THE EFFECT OF NITROGEN FERTILIZER APPLIED IN SPRING AND AUTUMN ON THE PRODUCTION AND BOTANICAL COMPOSITION OF TWO SUB-TROPICAL GRASS-LEGUME MIXTURES

R. J. JONES*

ABSTRACT

Urea at 0, 100 and 300 lb N/ac/annum was applied in two equal dressings in early spring and mid autumn to Setaria sphacelata *cv. Nandi*—Phaseolus atropurpureus *cv. Siratro*—Phaseolus lathyroides *cv. Murray and* Chloris gayana *cv. Samford*—P. atropurpureus *cv. Siratro*—P. lathyroides *cv. Murray pastures beginning one year after establishment.*

Relatively low mean responses of 18.5 and 18.1 lb dry matter per lb N applied and 0.27 lb and 0.32 lb N in plant tops per lbN applied were recorded for the N_{100} *and* N_{300} *treatments respectively. Yields at the spring and autumn harvests were increased 60% and 110% at the* N_{100} *and* N_{300} *rate compared with a mean overall response of 28% and 83% for the two N rates.*

There was no reduction in legume yield at the N_{100} *level in the first year of application, but thereafter it was reduced, and over the four year period it was halved by the application of 100 lb N/acre/annum. At the* N_{300} *rate the yield of legume was reduced in yield early and eliminated by the fourth year.*

It is suggested that nitrogen at the lower rate could be used strategically to increase yields without loss of legume if the area used for such early feed be changed each year.

In the establishment year and the first year of nitrogen application legume yield was higher with Setaria than with Rhodes grass. Thereafter the yields were similar. Over the four years Siratro contributed 37% of the total N yield of the pasture at the N_0 *level.*

Setaria outyielded Rhodes grass at all nitrogen levels in each of the four years and maintained a more weed free pasture. Blue couch grass (Digitaria didactyla) *increased in the Rhodes grass treatments after the second year, particularly at the* N_{100} *level.*

INTRODUCTION

Sub-tropical grass-legume pastures at Samford, S.E. Queensland are less productive in terms of dry matter than are grass pastures fertilized with more than 100 lb N/acre/annum (Jones, Davies and Waite 1967, Jones 1967). The application of 300 lb N/acre/annum in four split applications over the growing season to a number of grass-legume mixtures eliminated the legumes within a period of 12 months from the commencement of nitrogen fertilization (Jones, Davies and Waite 1969). Lower dressings of nitrogen at 68 and 200 lb/ac over the growing season also reduced the legume yield over a range of cutting intervals in a Siratro pasture (Jones 1967).

Grasses in association with tropical legumes grown at Samford invariably appear nitrogen deficient in the spring. The late start of the legumes in spring also results in low total pasture yields at a time when feed is in short supply.

Application of nitrogen before the legume becomes active in late spring and subsequently in the autumn after active legume growth had ceased, was considered as a means of increasing production at these periods without eliminating the tropical legume.

* C.S.I.R.O., Division of Tropical Pastures, Cunningham Laboratory, Mill Road, St. Lucia, Brisbane, Queensland.

MATERIALS AND METHODS

The experiment was carried out at the C.S.I.R.O. Pasture Research Station, Samford on a red podzolic soil with a gravelly sub-surface overlying red clay at 12 inches (Thompson and Murtha 1960).

The area was broken from naturalised pasture (*Imperata cylindrica, Digitaria didactyla, Cynodon dactylon* and *Sporobolus* spp.) in August 1961 and cultivated to a fine seedbed. In October 1961 560 lb lime (200 lb Ca) 450 lb Mo superphosphate (43 lb P, 45 lb S, 3 oz Mo), 224 lb potassium chloride (112 lb K), 7 lb copper sulphate and 7 lb zinc sulphate an acre were disced into the top 4 to 6 inches. In the spring (Sept/Oct) of each subsequent year 224 lb superphosphate (21 lb S and 22 lb P) and 112 lb potassium chloride (56 lb K) an acre were applied as a top dressing.

Three nitrogen rates and two pasture mixtures were compared in a split plot design. The fertilizer rates (main plots) and pasture mixtures (sub-plots) were:—

Fertilizer Rates:

N_0 — control
N_{100} — 100 lb N/acre/annum
N_{300} — 300 lb/acre/annum

Pasture Mixtures:

A Samford Rhodesgrass (*Chloris gayana*) 2 lb/acre
B Nandi Setaria (*Setaria sphacelata*) 7.5 lb/acre

each with Siratro (*Phaseolus atropurpureus* cv. Siratro) 2.5 lb/acre and Phasey bean (*P. lathyroides* cv. Murray) 4 lb/acre.

Sub-plots measured 33 ft x 33 ft; there were four replications in a randomised block layout.

The nitrogen (as urea) was applied in two equal dressings in September (spring) and in April (autumn) each year after the establishment year.

The legume seeds were dressed with dieldrin to control bean fly (Jones 1965) prior to inoculation with C.B. 451 strain of *Rhizobium,* and then drilled over the whole experiment. All plots were sown on November 19, 1961.

Emergence counts were made on November 28, 1961 by counting the sown species in five randomly placed 8 in. x 8 in. quadrats in each of the 24 sub-plots.

No nitrogen treatments were imposed in the establishment season but the plots were sampled for yield three times in January, March and May, 1962.

After the January 1962 harvest all plots were harvested for silage leaving a 5 in. stubble. After all other samplings the plots were heavily grazed by beef cattle and uneaten residues were topped with a mower.

For the first three harvests in 1962 (establishment year) one randomly placed 10.9 sq. ft quadrat was cut with hand shears to 1.5 inches in each sub-plot. Thereafter, before each grazing, three 10.9 sq. ft quadrats were cut in each sub-plot using a scythette (Hedrick and Hitchcock 1953), set to cut at 1.5 inches. Plots were sampled four times a year over four years in spring (Sept., Oct. or Nov.), early summer, (Dec. or Jan.), late summer (March or April) and autumn (May or June). Samples were hand sorted into planted grass, legume and weed species and dried overnight at 100°C in a forced draught dehydrator. Nitrogen determinations were made on the botanical separates for each sub-plot up to May 1964. After that date replicates were bulked prior to analysis.

RESULTS

Establishment

Rapid establishment of all sown species occurred after excellent rainfall soon after sowing (Table 1). The seed rates of the grasses had been chosen on the basis of

TABLE 1

Rainfall data for Samford for the period September 1961 to August 1966 (inches)

Year	Month	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	July	August	Total	Effective Oct.–May
1961–2	T+	1.74	6.38	10.52	5.41	7.33	3.76	6.50	2.51	1.32	0.45	3.77	1.18	50.87	
	E°	(1.74)	(5.13)	(5.44)	(3.93)	(5.12)	(3.76)	(5.22)	(2.07)	(1.32)	(0.45)	(3.77)	(1.18)	(39.13)	(31.99)
1962–3	T	2.32	1.76	5.40	7.63	6.19	0.94	14.53	2.70	8.16	0.33	0.03	2.50	52.49	
		(2.32)	(1.76)	(4.78)	(5.67)	(3.40)	(0.94)	(6.05)	(2.70)	(1.52)	(0.33)	(0.03)	(2.50)	(32.00)	(26.82)
1963–4	T	0.85	3.23	3.21	4.69	5.53	4.96	11.95	5.47	2.80	1.06	1.84	0.84	46.43	
	E	(0.85)	(3.23)	(3.21)	(4.69)	(5.53)	(4.96)	(6.09)	(2.26)	(2.80)	(1.06)	(1.84)	(0.84)	(37.36)	(32.77)
1964–5	T	3.36	2.45	2.09	5.54	3.92	2.37	0.56	2.46	1.95	2.73	9.58	3.78	40.79	
	E	(3.36)	(2.45)	(2.09)	(5.54)	(3.92)	(2.37)	(0.56)	(2.46)	(1.95)	(2.73)	(2.26)	(2.93)	(32.62)	(21.34)
1965–6	T	1.98	1.30	2.21	7.64	1.30	5.00	4.16	3.93	0.62	5.22	0.84	4.12	38.32	
	E	(1.70)	(1.30)	(2.21)	(4.66)	(1.30)	(5.00)	(4.16)	(3.76)	(0.62)	(2.22)	(0.84)	(2.95)	(30.72)	(23.01)
27 Year Mean		1.98	2.66	3.43	5.22	5.46	5.88	5.33	3.74	2.01	2.43	1.72	0.85	40.71 30.81	

+ Total Rainfall ° Effective rainfall—Total rainfall minus discharge (Data supplied by Mr. G. B. Stirk, C.S.I.R.O. Division of Soils, Brisbane).

germination tests to provide a similar number of grass plants for both grass species. This aim was achieved as plant counts showed a mean number of plants per acre of 174,000 for Rhodes grass, and of 151,000 for Setaria. Siratro sown with Rhodes grass had 71,000 plants per acre and with Setaria 48,000. Phasey bean had 123,000 and 88,000 plants per acre respectively for the two mixtures. No explanation can be given for the significant difference in legume establishment since the vigour of the Setaria in the seedling stage was lower than that of the Rhodes grass and there was very little competition from weed species.

Pasture yields in the establishment year

The Rhodes grass mixture outyielded the Setaria mixture in the first year by 2,700 lb dry matter (DM)/acre (table 2). Much of this difference occurred in the first harvest when the Rhodes grass mixture outyielded Setaria mixture by 40%.

TABLE 2

Dry matter yields and nitrogen yields of the two mixtures in the establishment season—1961–62. *lb/acre*

(Means of 12 Replicates)

(a) *Dry matter*							
Harvest	Days after	Rhodes grass mixture			Setaria mixture		
Date	sowing	*Siratro*	*P. lathyroides*	*Total*	*Siratro*	*P. lathyroides*	*Total*
23.1.62	75	214	646	6,390**	420**	1940**	4,550
6.3.62	118	78	176	2,230	310**	431**	2,220
30.4.62	173	48	38	4,110*	113*	86*	3,240
	Total	340	860	12,730**	843**	2457**	10,010

(b) *Nitrogen*							
Harvest	Days after	Rhodes grass mixture			Setaria mixture		
Date	sowing	*Siratro*	*P. lathyroides*	*Total*	*Siratro*	*P. lathyroides*	*Total*
23.1.62	75	6	13	74	13**	43**	80*
6.3.62	118	2	4	22	8*	9*	30*
30.4.62	173	1	1	50	3	2	44
	Total	9	18	146	24**	54**	164**

*, **, Indicates significantly higher yield than the corresponding component for the other grass mixture at $P<0.05$ and $P<0.01$.

Yields of both legumes were higher for the Setaria mixture than for the Rhodes mixture at all harvests. There was a fall in legume yield and legume percentage in both mixtures as the season progressed, the fall being most marked in the case of the annual phasey bean. Over the whole season the yield of legume in the Setaria mixture was nearly three times that in the Rhodes grass mixture—this difference was highly significant ($P < 0.01$). Phasey bean was the dominant legume in the establishment year, yielding almost three times as much as Siratro.

Because of the higher legume component in the Setaria mixture and also the higher nitrogen content of the Nandi setaria compared with Rhodes grass, yields of nitrogen were 12.3% higher than those of the Rhodes grass mixture (Table 2).

The phasey bean died out after the May harvest and did not regenerate.

Pasture yields in subsequent years

Nitrogen effects

A linear response to nitrogen was recorded in each year and the mean effect over the four years was equivalent to 18.5 and 18.1 lb DM per lb N applied, and

0.27 and 0.32 lb N in plant tops per 1 lb N applied for the N_{100} and N_{300} treatments respectively (Table 3).

When the data for the 'grass + weed' fraction of the pasture alone was considered there was again a linear response to nitrogen fertilizer of 23.2 and 21.7 lb DM per lb N applied and 0.41 and 0.42 lb N in plant tops per lb N applied for the N_{100} and N_{300} treatments respectively.

TABLE 3

Dry matter and nitrogen yields and dry matter and nitrogen responses for the two pasture mixtures at three nitrogen rates over four years

(Means of four replicates)

		Dry matter yields (lb/acre)				Response to nitrogen (lb DM/lb N applied)			
						As Total Yield		As Yield of Grass + Weed+	
Year	Grass	N_0	N_{100}	N_{300}	N effect	N_{100}	N_{300}	N_{100}	N_{300}
	Rhodes	7870	8310	13430		4.4	18.5	3.9	19.2
1962/63	*′				***″				
	Setaria	8470	10880	16320		24.1	26.2	24.0	28.3
	Rhodes	6680	8470	11310		17.9	15.4	26.2	20.8
1963/64	*				**				
	Setaria	8290	10940	13670		26.5	17.9	40.0	25.2
	Rhodes	4870	6270	9660		14.0	16.0	15.3	17.4
1964/65	***				***				
	Setaria	6270	9580	10960		33.1	15.6	37.1	17.8
	Rhodes	4570	5540	9330		9.7	15.9	15.4	20.0
1965/66	**				***				
	Setaria	5170	7650	11230		24.8	20.2	32.2	25.3
† Total	Rhodes	24100	28800	44100		11.6	16.6	15.4	19.7
1962/66	***				***				
	Setaria	28500	39300	52300		26.9	19.8	32.8	23.9

		Nitrogen yields (lb/acre)				Response to nitrogen (lb N/lb N applied)			
						As Total Yield		As Yield of Grass + Weed+	
Year	Grass	N_0	N_{100}	N_{300}	N effect	N_{100}	N_{300}	N_{100}	N_{300}
	Rhodes	72	92	163		0.20	0.30	0.19	0.32
1962/63	**				***				
	Setaria	85	119	208		0.34	0.41	0.34	0.45
	Rhodes	102	111	151		0.09	0.16	0.33	0.31
1963/64	*				***				
	Setaria	121	138	182		0.17	0.20	0.51	0.39
	Rhodes	63	98	180		0.35	0.39	0.42	0.43
1964/65	**				***				
	Setaria	69	120	195		0.51	0.42	0.60	0.47
	Rhodes	89	104	192		0.15	0.34	0.35	0.47
1965/66	N/S				***				
	Setaria	92	134	202		0.42	0.37	0.60	0.50
† Total	Rhodes	325	407	689		0.20	0.30	0.32	0.38
1962/66	**				***				
	Setaria	367	511	785		0.36	0.35	0.54	0.45

+ This represents the non leguminous fraction of the yield. The weed species was mainly blue couch (*Digitaria didactyla*). *′ Indicates significant difference due to species *, **, *** $P<0.05$, 0.01 and 0.001 respectively. ***″ Indicates significant N effect, $P<0.001$.

† The analyses were performed on transformed data so the totals do not necessarily equal the sum of the four years.

At every harvest the N_{300} treatment gave the highest dry matter yields. Nitrogen significantly increased yields each spring and autumn but in late summer there were no significant differences between the yields of the N_0 and N_{100} treatments in any year and for two years—1964 and 1965—there were no significant differences between any nitrogen treatment at this third harvest (figure 1).

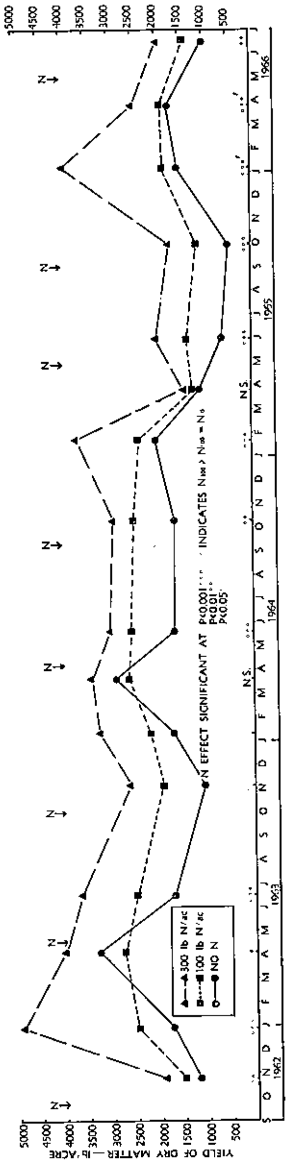

FIGURE 1

Dry matter yields at each harvest for the three nitrogen rates over four years. (Means of the two pasture mixtures and four replicates)

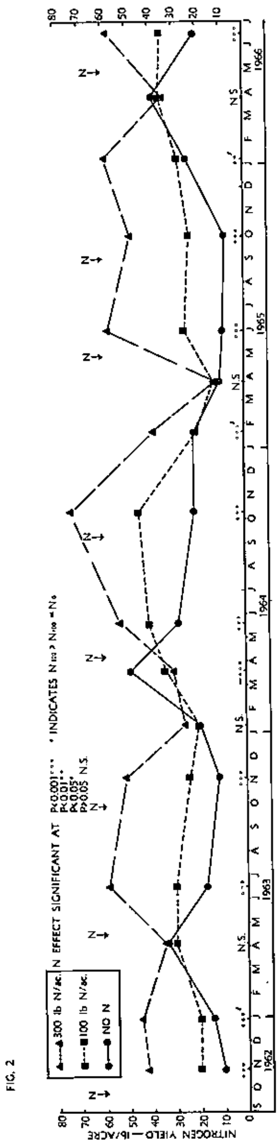

FIGURE 2

Nitrogen yields at each harvest for the three nitrogen rates over four years. (Means of the two pasture mixtures and four replicates)

Nitrogen yields were greatly increased with nitrogen fertilization for the spring and autumn harvests in every year ($P < 0.001$) (Figure 2). At the early summer harvest the N_{300} treatment gave higher yields than the N_0 and N_{100} treatments except in 1963-64. At the late summer harvests there was no significant difference between treatments in three of the four years but in 1963-64 there was a highly significant ($P < 0.001$) decrease in nitrogen yield with increasing nitrogen rates (figure 2).

Mean nitrogen content of the grass fraction of the pastures increased with increasing nitrogen fertilizer rate in every year and in addition there was an upward trend in nitrogen content with time (Table 4).

TABLE 4

Mean nitrogen content (% of dry matter) of the sown grasses at three fertilizer nitrogen rates over four years

(Means of four replicates)

Grass	1962/63	1963/64	Year 1964/65	1965/66	Weighted Mean	Mean N% of Total Pasture
N_0						
Rhodes	0.82	1.01	1.07	1.54	0.99	1.35
Setaria	0.85	0.98	0.93	1.40	0.98	1.29
N_{100}						
Rhodes	1.02	1.06	1.49	1.71	1.14	1.41
Setaria	0.98	1.08	1.18	1.60	1.17	1.30
N_{300}						
Rhodes	1.19	1.28	1.90	2.04	1.51	1.56
Setaria	1.25	1.30	1.77	1.80	1.49	1.50

Differences for total nitrogen contents of the total pasture were less than those recorded for the grass fraction alone. Again the mean N% of the pastures increased with N rate but of greater interest was the interaction of nitrogen rate and sampling date (table 5). At both N_{100} and N_{300} the nitrogen contents of total pasture were highest in the spring and autumn harvests which followed the N application. In the N_0 treatment the late summer and autumn harvests had consistently higher nitrogen contents than the spring and early summer harvests. At the early summer harvests the N_{100} gave lower values than the N_0 and at the late summer harvests there was a consistent decrease in nitrogen content with increasing N rate.

TABLE 5

Mean nitrogen content (% of dry matter) of total pasture at the four harvest periods for each of the nitrogen levels

(Means of two mixtures and four replicates over four years)

Fertilizer Treatment	Spring	Early Summer	Late Summer	Autumn	Mean
N_0	1.24	1.16	1.49	1.53	1.32
N_{100}	1.60	1.02	1.35	1.76	1.35
N_{300}	2.34	1.25	0.95	2.29	1.53

Nitrogen fertilizer depressed legume yield in every year ($P < 0.01$—$P < 0.001$) (Table 6). At the N_{300} rate there was a gradual decline in legume yield until in the final year the legume was eliminated. There was no reduction in legume yield at the

N_{100} rate during the first year of application, but in each year thereafter yields were approximately halved compared with the N_0 treatment (Table 6).

TABLE 6

Yields of legume (Siratro) with the two grass species and three nitrogen levels over the four year period
(Means of four replicates)

Year	Grass	Yield of Siratro—lb DM/acre N_0	N_{100}	N_{300}	N Effect
1962/3	Rhodes	386	417	154	**
	Setaria	724	717+	172	
1963/64	Rhodes	1710	923	134	***
	Setaria	2190	821	88	
1964/5	Rhodes	503	340	14	***
	Setaria	551	238	8	
1965/6	Rhodes	1470	446	0	***
	Setaria	1510	658	0	
1962/6	Rhodes	4070	2130	300	***
	Setaria	4970	2430	270	

+ Indicates significant difference $P<0.05$ between Setaria and Rhodes.
, * Indicates significant difference at $P<0.01$ and $P<0.001$ respectively.

Grass species effects

After the establishment year the Setaria pasture outyielded the Rhodes grass pasture in terms of dry matter and nitrogen at all nitrogen levels and over all four years ($P < 0.01$ — $P < 0.001$) (Table 3). The mean superiority of Setaria over Rhodes grass for all nitrogen rates over all four years was 24% for dry matter and 18.6% for nitrogen ($P < 0.001$).

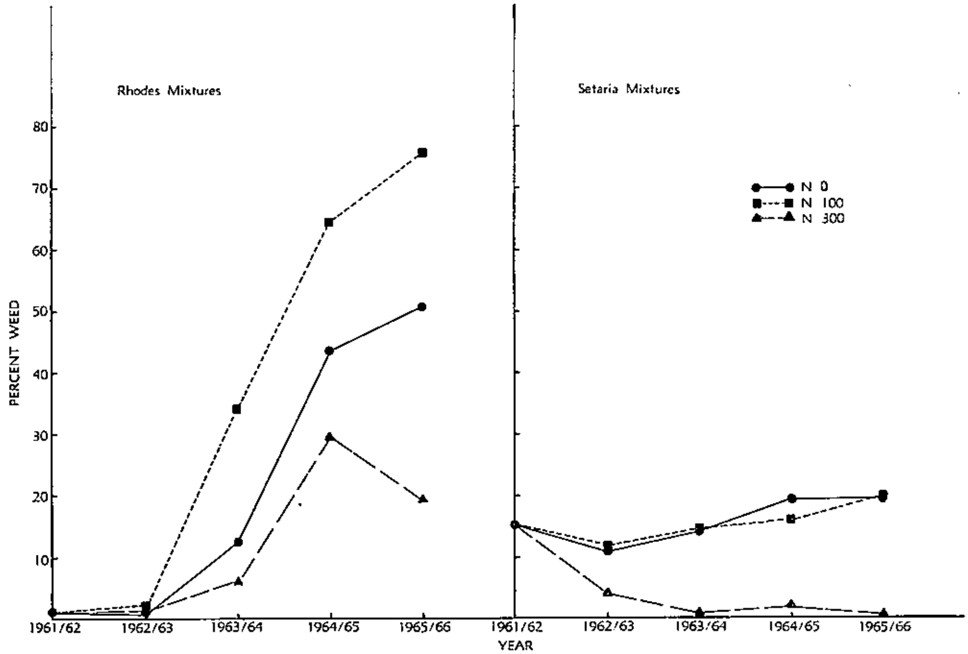

FIGURE 3

The effect of nitrogen fertilizer on the weed component of two sub-tropical pastures. (Mean of four replicates)

Grass species effects on the legume component were significant in 1962/63 only. At the N_0 and N_{100} level the yields of Siratro were higher with Setaria than with Rhodes grass ($P < 0.01$) (Table 6). Over the 4 year period at the N_0 level Siratro yields were 900 lb/acre greater with Setaria than with Rhodes grass but the difference was not significant.

After the 1962/63 season the yield of weed was significantly higher ($P < 0.01$) at all N levels with the Rhodes grass, and in the final year the percentage weed was far higher in the Rhodes grass mixtures than in the Setaria mixtures at all N levels (Fig. 3).

The marked difference in nitrogen content which occurred in the establishment year between the two grass species (Setaria > Rhodes) was reduced in the 1962/63 season, disappeared in 1963/64, and was reversed in 1964/65 and 1965/66. (Rhodes > Setaria). Mean nitrogen values for the two grasses over the four years were very similar (table 4).

Grass x nitrogen interactions

Over all four years the N_{100} treatment increased yields of Setaria but with Rhodes grass there was no significant increase in yield of sown grass compared with the N_0 control (Fig. 4).

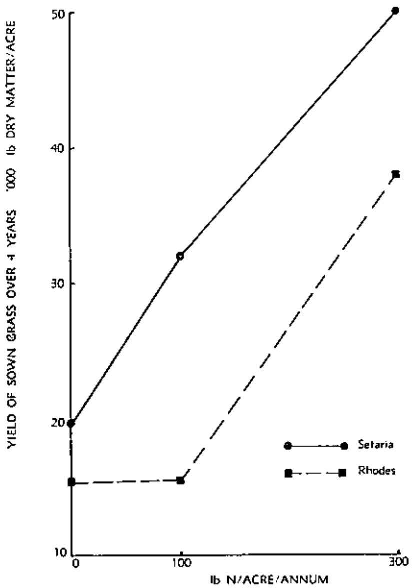

FIGURE 4
The effect of nitrogen on the yield of sown grass for the two mixtures.
(Means of four replicates)

A significant interaction between N and sown grass occurred in 1964/65. The N_{100} treatment reduced the yield of Rhodes grass compared with the N_0 treatment, but increased the yield of Setaria, as occurred in every year.

Seasonal effects

Total dry matter yields fell from year 2 to year 5. This was due in part to declining effective rainfall as the experiment progressed. Legume yields were very low in 1962/63 and again in 1964/5. In 1965 severe summer drought, when there was only 41% of the mean summer rainfall (Jan.-March), had a pronounced effect on the Siratro yield. In that year the yield of legume on the N_0 plots was less than

10 % of the total yield compared with 30% in 1965/66. Total effective rainfall was less in 1965/66 but its distribution favoured the Siratro more than in the previous year.

DISCUSSION

The grazing management imposed is open to criticism since only four grazings were given annually. However, the grazings were heavy and intended to graze the pasture down to the sampling height of about 2 inches. The spring sampling was undertaken when about 500-1000 lb DM per acre was present on the N_0 plots. Earlier sampling and grazing could have occurred on the N treatments but this would have meant either a differential grazing on the N treatments which was undesirable, or a tendency to over-estimate yields in the low yielding N_0 plots. From previous work with Siratro (Jones 1967) additional grazings would be expected to reduce Siratro yields and hence inflate the differences recorded. It is very difficult to impose 'practical' grazing treatments and yet obtain accurate pasture growth data especially when little is known of the grazing management best suited to these species.

The low production of the perennial legume Siratro in the first and second years of the trial despite good establishment may be associated with the sowing of the rapidly growing *phasey bean*. When it died out after the first year there appeared to be a marked beneficial effect on the associate grass which served to suppress Siratro. It was not until the third year that more than 25% legume in the N_0 treatments were obtained. The treatment effects reported here should be viewed in this light. Had the annual legume not been sown, higher yields of the perennial Siratro might have been obtained in the early years.

Mean yields for the N_0 treatments were lower than those reported earlier for *P. atropurpureus* pastures at Samford (Hutton 1962, Jones, Davies and Waite 1967). In addition to the effect of the annual legume noted above, the soil was much shallower than on the previous trial with an expected lower moisture retaining capacity (Thompson and Murtha 1960). Over the four years the Siratro contributed a mean of 37% of the total nitrogen in the pasture at the N_0 level compared with 50% for *P. atropurpureus* X in the previous trial. Furthermore, yields of Siratro never exceeded 3000 lb DM in any year and so contributed far less than 100 lb N/acre/yr to the system (Jones, Davies and Waite 1967).

Nitrogen responses

The responses of 18 lb DM and 0.30 lb N/lb N applied are low compared with other experiments (Henzell 1962; Henzell 1963; Jones 1966; Jones, Davies and Waite 1967) but most studies report responses on grass pastures without a legume. A more realistic response for comparison with other results is obtained using the data for 'grass + weed'. Here a value of 22 lb D.M. and 0.42 lb N per lb N applied was obtained. This is nearer to the values reported above but lower than many. The low values could be due to a number of reasons—the chief ones being the use of urea as the fertilizer, the application of the nitrogen when growth was slow, and the possibility of high losses resulting from dry spells when the urea was applied out of season.

Lower efficiency can, however, be of minor importance if feed is being produced at a time when it can be utilized more efficiently by stock. This can be expected in spring when feed is in short supply and also in late autumn and winter. In this study a response of approximately 60% at the N_{100} rate and 110% at the N_{300} rate was obtained at the spring and autumn harvests compared with a mean overall response of 28% and 83% for the two N rates.

The higher total dry matter production resulting from the use of nitrogen was achieved at the expense of loss of legume. This is in keeping with the results reported for green panic-lucerne and green panic-glycine pastures receiving 50 or 200 lb N/

ac/annum at Lawes, S.E. Queensland, where legume yields were reduced at the N_{50} rate and halved at the N_{200} rate. This reduction with nitrogen fertilizer appeared not to be associated with competition for water since a similar reduction occurred in irrigated treatments (Kleinschmidt 1967). Elimination of the legume at the N_{300} treatment was slower than in a previous trial (Jones, Davies and Waite 1969), where the nitrogen was applied throughout the growing season and there seems little point in including Siratro in pasture mixtures that are to be heavily dressed with nitrogen each year even if such dressings are applied outside the normal growing season of the associate legume.

At the N_{100} rate, total yields were again increased but the legume component was reduced. The absence of a reduction in legume yield in the first year of application at the N_{100} rate is not easy to explain. Only 50 lb of this 100 lb rate would have had much effect in the first season since the Siratro would virtually have ceased growing by the time the autumn application was applied. It was noticeable that on the N treatments the canopy of Siratro was elevated to compete with the taller grass associate. As a result more of the actual legume yield was removed in the sampling and grazing on the N treatments. This removal could have maintained or even increased recorded yields for one season but the more severe defoliation would be expected to jeopardise legume yields in the following year.

The effect of the applied nitrogen in reducing legume percentage appeared to be cumulative. The lack of any noticeable effect after one year might indicate that pastures could be dressed with nitrogen for one year without seriously reducing the legume component. This would mean that nitrogen could be used strategically to provide early or late feed from grass-legume pastures provided the area of pasture chosen was different in each year. This particular aspect was not specifically tested in this trial so further testing would be required to substantiate this claim. Botanical estimates of the pastures for two years after the cessation of nitrogen application indicated that recovery of the legume component was slow especially following the N_{300} treatment. Rating the N_0 treatment as 100 the values were 16, 2 and 67, 13 for the N_{100} and N_{300} treatments for the two years.

The problem of maintaining the perennial legume in mixed tropical pastures supplied with nitrogen is more acute than in temperate pastures. Tropical grasses have far higher growth rates than tropical legumes and than temperate grasses and legumes (Tow 1967, Ludlow and Wilson 1968, El-Sharkawy and Hesketh 1965); and in consequence use water much more efficiently (Tow 1967). In addition they take up more of the nitrogen applied to mixed grass legume swards (Henzell *et al.* 1968), and persist and produce better under frequent defoliation (Santhirasegaram, Coaldrake and Salih 1966, Jones 1967, Whiteman 1969). In a situation of increasing fertility and with the possibility of increasing stocking rates the legume must be at a disadvantage in competition with the grass unless the grass is preferentially grazed or the habit of the legume reduces tillering and regeneration of the grass by shading. In practice therefore any gain in dry matter production by the use of nitrogen must be viewed in the light of reduced legume yield. This will undoubtedly vary with the inherent soil fertility, moisture status, legume used, rate of nitrogen and grazing management. The final result can only be assessed in terms of animal production and economic returns which were not covered in this study.

Grass species differences

The results clearly show the effect of an associate grass species on the growth of the legume in the establishment year. The initially slower growing Setaria enabled a far higher yield of legume to be obtained even though the legume establishment was poorer on the Setaria plots. Rhodes grass is extremely competitive in establishment if fertility conditions allow and Rhodes grass cv. Samford is particularly aggressive (Jones, Davies and Waite 1969). The severity of the effect of such an associate will depend on the initial legume density and on the seasonal conditions prevailing. In this study the Siratro was able to build up to a level similar to that in the Setaria treatments by the third year and recovered to a similar extent after the 1965 drought with both species.

Setaria was clearly superior to Rhodes grass under these conditions and this supports the findings of a previous study (Jones, Davies and Waite 1969). It seems apparent that the early vigour and aggressiveness of Samford Rhodes grass is not maintained unless fertility levels are maintained throughout the growing season. The ingress of weed species after the second year occurred at all N levels but particularly at N_{100}. Blue couch (*Digitaria didactyla*) was the main weed component but toward the end of the trial Nandi setaria also invaded the Rhodes grass. The ingress of blue couch was more rapid than in the study reported by Jones, Davies and Waite (1969), where blue couch ingress was associated with a change of grazing management. In this study ingress occurred under a relatively constant grazing management. With no nitrogen applied in summer, however, the Rhodes grass did not possess the vigour to suppress blue couch. In the N_0 treatment Siratro effectively shaded much of the area between Rhodes grass tufts so reducing ingress of blue couch. At the N_{100} level the legume density after 1962/3 was much lower than at N_0 and blue couch ingress was rapid.

With both species there was a continuing rise in nitrogen content as the trial progressed. This rise cannot be ascribed solely to recycling of nitrogen as yields were falling over the period of the trial and this alone could have explained the rise in nitrogen content. If this is so it must mean that growth was reduced more by the seasonal conditions than was nitrogen uptake.

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