EFFECT OF STOCKING RATE AND SUPERPHOSPHATE LEVEL ON AN OVERSOWN FIRE CLIMAX GRASSLAND OF MISSION GRASS (*PENNISETUM POLYSTACHYON*) IN FIJI

1. BOTANICAL COMPOSITION OF PASTURE

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ABSTRACT

*Mission grass (*Pennisetum polystachyon*) pastures on steep hill land were oversown with legumes, fertilized with superphosphate at three levels, and grazed continuously for eight years at a series of 6,6 and 12 stocking rates between 0.9 and 3.5 steers* ha^{-1}.

Superphosphate increased total presentation yields of herbage, especially at low stocking rates.

*Heavier stocking decreased the contribution from mission grass and increased that from the native legume, hetero (*Desmodium heterophyllum*) and a weed legume,* Mimosa pudica, *irrespective of fertilizer level. Siratro (*Macroptilium atropurpureum*) dominated Schofield stylo (*Stylosanthes guianensis*) in the early years only when heavily fertilized, but both declined with increasing stocking rate and with time. Total legume (siratro, stylo and hetero) contribution was nearly constant, at about 25%, over the range of stocking rates for the oversown pastures after 8 years.*

The grasses, Chrysopogon aciculatus *and* Axonopus *spp., became more prevalent at high stocking rates with nil or low fertilizer, while a herbaceous creeper (*Mikania micrantha*) increased greatly following three years of vigorous growth of siratro at low stocking rates and high fertilizer.*

Changes in the composition of major species were continuing in the eighth year of grazing.

*Improved grasses oversown at the beginning of the experiment failed to establish but creeping Nadi blue grass (*Dichanthium caricosum*), oversown later, had spread to contribute up to 14% of the herbage after 4 years and was suppressing weed growth. It combined with hetero to form a stable permanent pasture at the higher stocking rates needed to justify fertiliser application.*

INTRODUCTION

The main areas available for grazing in Fiji are on moderate to very steep hill land with "nigrescent" clay soils (Twyford and Wright 1965). Most of the upper slopes are covered by almost pure stands of mission grass (*Pennisetum polystachyon*), which was introduced into Fiji in 1920 and has spread following repeated burning of dense original stands of reeds (*Miscanthus floridulis*). Oversown siratro (*Macroptilium atropurpureum*) and Schofield stylo (*Stylosanthes guianensis*) combine well with mission grass (Partridge 1975, 1979) when fertilized with sufficient phosphorus and sulphur (Partridge 1981) and cattle grazing can gain up to 180 kg liveweight per head per year (Partridge 1978).

This trial was carried out to measure the productivity of these hill pastures and to observe the effect of grazing on the vegetation. This paper describes changes in botanical composition caused by increasing stocking rates and by applying different levels of superphosphate during eight years of continuous grazing. Animal production data is presented in a second paper (Partridge 1986).

MATERIALS AND METHODS

Site

The trial covered 60 ha of mission grass on broken, steep hill land, much being over 25° slope, at Uluisila (18°05′S; 177°26′E) about 10 km northwest of Sigatoka in southwestern Viti Levu. The annual rainfall averages 1800 mm with a 6-month, moderately dry season. Monthly rainfall figures are given in Part 2 of this series. The first three years had higher than average rainfall but 1977–78 was the driest 12 month period in the 52 years recorded.

The soil is a montmorillonitic clay, described as "nigrescent" by Twyford and Wright (1965), overlying basic tuff. It is moderately acid (pH 5.6) with available phosphorus (dilute sulphuric acid extraction) levels of 7 to 12 ppm.

Treatments and layout

There were four pasture-fertilizer treatments with six stocking rates for each treatment.

Nil	(O)	— natural mission grass
Low	(L)	— 220 kg ha^{-1} single superphosphate, 2 kg ha^{-1} stylo, 1 kg ha^{-1} siratro
High	(H)	— 440 kg ha^{-1} single superphosphate, 1 kg ha^{-1} stylo, 2 kg ha^{-1} siratro
High + grass	(HG)	— 440 kg ha^{-1} single superphosphate, 1 kg ha^{-1} stylo, 2 kg ha^{-1} siratro, plus 2 kg ha^{-1} each of guinea grass (*Panicum maximum*), setaria (*Setaria sphacelata*), plicatulum (*Paspalum plicatulum*).

The area was subdivided into 24 paddocks, each with natural shade and water along creeks, with each paddock ranging from creek to ridge top. Because of the difficulty of fencing in such rough terrain, the trial design used 6 unreplicated stocking rates per treatment ranging from 3.5 to 0.9 steers ha^{-1}. Stocking rates were not equal for each treatment (Partridge 1986).

All seeds were oversown after a burn in November 1973. Two kg ha^{-1} of signal grass (*Brachiaria decumbens*) was oversown in treatment HG in 1977 and, when this also failed to establish, 2 kg ha^{-1} of Nadi blue grass (*Dichanthium caricosum*) was oversown in November 1978.

Maintenance fertilizer dressings in the H and HG treatments were 220 kg ha^{-1} single superphosphate (1974), 90 kg ha^{-1} 25% sulphur superphosphate (1975), 120 kg ha^{-1} 25% sulphur superphosphate (1976), 220 kg ha^{-1} single superphosphate in 1977. No fertilizer was then applied for 3 years until 220 kg ha^{-1} single superphosphate in 1981. The L treatments received half these rates.

Accidental fires from neighbouring land burnt some paddocks where excessive material had accumulated, in November 1977 and October 1981. All other paddocks were then burnt where possible but not destocked.

The oversown grasses failed to provide a significant contribution in the early years. Accordingly, the H and HG treatments were combined to provide a range of 12 stocking rates hereafter described as the high fertilizer (H) treatment, except in the presentation of component yields in Figure 2.

Measurements

From June 1977 to August 1982, frequency and percentage contribution to dry matter yield ('t Mannetje and Haydock 1963) and presentation yields were estimated annually in 1 m^2 quadrats covering 0.5% of the trial area. Frequency is defined as the presence or absence of a species in the quadrat.

About 40 species were scored. These are listed in Appendix 1, but only the major contributors to yield are presented in the results.

Analyses

Species which responded to treatments in terms of frequency and dry matter contribution were identified by pattern analysis and ranked according to their "Eident" values (Dale and Williams 1978). Eident values measure the importance of a species in a treatment community.

Regressions were calculated, for each responsive species, of percentage contribution to dry matter yield against stocking rate for each fertilizer level (O,L,H). These are shown graphically in Figure 1 at two-year intervals between 1977 and 1981.

Although correlations for some species between treatments and between years are not significantly different, these were not averaged. All significant correlations for each treatment and time interval are shown for symmetry of presentation.

While, in many cases, there were no significant differences between linear or quadratic regressions, quadratic functions are presented as they have a sounder biological basis.

RESULTS AND DISCUSSION

Presentation yields

Presentation yields of herbage were reduced by increasing stocking rate but increased by applying low levels of superphosphate.

Presentation yields of dry matter are illustrated by June 1979 data in Table 1. Yields at three stocking rates have been calculated from linear regressions with correlation coefficients (r) of —0.897, —0.918 and —0.876 for O, L and H fertilizer treatments respectively.

TABLE 1

Effect of stocking rate and fertiliser application on presentation yields ($t\ ha^{-1}$ DM)

Treatment	Stocking rate (Steers ha^{-1}) 1	2	3
		($t\ ha^{-1}$)	
O	2.1	1.6	1.1
L	6.0	3.9	1.8
H	5.5	3.8	2.0

Botanical composition

All species recorded in the frequency counts are listed in Appendix 1. Pattern analysis of frequency percentage and dry weight contribution in 1977 identified responsive species by "Eident" values. Designating an "Eident" value of 100 as indicative of a major response, the frequencies of 17 species were affected by the treatments applied but only four of these were important in terms of contribution to yield in 1977.

The trends of the effect of stocking rate on the contribution of eight responsive species are shown in Figure 1 for each fertilizer level (O,L,H) and with time for years 1977, 1979 and 1981, that is after 3, 5 and 7 years of grazing.

The adjusted coefficients of correlation showing the percentage variance accounted for (r^2), are included to indicate the goodness of fit of the calculated regression to the actual values. The regression coefficients are not presented as the graphical trends are self-explanatory.

Grasses

Mission grass, a fire climax species, declined under heavier stocking irrespective of level of superphosphate application. The changes were rapid and did not alter much after the third year. At 3.5 beasts ha^{-1} the 1.5 m high clumps of grass had receded to a few small tillers, leaving open ground which was colonised by other species.

Seed grass (*Chrysopogon aciculatus*) increased under heavier grazing, especially in the low and nil fertilizer treatments, reinforcing its reputation as a species encouraged by overgrazing and poor fertility.

Carpet grasses (mainly *Axonopus compressus*, with some *A. affinis*) were rarely evident in the first 5 years of grazing. They then increased rapidly, especially at nil and low fertilizer levels under heavy grazing. They provided nearly 50% of the herbage at high stocking rates in the nil treatment by the eighth year. Seed of carpet grass was spread through the dung of grazing steers. Levels of up to 50 seeds per 50 g of fresh faeces were recorded in 1981 (Partridge 1981).

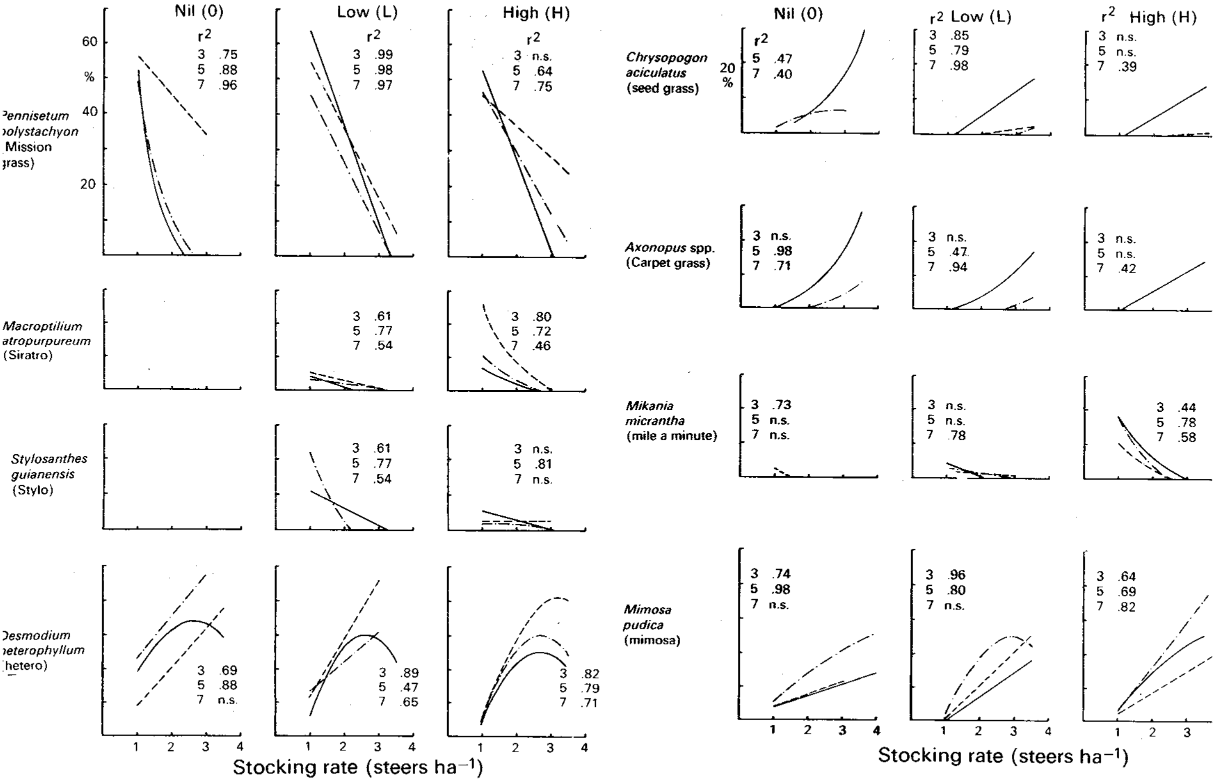

FIGURE 1

The effect of stocking rate, fertilizer level and years of grazing on the percentage contribution to dry matter yield of responsive species in mission grass pastures. (- - 3 yrs, .—. 5 yrs, —— 7 yrs grazing).

Nadi blue grass was oversown after 4 years of grazing. The fluffy awned seed is difficult to spread and in lightly stocked paddocks with tall stemmy mission grass it tended to be broadcast in the more heavily grazed patches. The seed established well and plants spread slowly from runners despite preferential grazing.

In 1979, Nadi blue grass contributed an average of 4.6% of dry matter yield, in 1981, 6.5% and in 1982, 9.2%, with up to 14% in one highly stocked paddock. The spread of this species would tend to be exponential as the grass ran from the periphery of ever enlarging patches but the trial would have needed to continue longer to achieve a complete cover. The effect of blue grass in suppressing *Mimosa* was noticeable; random quadrats cut inside the blue grass patches showed Nadi blue contributed 92% of the dried green material with hetero 5%, weeds 1% and carpet grass 2%, while immediately outside the blue grass patch *Mimosa* contributed 30%, small herbaceous weeds 63%, hetero 4% and carpet grass 2%.

The value of more stable, lower fertility demanding grass species has become more widely appreciated. The spread and effect of Nadi blue justified this line of development. *Dichanthium* species have the ability to establish successfully because of seedling survival mechanisms (Peart 1979; Watt 1982) while Nadi blue (*D. caricosum*) spreads rapidly from rooting runners in self mulching heavy clays of moderately low fertility.

The failure of the improved grasses, guinea, setaria and plicatulum, to establish under these conditions was most likely due to competition from the established grasses (Cook 1980). Seed was oversown into a burnt but undisturbed seedbed, before soil fertility was raised by nitrogen fixation. Competition from the established mission grass was intense and the area could not be grazed for 6 months because of its isolation. Signal grass has been oversown successfully elsewhere and had a better opportunity here as the paddocks were being grazed by 1977. However, the wet season effectively failed in 1977 and few seeds germinated.

Legumes

Siratro was not sown without fertilizer and was relatively sparse with a low level of superphosphate. Although it initially grew well with high fertilizer it did not withstand heavy grazing. In later years, even at low stocking rates, it declined as a vigorous, perennial creeping plant "mile a minute" (*Mikania micrantha*) spread widely, responding to the fixed nitrogen. Siratro was also affected by leaf blight (*Rhizoctonia solanii*) during wet weather, by leaf rust (*Uromyces appendiculatus*) and red spider mite on older leaves and by a black pentotomid bug (*Brachyplatys pacificus*) on seed pods and growing points.

Stylo under the lower fertilizer levels would appear to fix insufficient nitrogen to encourage the spread of *Mikania*, even at low stocking rates. With high fertilizer it was smothered by the more vigorous siratro. It also declined under heavy grazing.

The response of the naturalised legume, hetero (*Desmodium heterophyllum*), after 3 years of grazing has been described previously (Partridge 1980). The contribution of hetero had increased up to 60% of the total dry matter yield with increasing stocking rate irrespective of fertilizer level, although the latter increased total yields. In subsequent years, the percentage of hetero declined at stocking rates above 3 beasts per ha, especially after the very dry year (1977–78), when only 700 mm of rain were recorded in 12 months. During this period of very high grazing pressure, other species, notably *Mimosa*, increased; in later years the sown Nadi blue grass or carpet and seed grass component increased.

Mimosa pudica increased with increasing stocking rate irrespective of fertilizer application. Although a well nodulated legume, when dominant, Mimosa tended to reduce available feed, and subsequently cattle growth rates, because of its thorny stems. Cattle can only nibble the growing tips. Hetero grew well under the *Mimosa* leaf canopy. After 6 years of grazing, carpet grass invasion tended to reduce the density of *Mimosa*, as did Nadi blue grass (where sown).

Weeds

Mikania micrantha spread from along the creek banks to blanket those parts of the paddocks in which there was a soil fertility build up from a high density of siratro. In turn *Mikania* was parasitised by dodder (*Cuscuta* sp.) which markedly affected its vigour along a visible front. The effect was not permanent and *Mikania* regrew. Siratro was also lightly attacked by dodder when intermingled by *Mikania*.

Woody weeds, especially guava (*Psidium guajava*) were present but were controlled, with varying effectiveness, by cutting and chemical treatment throughout the trial period. Guava frequency remained at about 18% over all paddocks between 1977 and 1982. It appeared more prevalent at low stocking rates as the plants were larger, but it was easier to reach and control in the smaller, closely grazed paddocks. There is less opportunity for periodic grass fires to check aerial growth under heavy grazing. Other woody weeds included prickly solanum (*Solanum torvum*) with a 5% frequency in 1982 and "dralakaka" (*Vitex trifolia*) at about 4%. *Vitex* is tolerant of all available arboricides.

Other broadleaf weeds included tobacco weed (*Elephantopus mollis*) and "kaumoce" (*Cassia tora*). *E. mollis* seed is wind dispersed, and spread to provide about 4% of d.m. yield. It was common throughout all paddocks but more frequent at higher stocking rates. In 1982, the population of *C. tora* exploded to provide about 25% of yield in some high stocking rate, high fertilizer paddocks.

The small herbaceous weed, *Borreria laevis*, became very common but made negligible contribution to yield. It is spread in dung. Up to 70 seeds of *B. laevis* were measured per 50 g of fresh faeces.

Although fire defoliated the mission grass, siratro, stylo, *Mikania*, and woody weeds, all recovered without noticeable long term effects.

Balance of herbage components

The species present were classed as grass, legume, grass weeds and herbaceous weeds. Their contribution in the final year, after 8 years of grazing at the different stocking rates is shown in Figure 2. Classification of individual species, given in Appendix 2, is somewhat arbitrary. It is based on a subjective assessment of a species' agronomic merit; for example, carpet grass is classed as a grass weed while mission grass is rated as useful. The highest contribution of each species in any paddock in 1982 is also shown in this appendix.

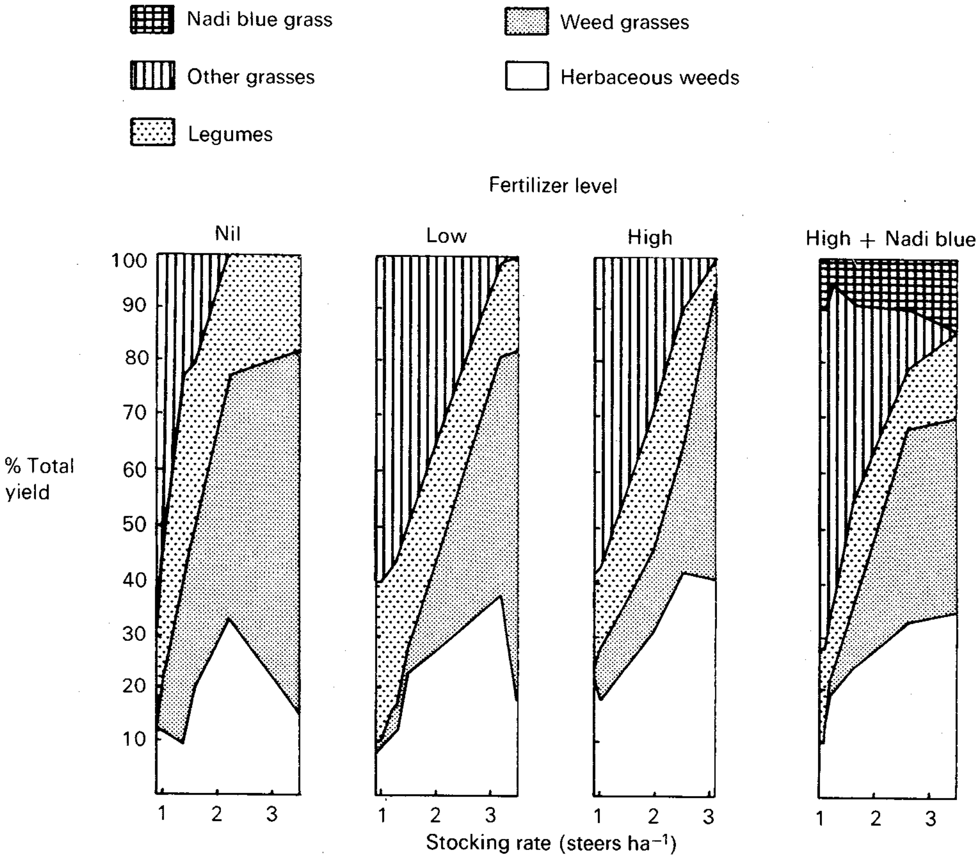

FIGURE 2

The effect of fertilizer with oversown legumes and grasses and stocking rate on the proportion of grass, legume, weed grasses and herbaceous weeds in mission grass pastures grazed for 8 years.

Total legume percentage remained fairly constant, between 20 to 30%, irrespective of stocking rate in legume oversown paddocks but increased with stocking in natural pasture. With heavier stocking, useful grasses declined and weed grasses invaded to become the major component, especially with no, or low, fertilizer. The exception was in the treatment of high fertilizer plus sown grasses where Nadi blue reduced weed levels at high stocking rates.

RECOMMENDATIONS TO FARMERS

As a general recommendation, mission grass-based pasture can be grazed for many years up to the moderate stocking rate of 1.5 steers ha^{-1} (about 1 steer on 1.5 acres). At this intensity it combines well with a mixture of Siratro, stylo and hetero. A lower grazing intensity under high fertilizer will encourage *Mikania*. However, the economics of even low fertilizer application are marginal at 1.5 steers ha^{-1}. Higher stocking rates will cause instability and weed problems after a few years of grazing. It seems imperative that a more stable grass like Nadi blue is oversown as soon as grazing starts and also that a sufficiently high seed rate (4–5 kg·ha^{-1}) is used to allow its spread by runners to prevent invasion of less useful grasses, herbaceous weeds and the thorny *Mimosa pudica*.

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APPENDIX 1

Species recorded in natural and oversown pasture in 1977.

Species	Eident value*
Macroptilium atropurpureum	730
Desmodium heterophyllum	516
Kyllingia spp.	387
Mimosa pudica	385
Mikania micrantha	349
Stylosanthes guianensis	309
Elephantopus mollis	256
Pennisetum polystachyon	226
Sacciolepis indica	207
Atylosia scarabaeoides	207
Cyclosorus sp.	204
Cuphea carthagenensis	161
Psidium guajava	144
Hyptis pectinata	135
Miscanthus floridulis	131

Species recorded in natural and oversown pasture in 1977 (continued).

Species	Eident value*
Chrysopogon aciculatus	111
Euphorbia hirta	101
Crotalaria striata	98
Paspalum orbiculare	98
Polygala paniculata	95
Paspalum conjugatum	88
Vitex trifolia	85
Borreria laevis	65
Ageratum houstonianum	61
Piper aduncum	61
Sida acuta	58
Dichanthium caricosum	53
Eleusine indica	45
Solanum torvum	42
Sporobolus indicus	35
Desmodium triflorum	33
Urena lobata	32
Bothriochloa glabra	21
Stachytarpheta urticaefolia	17
Uraria lagopoides	17
Hydrocotyle asiatica	17
Alysicarpus vaginalis	13
Paspalum plicatulum	10
Leucaena leucocephala	7
Cassia tora	4

*"Eident" values indicate the magnitude of response in frequency to stocking rate and fertilizer treatments.

APPENDIX 2

Classification of species for Figure 2, with the maximum contribution (%) recorded for each species in any paddock after 8 years of grazing

Grasses	%	Legumes	%
Pennisetum polystachyon	70	*Desmodium heterophyllum*	32
Dichanthium caricosum	14	*Stylosanthes guianensis*	20
Paspalum plicatulum	7	*Macroptilium atropurpureum*	15
Brachiaria decumbens	1	*Atylosia scarabaeoides*	5
		Desmodium triflorum	1
Grass weeds		Herbaceous weeds	
Axonopus spp.	48	*Cassia tora*	27
Chrysopogon aciculatus	32	*Elephantopus mollis*	22
Sporobolus indicus	28	*Hyptis pectinata*	19
Kyllinga spp.	4	*Mimosa pudica*	17
Paspalum conjugatum	3	*Mikania micrantha*	16
Eleusine indica	1	*Jussiaea suffruticosa*	6
		Cuphea carthagenensis	5
		Urena lobata	3
		Stachytarpheta urticaefolia	2
		Borreria laevis	1
		Ageratum houstanianum	1