flowering stage increased seed production of Verano stylo, due to the removal of apical dominance by the defoliation treatment[18]. This treatment increased branch density and provided more sites for inflorescence development, and competition by companion grasses was reduced.

Residual disposal by burning or "cut-and-pasture-remove" treatments in January increased seed yield for signal grass up to 32% compared with the same treatment in November, because of fewer spikelets per raceme in the latter[17].

In this study, the compensatory trends between seedling recruitment and vegetative perennation (Tables 4, 5, 6) reflect the resilient response of lotononis to short-duration heavy grazing. However, significant seedling recruitment by the December 1985-grazing led to much less nodal root density, which resulted in poor seed setting in the subsequent flowering season (Tables 4, 5, Fig. 1). The January 1987-grazing also reduced nodal root density significantly (Table 6). The equilibrating tendency in seed head density in November and December 1985 (Table 4) is in accord with the finding by Marshall and James[10], where a low density of *Trifolium repens* plants showed increased reproductive nodes per primary stolon, thus equilibrating inflorescence density and seed yield components were also independent of plant density.

4) Time of short-duration heavy grazing

Seasonal timing of exposure of the soil surface by pasture renovation techniques may stimulate pasture and volunteer species to regenerate and may also change the rate of hardseededness breakdown.

A population dynamics study of lotononis by Fujita[3] revealed that the seedling cohort which emerged in late summer or early winter had better survival rates and contributed well to the whole population under the seasonal grazing system imposed. In contrast, crash grazing in May did not induce successful seedling recruitment and nodal root survival (Tables 5, 6), nor result in a significant increment of soil seed reserves (Table 6).

In a previous treading study of pangola/lotononis pasture at Mt. Cotton[16], an incidence of greater seedling emergence occurred in December 1977 (post 5th treading) at a treatment intensity of 28 sheep/ha compared with lighter stocking rates; this was the same treading intensity as the heavy grazing of this report. Similarly, the December-grazing in 1985 and the January-grazing in 1987 led to higher seedling emergence. These similar responses in summer may be associated with higher soil seed reserves measured (Table 6) and possibly higher rate of hardseededness breakdown on soil surface under the "gap", where temperature fluctuation might be much greater as reported by Mott et al.[13] at the burnt sites. No evidence is available to explain the higher soil seed reserves obtained by the January- and December-grazing relative to the September and May treatments (Table 6). The significant increase of soil seed reserves by nil grazing, approximately 6 times, and the significantly higher nodal roots density were noticeable. Hence, spelling may be conveniently applied where soil seed reserves are less than $6{,}000/m^2$, which usually indicates poor lotononis presentation yield.

The inconsistent plant responses to different times of application during those experimental years appear to be due to an absence of a favourable combination of soil seed reserves increment and favourable conditions for seedling recruitment.

Special attention should be drawn to the soil seed reserves, particularly their distribution and the germinability of these seeds, when any renovation technique is to be applied. The success of pasture renovation requires a combination of germinable seeds and favourable conditions for seedling recruitment.

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References

1) Bruce, R. C. & Ebersohn, J. P. (1982): Litter measurements in two grazed pastures in southeast Queensland. *Trop. Grassl.*, **16**, 180.
2) Cook, S. J. (1982): Herbicide banding to aid establishment of sod-sown pastures in southern Queensland. *In* Proc. Second Aust. Agron. Conf., 189.
3) Fujita, H. (1989): Effects of variation in seasonal stocking intensity and mechanisms of adaptation to grazing in *Lotononis bainesii*. PhD thesis, University of Queensland.
4) Fujita, H. & Humphreys, L. R. (1991): Contractile growth of the hypocotyl of *Lotononis bainesii* seedlings in relation to some environmental factors. *J. Appl. Ecol.* (In printing).
5) Fujita, H. & Humphreys, L. R. (1991): Variation in seasonal stocking rate and the dynamics of *Lotononis bainesii* in *Digitaria decumbens* pastures. *J. Agr. Sci. Camb.* (In printing).
6) Gillard, P. (1977): Establishment of Townsville stylo in native perennial grass pastures. *Aust. J. Exp. Agr. Anim. Husb.*, **17**, 784.
7) Jones, R. J. & Jones, R. M. (1978): Ecology of Siratro-based pastures. *In* Plant relations in pastures. ed. Wilson, J. R. CSIRO, Melbourne. 353–367.
8) Keya, N. C. O., Olsen, F. J. & Holliday, R. (1972): Comparison of seedbeds for oversowing a *Chloris gayana* (Kunth.) — *Desmodium uncinatum* (Jacq) mixture in Hyparrhenia grassland. *East Afr. Agron. Forage J.*, **37**, 286–293.
9) Middleton, C. H. (1973): Oversowing legumes into grass swards. *QLD. Agr. J.*, **99**, 217–220.
10) Marshall, A. H. & James, I. R. (1988): Effect of plant density on stolon growth and development of contrasting white clover (*Trifolium repens*) varieties and its influence on the components of seed yield. *Grass. Forage Sci.*, **43**, 313–318.
11) Miller, H. P. (1967): The effect of pre-treatment of native pasture and sowing rate on establishment of Townsville lucerne on Tippera clay loam at Katherine, N. T. *Aust. J. Exp. Agr. Anim. Husb.*, **7**, 515–517.
12) Mott, J. J. (1982): Fire and survival of *Stylosanthes* spp. in the dry savanna woodlands of the Northern Territory. *Aust. J. Agr. Res.*, **33**, 203–211.
13) Mott, J. J., McKeon, G. M. & Moore, C. J. (1976): Effects of seed bed conditions on the germination of four *Stylosanthes* species in the Northern Territory. *Aust. J. Agr. Res.*, **27**, 811–823.
14) McKeon, G. M. & Mott, J. J. (1982): The effect of temperature on the field softening of hard seed of *Stylosanthes humilis* and *S. hamata* in a dry monsoonal climate. *Aust. J. Agr. Res.*, **33**, 75–85.
15) Pott, A. & Humphreys, L. R. (1983): Persistence and growth of *Lotononis bainesii–Digitaria decumbens* pastures. 1. Sheep stocking rate. *J. Agr. Sci. Camb.*, **101**, 1–7.
16) Pott, A., Humphreys, L. R. & Hales, J. W. (1983): Persistence and growth of *Lotononis bainesii–Digitaria decumbens* pastures. 2. Sheep treading. *J. Agr. Sci. Camb.*, **101**, 9–15.
17) Stür, W. W. & Humphreys, L. R. (1987): Seed production in *Brachiaria decumbens* and *Paspalum plicatulum* as influenced by system of residue disposal. *Aust. J. Agr. Res.*, **38**, 869–880.
18) Wilaipon, P. & Humphreys, L. R. (1976): Grazing and mowing effects on the seed production of *Stylosanthes hamata* cv. Verano. *Trop. Grassl.*, **10**, 107–111.

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