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EFFECT OF FERTILIZER NITROGEN ON A DENSE SWARD OF KIKUYU, PASPALUM AND CARPET GRASS. 2. INTERACTIONS WITH PHOSPHORUS AND POTASSIUM

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SUMMARY

On the Atherton Tableland superphosphate and muriate of potash were applied in the N:P_2O_5:K_2O ratio 2:1:2 to plots of kikuyu-paspalum-carpet grass which had been fertilized with urea at rates up to 400 lb N/ac/year for the previous 3 years.

The application of potash increased dry-matter yield by 31% at 400 lb N/ac and 10% at 200 lb N/ac. It did not affect yield at 100 lb N/ac. These responses are linked with levels of available potassium in the soil at the commencement of the experiment and the nitrogen:potassium ratio in the herbage.

The application of phosphorus did not influence yield to any great extent.

I. INTRODUCTION

At Minbun, Queensland, nitrogen was applied to a sward of kikuyu, paspalum and carpet grass at rates up to 400 lb/ac/year for 3 years (Gartner 1969). The annual dry-matter yields of 9,000–11,000 lb/ac were considered low for the amount of nitrogen used when compared with those recorded by other workers with tropical grasses under cutting management (Vicente-Chandler, Silva, and Figarella 1959; Henzell 1963; B. Grof, personal communication).

The vigour of kikuyu weakened in the third year of the experiment and a significant decline in exchangeable potassium was recorded in the soil under high-nitrogen treatments. Thus, factors other than the environment may have limited dry-matter yields to this level.

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One limit considered was nutrient imbalance induced by continued massive doses of nitrogen, particularly in regard to potassium nutrition, which probably was further altered by the cut-and-remove harvesting technique (Little, Vicente, and Abruna 1959; Herriott and Wells 1963; Wolton 1963).

Therefore, an experiment was set up to investigate whether nutrient imbalance with reference to phosphorus and potassium had occurred in the plots previously treated with nitrogen fertilizer.

II. EXPERIMENTAL

Site location, climate, soil fertility and other environmental factors were described in the first paper on this work (Gartner 1969). During the experimental period of 33 weeks from November 4, 1964, to June 23, 1965, rainfall was adequate and well distributed. Funnel ants (*Aphaenogaster* spp.) continued to spread throughout the site.

Plots in four replications of the original experiment were split and four new treatments introduced, viz. N, NP, NK and NPK in the N:P_2O_5:K_2O ratio of 2:1:2 where applicable.

Treatments then were:

Nitrogen as urea (46%N) applied half on November 25, 1964, and half on March 24, 1965, giving total applications of 0, 50, 100, 200 and 400 lb N per acre.

Phosphorus as superphosphate (22% P_2O_5) applied on November 25, 1964, at the rates of 0, 25, 50, 100, and 200 lb P_2O_5 per acre.

Potassium as muriate of potash (60% K_2O) applied half on November 25, 1964, and half on March 24, 1965, giving total applications of 0, 50, 100, 200 and 400 lb K_2O per acre.

All fertilizers were hand-broadcast onto the sward, which had been mown 3 weeks previously.

Main plots were 40 lk x 40 lk and subplots 10 lk x 40 lk. At each of the four harvest dates (Table 2) the whole datum area of 60 sq ft (3 ft x 20 ft) was sampled, using an Allen-Oxford Autoscythe. The cut green material was weighed in the field and subsampled into airtight bottles for dry-matter determination. These samples were dried at 160°F in a forced-draft oven. N, P and K analyses of this material were done by routine procedures. After each harvest the borders were mown to sampling height and the herbage removed.

III. RESULTS

(a) Dry-matter Yield

Since there was no suggestion of a response to P and K applied to plots receiving 0 and 50 lb N, yields from these treatments have not been included.

Mean total dry-matter yields from the individual elements are shown in Table 1. The differences between 100, 200 and 400 lb N are highly significant ($P<0{\cdot}01$). There is a suggestion of a response to P at 400 lb N. The response to K is highly significant ($P<0{\cdot}01$) at 200 and 400 lb N.

TABLE 1

MEAN TOTAL DRY-MATTER YIELDS (LB/AC) AT EACH LEVEL OF NITROGEN APPLICATION FROM THE INDIVIDUAL ELEMENTS NITROGEN, PHOSPHORUS AND POTASSIUM FOR THE 33-WEEK EXPERIMENTAL PERIOD

Element	Nitrogen Rate (lb/ac)			s.e.	L.S.D.	
	100	200	400		5%*	1%**
Nitrogen						
N (2)†	5,080	7,070	9,260	330	1,160	1,750
Phosphorus						
O	4,940	7,020	8,920	260	750	1,020
P_2O_5 (1)†	5,230	7,120	9,600			
Potassium ..						
O	4,970	6,540	7,940	260	750	1,020
		**	**			
K_2O (2)†	5,200	7,600	10,580			

† $N:P_2O_5:K_2O$ ratio = 2:1:2

Dry-matter yields at each harvest together with total yields are shown in Table 2. In plots fertilized only with nitrogen, the difference in total yield from 200 lb N to 100 lb N is highly significant ($P<0{\cdot}01$). The response quickly falls off between 200 lb N and 400 lb N, approaching significance only at the 5% level. Almost all of this response occurred at the harvest following fertilizing, but at the 400 lb N level there was no additional response to the second application of nitrogen.

The K response is in reverse: nil at 100 lb N, approaching significance at 200 lb N, and highly significant ($P<0{\cdot}01$) at 400 lb N. Again, most of the response occurred at the harvest after fertilizing.

The data also suggest that P has reinforced the K effect, since the highest total yields at the three levels of N fertilization were recorded with the use of a PK mixture. The overall PK interaction was significant at the 5% level when compared with K itself.

As well as the measured yield response, the differences due to K and PK were visually evident in the 200 and 400 lb N plots. The kikuyu in these plots had thick, fleshy stems with internodes carrying broad, long leaves. The kikuyu in the O and P plots looked unthrifty, with narrow, short, pointed, erect leaves on spindly stems with short internodes. Leaf diseases were more prominent in these plots.

TABLE 2

Dry-matter Yields from each Treatment at Each of the Four Harvest Times and Total Dry-matter Yield for the 33-week Experimental Period

Date fertilized			25.xi.64—NPK		24.iii.65—NK		
Date harvested			29.xii.64	17.iii.65	27.iv.65	23.vi.65	—
Harvest interval (days)			55	78	41	57	
N (lb/ac)	P_2O_5 (lb/ac)	K_2O (lb/ac)	D.M. Yield (lb/ac)	D.M. Yield (lb/ac)	D.M. Yield (lb/ac)	D.M. Yield (lb/ac)	Total Dry-matter Yield (lb/ac)
100	..	..	1,090	2,030	890	930	4,940
100	50	..	950	2,280	1,060	710	5,000
100	..	100	1,090	1,970	980	900	4,940
100	50	100	1,020	2,140	1,220	1,080	5,460
200	..	..	1,820	2,290	1,490	1,100	6,700
200	100	..	1,720	2,330	1,380	950	6,380
200	..	200	2,230	2,220	1,730	1,170	7,350
200	100	200	2,430	2,440	1,560	1,420	7,850
400	..	..	2,810	2,330	1,400	1,180	7,720
400	200	..	3,290	2,220	1,560	1,080	8,150
400	..	400	3,280	2,710	2,490	1,650	10,130
400	200	400	3,860	2,960	2,460	1,770	11,050
S.E.			138	188	132	104	367
Necessary differences for significance		5%	394	537	383	301	1,065
		1%	526	717	517	407	1,439

(b) Chemical Composition

Mean nitrogen, phosphorus and potassium contents in the herbage, weighted for dry-matter yield at each harvest, are shown in Table 3, together with total yield of each element during the period of the experiment.

Nitrogen content increased with rate of nitrogen fertilization but was independent of phosphate and potash treatment. Thus nitrogen recovery was dependent on dry-matter response.

Phosphorus content of herbage fertilized with phosphate was higher than that of unfertilized herbage at the 400 lb level of nitrogen. This effect was suggested at the lower levels of nitrogen at individual harvests. An increase in content occurred with nitrogen fertilization from 100 to 200 lb N but then levelled off at 400 lb N. Yield of phosphorus was modified by the dry-matter response to potash.

Potassium content increased with rate of potash fertilization but there was a decline with increasing nitrogen fertilization when no potash was used. This had a synergistic effect on potassium yield, since the major dry-matter response was to potash fertilization.

TABLE 3

WEIGHTED MEANS FOR PERCENTAGE NITROGEN, PHOSPHORUS AND POTASSIUM CONTENTS IN THE HERBAGE AND THE TOTAL YIELD OF EACH ELEMENT FOR THE 33-WEEK EXPERIMENTAL PERIOD

N (lb/ac)	P_2O_5 (lb/ac)	K_2O (lb/ac)	Yield of Elements (lb/ac)			Weighted Mean (%)		
			N	P	K	N	P	K
100	..	..	86·3	11·5	93·6	1·75	0·23	1·90
100	50	..	83·9	12·4	86·3	1·68	0·25	1·72
100	..	100	83·4	12·1	96·1	1·69	0·25	1·95
100	50	100	97·5	14·1	111·6	1·79	0·26	2·04
200	..	..	131·2	19·2	131·0	1·96	0·29	1·96
200	100	..	128·3	18·6	105·7	2·01	0·29	1·66
200	..	200	148·2	19·6	183·2	2·02	0·27	2·49
200	100	200	154·6	22·2	196·2	1·97	0·28	2·59
400	..	..	184·4	19·3	130·7	2·39	0·25	1·69
400	200	..	191·0	23·4	135·9	2·34	0·29	1·67
400	..	400	233·1	25·0	318·3	2·30	0·25	3·15
400	200	400	262·4	32·9	339·2	2·38	0·30	3·07

The addition of phosphate in the absence of potash appeared to upset the nutrient balance even further, resulting in a depression of potassium content below that of grass fertilized only with nitrogen; this effect, however, was less marked at the 400 lb N level.

A relationship has been derived in Figure 1 between chemical composition and dry-matter yield. The N:K ratio (using weighted percentages), where N=1, is plotted against the percentage treatment yield of harvest mean yield at each level of nitrogen. By using the latter value, yield differences due to nitrogen fertilization, harvest interval and time since fertilizing are reduced.

At the 100 lb N level, when there was no significant dry-matter response to potash (Table 2), most of the points are located in the area N:K>1 and 90-110% of harvest mean (HM). As the dry-matter response to potash increases, then the points are scattered further from the point N:K=1, HM=100 in the quadrants N:K>1, HM>100 or N:K<1, HM<100.

When linear regressions were calculated for these points at each level of nitrogen and for all treatments there was no significant correlation at 100 lb N, but there were highly significant correlations at 200 and 400 lb N and for all treatments (Table 4). The regression line for the latter, $y = 50{\cdot}7 + 45{\cdot}9x \pm 8{\cdot}6$, is drawn in Figure 1. When the harvest mean = 100 this line intersects at the N:K ratio of 1·08.

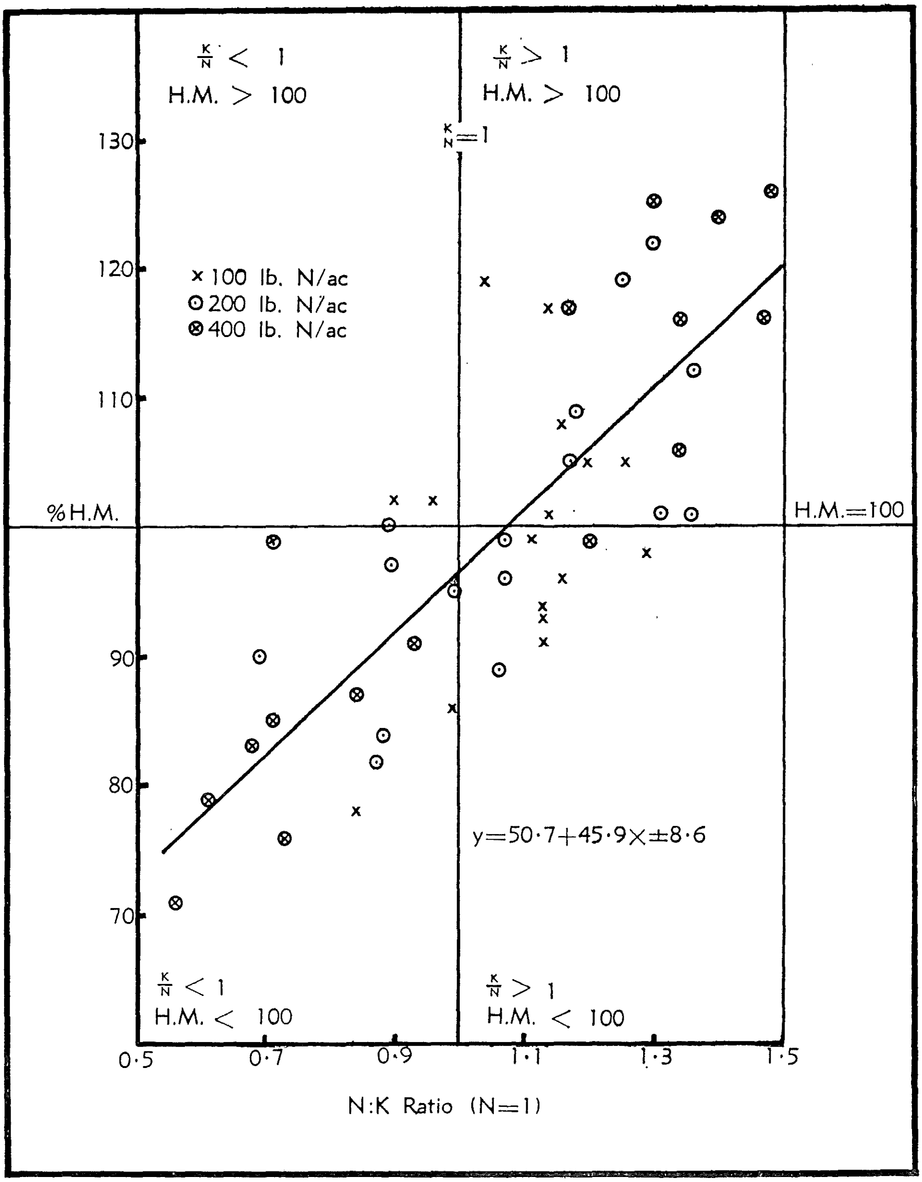

Fig. 1.—The linear regression of percentage treatment yield of harvest mean yield (HM) on the N:K ratio in the herbage.

IV. DISCUSSION

The potassium response obtained is typical of many experiments (Holmes and MacLusky 1954; Vicente-Chandler *et al.* 1962; Burton and Jackson 1962) under cutting management in which grass production is raised by the use of

TABLE 4

CORRELATION COEFFICIENTS (r) AND PROBABILITIES (P) FOR THE LINEAR REGRESSIONS OF PERCENTAGE TREATMENT YIELD OF HARVEST MEAN YIELD ON THE N:K RATIO IN THE HERBAGE AT EACH LEVEL OF NITROGEN AND FOR ALL TREATMENTS

Regression	r	P	n
100 lb N/ac	0·344	N.S.	16
200 lb N/ac	0·731	$<0{\cdot}001$	16
400 lb N/ac	0·916	$<0{\cdot}001$	16
All treatments	0·784	$<0{\cdot}001$	48

nitrogen fertilizer. However, Wolton (1963) doubted if the responses in these experiments would have occurred had they been conducted with excretal return, since under these conditions most of the potassium consumed in the herbage is returned to the sward, mainly in the urine.

Phosphorus is taken up in the herbage in much smaller amounts than nitrogen and potassium; this probably accounts for the lack of a highly significant response to this element under the cutting management imposed. In excreta, phosphorus is almost wholly contained in the dung portion. Since the availability of nutrients in dung appears to be low (Doak 1952), excretal return would have little effect on the response obtained.

At the commencement of the experiment, levels of available P_2O_5 (145 p.p.m) and available K (0·62 m-equiv. %) in the soil were considered adequate. However, in 3 years K level under the 400 lb N treatment had been reduced significantly ($P<0{\cdot}05$) to 0·32 m-equiv. %; there was no significant change in P_2O_5 values (Gartner 1969). This result closely parallels that of Herriott and Wells (1963). The dry-matter response to potash fertilizer increased with the fall in soil K, being 31% ($P<0{\cdot}01$) at 0·32 m-equiv. %; 10% (NS) at 0·37 m-equiv. % under 200 lb N treatment; and nil at 0·41 m-equiv. % under 100 lb N treatment. Values under 0 and 50 lb N were about 0·5 m-equiv. %. Therefore the threshold level of soil K in this experiment was about 0·4 m-equiv. %. This is higher than that estimated by the common rule-of-thumb for satisfactory soil K, which is 0·2 m-equiv. % or 2% of total replaceable bases, whichever is the greater; one would not expect the total replaceable bases in the soil under study to be much greater than 10 m-equiv. %.

Phosphorus and potassium contents (Table 3) at all rates of nitrogen are adequate if it is accepted that 0·2% P and 1·0% K in young growth are sufficient for optimum growth of the subtropical grasses concerned. (Burton (1954) and Jordan, Evans, and Rouse (1966) quoted levels ranging from 0·16 to 0·2% P and 0·8 to 1·0% K as sufficient for coastal bermuda grass). Thus the higher potassium contents obtained when potash fertilizer was used indicates luxury consumption of this element, particularly at the 200 and 400 lb K_2O levels; but the dry-matter response to potash at these levels belies this.

It is suggested that the increase in potassium content may only have been in sympathy with the appreciable rise in nitrogen content with increasing nitrogen fertilization. Therefore it may be important, once minimum levels of phosphorus and potassium have been established, to maintain a balance between the elements.

In this context a relationship between nitrogen and potassium and yield has been derived in Figure 1. The suggestion is that, when the potassium content of the herbage is greater than the nitrogen content, the potassium supply is adequate for maximizing herbage production with nitrogen fertilizer; when the potassium content falls below that of nitrogen, potassium is limiting the production potential of the nitrogen.

An experiment specifically designed to test this inference is necessary, using a pure sward of kikuyu.

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