EFFECTS OF PHOSPHORUS AND STOCKING RATE ON PASTURE AND ANIMAL PRODUCTION FROM A GUINEA GRASS-LEGUME PASTURE IN JOHORE, MALAYSIA

1. DRY MATTER YIELDS, BOTANICAL AND CHEMICAL COMPOSITION

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ABSTRACT

Changes in yield on offer, botanical composition, species frequency and chemical composition were measured from a continuously grazed guinea grass-legume (stylo, centro, puero) pasture over three years. The treatments were a factorial combination of three stocking rates and four annual maintenance rates of phosphorus comprising three rates of rock phosphate and one of superphosphate.

Pasture availability remained relatively constant at the low stocking rate, after the first year at the medium stocking rate, but declined markedly over the three years at the high stocking rate. The proportion of guinea grass, which was dominant, decreased with stocking rate in the third year. That of centro and stylo increased after the first year and was not affected by stocking rate except that of centro at the high stocking rate in the third year. Puero disappeared from the pasture at all stocking rates after two years. The phosphorus treatments had no effect on presentation yields.

There was a significant increase in phosphorus concentration of all species and calcium concentration of guinea grass with increasing rates of rock phosphate during the second and third year. Phosphorus treatments had no effect on the nitrogen concentration of species except for stylo in the third year.

INTRODUCTION

In Malaysia, considerable reseach has been done on the productivity of fodder grass—guinea grass (*Panicum maximum*) and napier grass (*Pennisetum purpureum*)—under various cutting regimes (Tan *et al.* 1973, Tan and Pillai 1975) and levels of fertilizer application (Balanchandran 1969, Ng 1972). Work on tropical legumes—centro (*Centrosema pubescens*), puero (*Pueraria phaseoloides*) and calapo (*Calapogonium mucunoides*)—has been mainly on their growth, nutritional requirements and fixation of nitrogen when grown as cover crops in plantations (Coulter 1972). Stylo (*Stylosanthes guianensis*) was suggested as a suitable fodder legume for the east coast of Malaysia (Vivian 1959).

Recent work in Malaysia has shown that these legumes could be grown successfully with improved grasses to form stable grass-legume mixtures under cutting (Ng and Wong 1976, Kerridge and Tham 1978). However, there has been no reported work on the productivity or persistence of these pastures when grazed by cattle in Malaysia.

The Pasture Unit of the Malaysian Agricultural Research and Development Institute (MARDI) in collaboration with the CSIRO Division of Tropical Crops and Pastures, Brisbane, Australia initiated a grazing experiment at the MARDI Research Station, Kluang, Johore (Lat. 2° N, long. 103° E, 200 m a.s.l.) in 1973. It was designed to study the effects of a range of stocking rates and annual maintenance phosphorus levels on pasture and animal production from a guinea grass-legume pasture. The grass (common guinea) and the legumes (centro, stylo and puero)

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were chosen as they are commonly grown throughout most tropical countries and locally have been found to grow well either as fodder or as cover crops in plantations. Phosphorus treatments were included as pot culture and field experiments had shown the soil to be deficient in phosphorus (Kerridge and Tham 1978).

The experiment was commenced in August 1974 and terminated in October 1977. This paper describes the seasonal changes in feed on offer, botanical and chemical composition. Animal production in relation to fertilizer treatments, and pasture production and composition will be considered in a second paper.

MATERIALS AND METHODS

Description of site

The area was previously under primary rain forest. It was cleared in 1973 and a cover crop of puero and centro sown in 1.5 m rows to prevent erosion. The soil, which is developed over granite, is a member of the Rengam Series and is classified as a Typic Tropudult (Soil Survey Staff 1975). It has been described by Law and Tan (1977) as a deep, friable, well-drained, brownish yellow soil with a coarse sandy clay to clay texture. Chemical analysis of a composite soil sample taken prior to planting indicated that it was an acid soil with a medium potassium level but low in phosphorus, calcium, magnesium and sodium (Table 1).

TABLE 1

Chemical analysis of 0–10 cm sample of Rengam Series soil from the experimental area

pH (Soil:H_2O 1:2.5)	N	P (0.1N HCl+0.03 N NH_4F) ppm	Exchangeable cations*				
			Ca	Mg	K	Na	Al
			me 100 g^{-1}				
4.6	0.17	7	0.45	0.40	0.24	0.05	1.98

*Exchangeable Ca, Mg, K and Na determined with NH_4OAc buffered at pH 7.0 and Al with 1 N KCl

Pasture establishment

Guinea grass and stylo were sown into the existing puero-centro cover in October 1973. A seedbed, 0.5 m wide, was prepared in strips 1.5 m apart along the contours and guinea grass (4 kg ha^{-1}) and inoculated stylo (3 kg ha^{-1}) broadcast into these strips together with 40 kg P ha^{-1} as triple superphosphate (TSP). After establishment, the experimental area was intermittently grazed and slashed until experimental grazing commenced in August 1974. A basal application of 50 kg K ha^{-1} as muriate of potash was applied annually, of 200 g Mo ha^{-1} as sodium molybdate in September 1974 and of 3 kg Cu ha^{-1} as copper sulphate in August 1975.

Design and treatments

Four phosphorus (P) maintenance levels and three stocking rates were combined in a 4 × 3 factorial arrangement with two replicates. Treatments were:
Annual phosphorus maintenance rates of:

(i) 20 kg P ha^{-1} as rock phosphate (Christmas Island 'A' dust)—$CIRP_{20}$
(ii) 40 kg P ha^{-1} as rock phosphate (Christmas Island 'A' dust)—$CIRP_{40}$
(iii) 80 kg P ha^{-1} as rock phosphate (Christmas Island 'A' dust)—$CIRP_{80}$
(iv) 20 kg P ha^{-1} as triple superphosphate—TSP_{20}

The $CIRP_{20}$ treatment was changed to a nil P treatment in October 1976 to achieve a wider range of available soil P levels. The P treatments were applied in September 1974 and 1975 and in October 1976.

Stocking rates of two (S_2), four (S_4) and six (S_6) head per hectare using Kedah-Kelantan bull calves between 8 and 12 months of age and averaging 80 kg hd^{-1} initial weight.

Stocking was continuous using three animals per paddock with paddock sizes of 1.5, 0.75 and 0.5 ha to achieve the desired stocking rates.

Measurements

The total feed on offer was determined at eight weekly intervals from March 1975. Strips of 1.2 m × 10 m were cut to a height of 10 cm from stratified random positions using a flail forage harvester. The number of strips harvested were four, six and twelve for the 0.5, 0.75 and 1.5 ha paddocks, respectively. The harvested material was weighed fresh and a sub-sample oven-dried.

The botanical composition of the pasture was determined at the same eight weekly intervals by the dry-weight rank method (Mannetje and Haydock 1963) using 2 m × 0.5 m quadrats. The method was modified in that the first and second ranks were given to any species which was estimated to be more than 75% of the total dry matter. This was necessary as guinea grass formed more than 70% of the pasture in most paddocks during the first year.

Frequency of occurrence of the main species, *viz.* guinea grass, centro, stylo, puero and volunteer species, was recorded in conjunction with the botanical ranking from March 1976. The frequency of occurrence of the individual volunteer species was recorded in June 1976 and the per cent bare ground estimated in August 1976. These estimates were then repeated at six-monthly intervals until the end of the experiment.

Chemical composition of guinea grass, stylo, centro and puero was determined from samples collected at eight-weekly intervals from October 1974 to September 1977. Samples consisted of the last expanded leaf (guinea) and the last three expanded leaves plus stem (legumes) from approximately fifty points in each paddock. During the first two years samples were collected at random throughout each paddock, but in the third year only those parts of the paddock which had been grazed were sampled. From March 1977, *Paspalum conjugatum* was also sampled from the high stocking rate paddocks as it formed a major portion of the pasture in these paddocks.

Samples were analyzed for a range of nutrients at each eight-weekly sampling in Year I. There was no obvious variation between sampling dates and subsequently detailed analysis was only made once in Year II and twice in Year III. Nitrogen (N) and P concentrations, however, were determined at all sampling dates. N, P, potassium (K) and sodium (Na) were determined by Kjedahl digestion and auto-analyser (William and Twine 1967), calcium (Ca), magnesium (Mg), zinc (Zn), copper (Cu) and cobalt (Co) by atomic absorption spectroscopy (David 1958, Allan 1961, Simmons 1975), molybdenum (Mo) and sulphur (S) by quantometer (Johnson and Simons 1972).

RESULTS

The annual rainfall totals for the three years beginning October 1974 were 1765, 1722 and 1805 mm. This was evenly distributed except for dry spells in January and February 1976 and in January, March and April 1977. There was no seasonal variation in temperature. Mean maximum and minimum temperatures were 31°C and 21°C, respectively.

Pasture yields and botanical composition

The eight-weekly changes in pasture composition, expressed as component dry matter (DM) on offer, together with stocking rate over the three years, are shown in Figure 1. The cumulative effects of stocking rate on the total DM on offer and percentage dry weight estimations are given in Table 2.

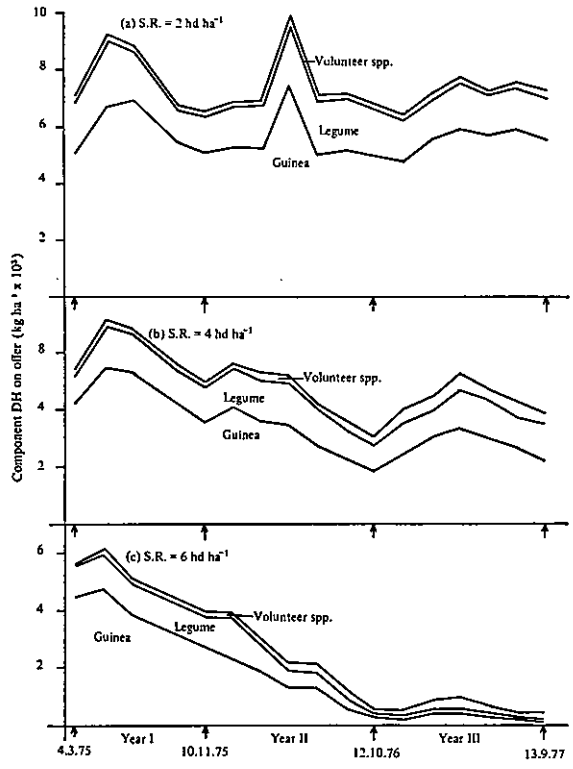

FIGURE 1

The effect of stocking rate on the component dry matter on offer.

The most dramatic result was the effect of stocking rate on the presentation yield of guinea grass, the change being similar to that of total DM. Total yield on offer (and that of guinea grass) was significantly reduced at each increase in stocking rate for each year and in the third year the proportion of guinea grass was also greatly reduced by stocking rate. Legume yield on offer remained relatively unchanged at the low and medium stocking rates but was markedly reduced at the high stocking rate. There were differences in the reaction of the legumes to stocking rate. The proportion of puero was significantly reduced by increased stocking rate from the first year, that of centro only by the highest stocking rate in the third year whereas the proportion of stylo, which was very variable, was not affected by stocking rate. The effect of stocking on puero was so severe that it was grazed out by the third year. It was apparent that there was an increase in stylo and centro from the first to the second and third years where there was no effect of stocking rate.

The yield on offer of volunteer species changed little over the years at all stocking rates. However, because of a large reduction in total DM yield at the high stocking rate, the percentage of volunteer species increased from 2% in Year I to 50% in Year III, whilst at the medium stocking rate it had increased from 1% to 11%. This increase in volunteer species during the third year was associated with an increase in per cent bare ground especially in the high stocking rate paddocks. By the third year, the mean per cent bare ground recorded in February and July 1977 for the low, medium and high stocking rate paddocks was 5, 10 and 30%, respectively.

There was no significant effect ($P > 0.05$) of P treatments on the proportion of guinea grass, stylo, centro or puero. However, the per cent dry weight of stylo was

TABLE 2

Cumulative effect of stocking rate on total DM on offer and dry weight percentage of the pasture components

Year	Stocking rate (hd ha^{-1})	Total DM on offer (kg ha^{-1})	Dry weight percentage				
			Guinea	Stylo	Centro	Puero	Vol. spp.
I	2	7630	77	6	3	13	1
(4.3.75–10.11.75)	4	5980	76	9	4	10	1
	6	5000	78	9	4	7	2
L.S.D. ($P<0.05$)		620	n.s.	n.s.	n.s.	3	n.s.
II	2	7510	76	9	8	5	2
(6.1.76–12.10 76)	4	4460	68	15	8	2	7
	6	2130	65	13	6	1	15
L.S.D. ($P<0.05$)		870	n.s.	n.s.	n.s.	2	2
III	2	7180	78	8	10	—	4
(7.12.76–13.9.77	4	4470	64	18	7	—	11
	6	920	38	10	2	—	50
L.S.D. ($P < 0.05$)		960	9	n.s.	3		7

n.s. not significant ($P<0.05$)

higher at the two lower CIRP treatments during the second and third year. Mean per cent stylo was 19, 14 and 10 in Year II and 17, 16 and 8 in Year III over the $CIRP_{20}$, $CIRP_{40}$ and $CIRP_{80}$ treatments, respectively.

Species frequency

Stocking rate had a major effect on the frequency distribution of guinea grass and volunteer species and of the three legumes present in the pasture (Figure 2).

Although the guinea grass on offer in the high stocking rate paddocks was reduced to a mean of 350 kg DM ha^{-1} in the third year, the mean frequency of occurrence of guinea grass plants of 77% was still high. Per cent frequency of puero was markedly reduced at all stocking rates, centro at the highest stocking rate while there was little effect on stylo frequency from the commencement of frequency determination. There was a marked increase in the frequency of volunteer species at the high stocking rate. Frequency distribution of the individual volunteer species recorded during the third year (Table 3) showed that *Paspalum conjugatum, Digitaria fuscescens* and *Eleusine indica* were the main grass species present whilst the marked increase in frequency of broadleaf species during the final scoring was mainly attributed to *Borrelia lactifolia*. There was no effect of P treatments on the frequency of occurrence of either sown or volunteer species throughout the experiment.

Chemical composition

Mean chemical composition of the main pasture species for the three years is shown in Table 4. There were no marked changes in nutrient concentrations between years except for Cu which increased after the application of copper sulphate. There were slight increases in the average P and Ca concentrations and a slight decrease in N concentration. Apart from P, other nutrient values shown in Table 4 appear adequate for plant growth. However, Na and Co concentrations are low in relation to animal requirements (Underwood 1971, N.R.C. 1976).

Although P treatments had no effect on P concentration in the first year, there was a significant increase in P concentration of all species with increasing rates of CIRP during the second and third year. This effect was relatively larger in guinea grass than the legumes. Similarly, there was also a significant increase in the Ca concentration of guinea grass in the second and third year with increasing rates of CIRP

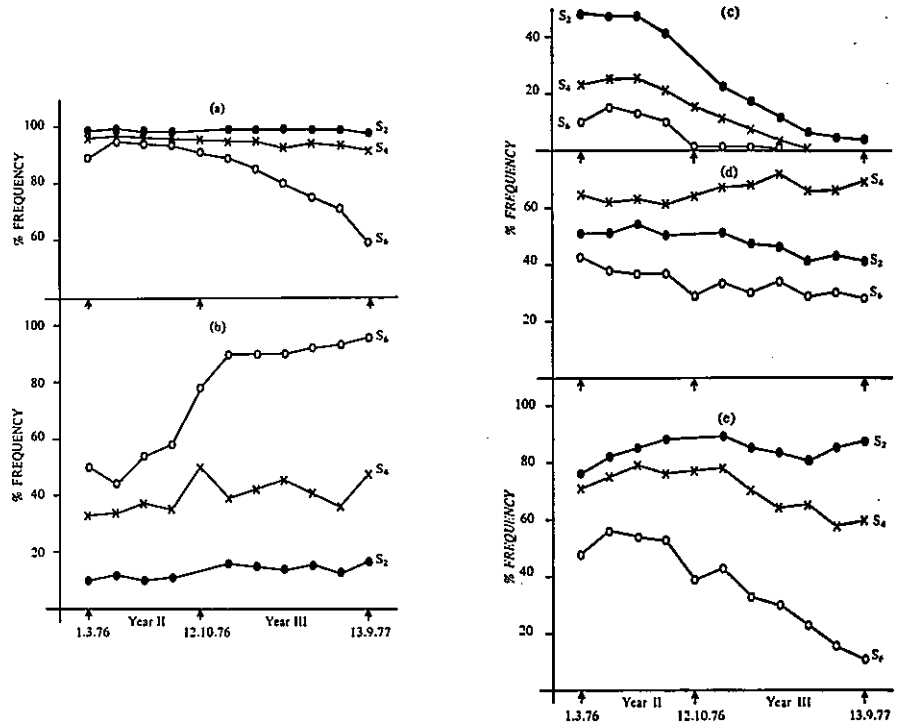

FIGURE 2

The effect of stocking rate on changes in per cent frequency of (a) Guinea, (b) Volunteer spp., (c) Puero, (d) Stylo and (e) Centro.

TABLE 3

Effect of stocking rate on frequency distribution of various volunteer species

Date of Sampling	Stocking Rate (hd ha^{-1})	% Frequency										
		1†	2	3	4	5	6	7	8	9	10	11
October, 1976	4	37	10	4	5	1	1	1	1	3	5	7
	6	64	30	14	12	4	0	5	0	2	5	17
March, 1977	2	12	2	21	1	0	0	0	0	0	0	2
	4	40	5	1	4	0	1	1	0	0	2	66
	6	83	41	12	10	4	4	6	0	2	3	22
September, 1977	2	14	4	1	3	0	0	0	0	2	0	2
	4	42	10	1	7	1	1	3	1	5	0	33
	6	73	60	12	18	11	6	0	0	2	3	46

† 1=*Paspalum conjugatum*
2=*Digitaria fuscescens*
3=*Cyperus* spp.
4=*Eleusine indica*
5=*Axonopus compressus*
6=*Eragrostis malayana*
7=*Paspalum commersonii*
8=*Sporobolus indicus*
9=Other grass volunteer spp.
10=*Calopogonium mucunoides*
11=Broad leaf volunteer spp. viz:—
(a) *Borrelia lactifolia*
(b) *Erechthites valerianifolia*
(c) *Sida acuta*
(d) *Solanum turvum*
(e) *Physalis minima*
(f) *Emilia sonchifolia*
(g) *Melastoma malabrathicum*
(h) *Clidemia hirta*
(i) *Lantana cinerea*

TABLE 4

Mean chemical composition of the main pasture species

	N	P	Ca	Mg	K	Na	S	Cu	Zn	Co
	%							ppm		
Year I										
Guinea	1.7	0.13	0.23	0.16	2.3	0.01	0.14	6	—	0.009
Stylo	3.2	0.15	1.28	0.38	2.1	0.01	0.17	8	—	0.014
Puero	3.8	0.20	0.37	0.24	2.9	0.02	0.18	8	—	0.009
Year II										
Guinea	1.8	0.17	0.28	0.21	2.1	—	0.15	7	29	—
Stylo	3.1	0.21	1.72	0.48	2.1	—	0.19	12	34	—
Centro	4.0	0.24	0.40	0.25	2.4	—	0.21	17	31	—
Year III										
Guinea	1.5	0.16	0.22	0.17	2.0	0.01	0.14	8	25	—
Stylo	2.9	0.19	1.70	0.50	2.1	0.01	0.19	14	34	—
Centro	3.6	0.23	0.49	0.25	2.4	0.01	0.21	19	30	—

Year I Mean for eight weekly samplings at S_4.
Year II Mean for sampling in April 1976 at S_2 and S_4.
Year III Mean for samplings on Dec. '76 and July '77 at S_2 and S_4.

(Table 5). This effect was also evident for stylo in the third year, but was below statistical significance. The only significant effect of P treatments on N concentration was with stylo during the third year where N concentration increased from 2.76% at nil P (previously $CIRP_{20}$) to 2.96% at the $CIRP_{80}$ treatment ($P < 0.05$).

TABLE 5

*Effect of fertilization on P and Ca concentration of the pasture**

Year	Fertilizer (kg P $ha^{-1}yr^{-1}$)	P (%)			Ca (%)
		Guinea	Stylo	Centro	Guinea
I	20 as CIRP	0.14	0.15	—	0.25
	40 as CIRP	0.12	0.15	—	0.25
	80 as CIRP	0.13	0.15	—	0.23
	20 as TSP	0.14	0.15	—	0.24
II	20 as CIRP	0.13	0.19	0.23	0.24
	40 as CIRP	0.13	0.19	0.23	0.31
	80 as CIRP	0.19	0.22	0.25	0.34
	20 as TSP	0.15	0.20	0.24	0.24
	L.S.D. ($P<0.05$)	0.03	0.01	0.02	0.07
III	nil	0.13	0.17	0.20	0.18
	40 as CIRP	0.15	0.19	0.23	0.24
	80 as CIRP	0.19	0.21	0.24	0.26
	20 as TSP	0.16	0.18	0.23	0.21
	L.S.D. ($P<0.05$)	0.01	0.02	0.02	0.03

*Average values for Year I at S_4 and Years II and III at S_2 and S_4.

The effect of stocking rate on N and P concentrations also became evident during the second year when they were significantly higher at the highest stocking rate (Table 6). Similar trends were also evident in the third year. The mean N and P concentrations of *Paspalum conjugatum* at the high stocking rate during the third year were 2.4 and 0.20%, respectively.

TABLE 6
Effect of stocking rate on chemical composition of pasture

YEAR	Stocking Rate (hd ha $^{-1}$)	N (%)		P (%)	
		Guinea	Stylo	Guinea	Stylo
I	4	1.70	3.30	0.13	0.15
II	2	1.69	3.05	0.16	0.20
	4	1.89	3.12	0.18	0.21
	6	2.58	3.42	0.22	0.25
	L.S.D. ($P<0.05$)	0.22	0.17	0.02	0.02
III*	2	1.49	2.85	0.16	0.19
	4	1.48	2.93	0.16	0.19
	6	2.41	3.29	0.22	0.23

*Year III not analyzed statistically due to incomplete samples for S_6.

DISCUSSION

This experiment represents an attempt to evaluate for the first time in Malaysia, animal and pasture production from grazed grass-legume pastures. The effect of these pasture measurements on animal production will be considered in the second paper of this series (Eng *et al.* 1978).

The major effect of stocking rate was a decline in guinea grass and legume content in the high stocking rate paddocks. This was accompanied by a marked increase in both bare ground and volunteer species indicating the pastures were not persisting at the high stocking rate treatment. The similar mean values for total DM on offer for the second and third year at the medium stocking rate suggests that pasture stability can be maintained at this stocking rate.

It is clear that puero did not tolerate continuous grazing, and, in this experiment, did not persist even at the low stocking rate. Similar results have been reported by Graham (1951) and Walsh (1958) in the wet tropical coast of North Queensland. They found that puero was very palatable and was often grazed out earlier than other legumes under continuous heavy grazing. Centro was more tolerant of increased stocking rates than puero, but stylo proved to be the most tolerant of the three legumes.

The increase in N and P concentration of guinea grass at the high stocking rate as observed by Winter *et al.* (1977) suggests an improvement of pasture quality with increasing stocking rate. However, this effect is probably largely due to morphologically different material being sampled under frequent defoliation than to nutrient recycling. Smith (1975) showed a marked decline in P concentration of the youngest expanded leaf of grasses from those in lower to higher positions on the stem.

The lack of significant responses in total DM on offer, as reported by Winter *et al.* (1977) and in the legume content, as observed by Evans and Bryan (1973), to increasing levels of P fertilization warrants further comment as responses were expected. In a cutting experiment run concurrently on the same soil and sown to guinea grass and stylo, there was no grass establishment without added P and very slow response to CIRP. The relative yields of the nil, 40 kg P per hectare as CIRP and 40 kg P per hectare as TSP treatments were 5, 30 and 80 per cent of the maximum yield in the first year. However, in subsequent years 80 per cent relative yield was obtained with 40 kg P initial + 20 kg P maintenance per hectare as CIRP or TSP. It is also possible that P was becoming deficient in the lower P treatments towards the end of the experiment and was not detected in the measurement of presentation yield. Yield responses to additional P did occur in the $CIRP_{20}$ and TSP_{20} but not the $CIRP_{40}$ and $CIRP_{80}$ treatments in a microplot experiment conducted at the conclusion of the grazing trial (unpublished data).

The higher stylo content in the two lower CIRP treatments is similar to the results reported by Winter *et al.* (1977) and is consistent with stylo being dominant at lower levels of available soil phosphorus (Bruce 1972) and having a low P requirement relative to other legume species (Andrew and Robins 1969).

The P concentration of stylo and centro (Table 5), were above the estimated critical values of 0.19 and 0.20 per cent, respectively, for the three-leaf tip samples in Year II and III, except for both legumes at nil P and stylo at TSP_{20} in Year III. While Andrew and Robins (1969) suggested a critical value of 0.17 per cent for centro shoots and Bruce (1974) 0.16 per cent for 25 cm stylo shoots, it has been shown locally (unpublished data) that the three-leaf tip samples are higher by approximately 0.03 per cent P than were the samples used to derive these critical values.

The high N and P concentrations of *Paspalum conjugatum* suggests this volunteer species has a high feed value on fertilized pastures. The mean N concentration of 2.4% is higher than the 0.9 to 1.0% N concentration reported by Ng (1976) for *Paspalum conjugatum* grown with similar legumes in a cutting experiment.

The increase in P and Ca concentration of guinea grass and P concentration of centro and stylo with increasing P fertilizer applications noted in this experiment was similar to the findings of Bryan and Evans (1973). The relevance of these results and other nutrient concentrations (Table 4) to animal production will be discussed in a following paper (Eng *et al.* 1978). The N concentration of the legumes in this experiment was not affected by P levels except for stylo in Year III. This is in contrast to the findings of Shaw *et al.* (1966), Andrew and Robins (1969) and Bryan and Evans (1973) who reported consistent increases in N concentration of the legumes as a result of increased P applications. This lack of a response in centro, similar to that of stylo in Year III, may be due to other factors limiting growth of centro. In cutting trials centro responded strongly to lime in addition to Mo, whereas stylo did not respond to lime or Mo (unpublished data). Nevertheless, the N concentrations of the legumes are quite high and this may reflect the high available soil N levels following clearing of rain-forests in addition to the adequate supply of other nutrients for N fixation.

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