QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES
DIVISION OF PLANT INDUSTRY BULLETIN No. 450

EFFECT OF FERTILIZER NITROGEN ON A DENSE SWARD OF KIKUYU, PASPALUM AND CARPET GRASS. 1. BOTANICAL COMPOSITION, GROWTH AND NITROGEN UPTAKE

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SUMMARY

Nitrogen nutrition is involved in "kikuyu decline" in the Millaa Millaa district of the Atherton Tableland, northern Queensland. It affects the proportion of kikuyu, paspalum and carpet grass occurring in pastures. In this experiment approximately 150 lb nitrogen per acre per year was the minimum level necessary to effect a reversion to dominance by the superior species, kikuyu and paspalum. More than 200 lb nitrogen was required to develop kikuyu dominance.

Dry-matter and nitrogen yield responses to the application of 0, 50, 100, 200 and 400 lb nitrogen were linear in each of the three years of measurement. Maximum annual dry-matter yields ranged from approximately 9,000 to 11,000 lb/ac. Nitrogen recovery improved from approximately 36 to 52% in the final year.

A significant trend towards lower levels of exchangeable potassium was recorded in the soil under the 200 and 400 lb nitrogen treatments.

I. INTRODUCTION

In warm humid climates, typical swards of the dense grassland types characterized by Brown (1954) include those formed by kikuyu (*Pennisetum clandestinum* Hochst.), paspalum (*Paspalum dilatatum* Poir.) and narrow-leaf carpet grass (*Axonopus affinis* Chase). In Queensland, these grasses have been introduced to dairying districts located along the humid coast and on adjacent plateaux.

On the Atherton Tableland, paspalum was sown when rain-forest areas were felled at the beginning of the present century. Later it was overplanted with kikuyu, which established extremely well in the Millaa Millaa district (latitude

17° 30′ S., altitude 2,700 ft). However, with time initial fertility and thus productivity declined and carpet grass began to invade. Similar situations have been described in Kenya by Edwards (1940) and Dougall (1953) and in Queensland by Cassidy (1957) and Goodchild (1960).

At Millaa Millaa, Shell Chemical (Australia) Pty. Ltd. (unpublished report 1958) and T. K. Kelly and A. J. Draper (unpublished report 1963) recorded greatly increased green-weight yields from such pastures when nitrogen fertilizer was applied.

The work described in this paper was designed to study more accurately the effects of rate of nitrogen application on the botanical composition of a mixed sward, its growth and consequent nitrogen uptake.

The experiment was sited on a dairy farm 2½ miles from Millaa Millaa, which has an annual rainfall average of 103 in. Of this, 67 in. is the average for the warmer 6 months, October to March. The average for the cooler 6 months, April to September, is 36 in. Monthly rainfalls for Millaa Millaa during the course of the experiment are given in Table 1 with the 50-year mean for each month. Frosts can be expected from June to August. Hours of bright sunshine are low from January to July, due to the large number of wet or overcast days. This period represents the effective growing season for kikuyu.

TABLE 1

MONTHLY RAINFALLS (IN.) AT MILLAA MILLAA

Year	1961	1962	1963	1964	50—Year Mean
Jan. ..	10·37	20·03	32·67	10·23	16·37
Feb. ..	3·35	17·73	30·63	11·05	17·51
Mar. ..	10·89	11·03	11·08	27·97	18·30
Apr. ..	10·04	12·83	21·29	5·96	11·31
May ..	10·10	2·26	9·75	21·22	7·71
Jun. ..	1·50	8·92	1·98	2·18	5·62
Jul. ..	1·32	5·83	1·21	2·78	4·52
Aug. ..	1·34	0·76	0·86	3·30	3·53
Sep. ..	0·95	7·26	0·76	7·20	3·39
Oct. ..	1·64	0·26	5·94	6·70	2·71
Nov. ..	6·19	4·46	1·14	6·29	4·41
Dec. ..	8·60	6·76	8·16	8·28	7·86
Total ..	66·29	98·13	125·47	113·16	103·24

II. EXPERIMENTAL

A suitable mixed sward was located on a flat alluvial terrace. The soil was a dark brown loamy sand. In October 1961, samples taken to a depth of 6 in. from each of six control plots had average values of 6·2 for pH, 145 p.p.m. of available P_2O_5 (B.S.E.S. method, Kerr and von Stieglitz 1938) and 0·62 m-equiv.% of exchangeable potassium. All plots were sampled to the same depth at the completion of the experiment in November 1964.

Paspalum and carpet grass dominated the sward (Figure 1). Kikuyu occupied an insignificant portion of it and was generally yellow and unthrifty. Specifically, there was a severe shortening of internode length with a proliferation of growth at the apical node, resulting in a rosette-type formation of the leaves. Such symptoms, together with falling productivity, have given rise to the term "kikuyu decline" in the area. They are similar to those described in south-eastern Queensland and northern New South Wales as "kikuyu yellows" and "yellow stunt disease" (N. E. Grylls, personal communication).

The plot area was trimmed to 1–4 in. on October 6, 1961. Plots were 40 lk x 40 lk and contiguous. Five nitrogen treatments—0, 50, 100, 200 and 400 lb nitrogen per acre per annum—were arranged in six randomized blocks. They were applied as urea in a split application, half at the beginning of summer (October-November) and half at the beginning of winter (April-May).

Initial botanical composition was estimated in the 3 weeks following establishment, when three methods of analysis were tested to choose one for use in subsequent years (Gartner 1967). A visual appraisal method was found to be most suitable and was used in November in the years 1962, 1963 and 1964 for the annual estimate of botanical composition.

At each harvest, two 10 ft x 3 ft strips were cut with an Autoscythe from previously determined random positions in each plot. This was approximately 15% of the datum area of 30 lk x 30 lk. The cut green material was weighed in the field and subsampled into air-tight bottles for the determination of dry-matter yields. These samples were dried in a forced-draught oven at 160°F. Nitrogen percentage was determined by routine Kjeldahl procedure. Five harvests per season were made in 1961-62 and 1963-64, and four in 1962-63. After each harvest the remaining herbage was mown to a uniform height and the cut material removed.

The area was lightly frosted in 1962 and 1964 and heavily frosted in 1963. A diversion bank was built to direct water off the hills away from the plots. However, waterlogging occurred in some parts of the site during periods of intense rainfall in January 1963 and May 1964.

Armyworms (*Spodoptera exempta* Walk.) defoliated the experiment in January 1962, January 1963 and February 1964. A leaf-sucking bug (*Halticus chrysolepis* Kirk.) was present throughout the experimental period and sometimes reached epidemic proportions; visual reduction in productivity was then observed. Funnel ants (*Aphaenogaster pythia* Forel) began invading the site in 1963 and eventually extended through all plots. Mound counts made in September 1963 showed difference between blocks but not between treatments (G. W. Saunders, personal communication).

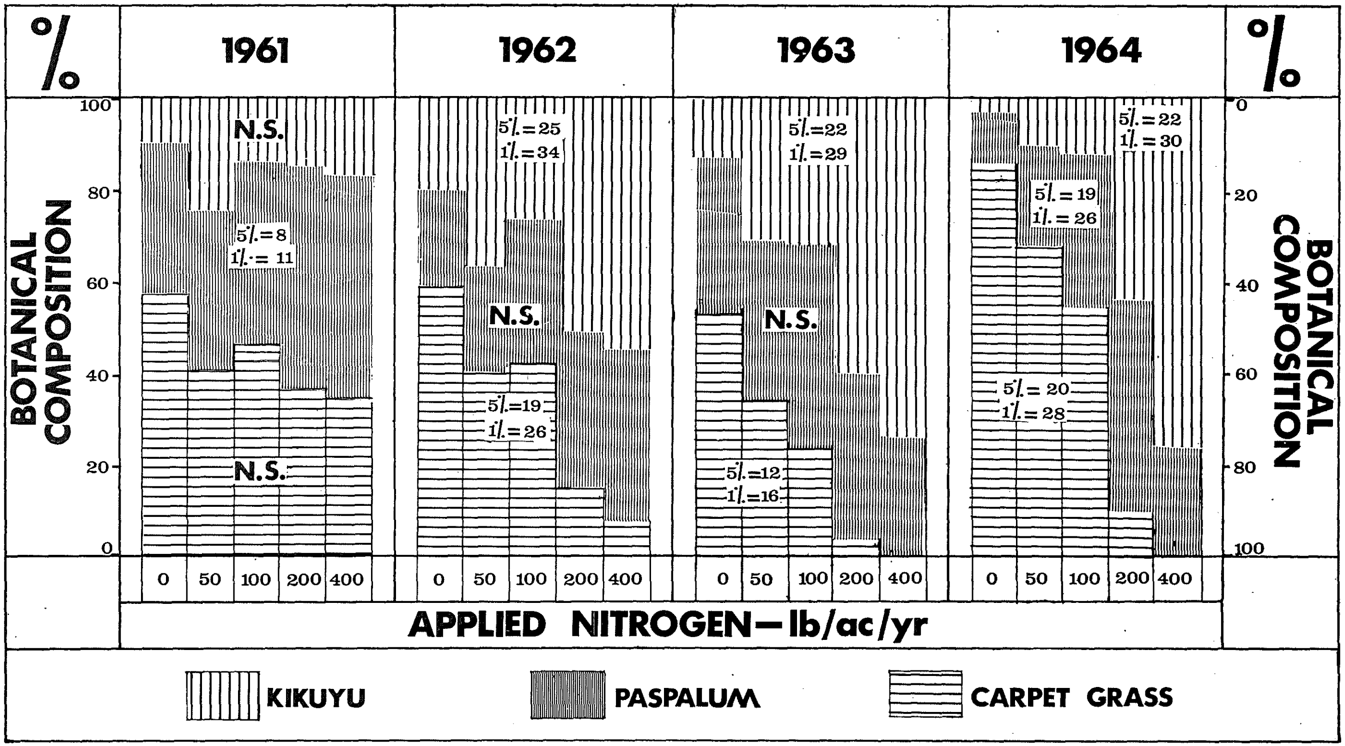

Fig. 1.—Annual estimates of kikuyu, paspalum and carpet grass in swards fertilized with five rates of nitrogen. 1961 = initial botanical composition.

III. RESULTS

(a) Botanical Composition

Annual estimates of botanical composition are shown in Figure 1. Carpet grass was virtually eliminated within a year from plots fertilized with 200 and 400 lb nitrogen per acre. It remained dominant in unfertilized plots. Paspalum occupied an intermediate position in the sward, being more or less co-dominant with carpet grass and/or kikuyu at the 50, 100 and 200 lb levels. Kikuyu dominated at the 400 lb nitrogen level.

Regression analysis of species composition on nitrogen rate showed that a significant linear fit was possible in any one year for each species. Using the form $y = a + bx$, y equals the percentage of a species in the sward, $x =$ lb elemental nitrogen per acre per annum.

Significant differences in the constant value "a" (percentage composition in unfertilized plots) indicate seasonal differences in species activity (Figure 2A). This was most striking in 1964, when conditions favoured the spread of carpet grass and the regress of kikuyu. However, the trend was arrested at the 400 lb nitrogen level, when kikuyu strongly maintained its dominance in the sward (Figure 1).

Plotting the linear coefficient "b" against year of estimate (Figure 2B) illustrates the dynamic interaction of nitrogen rate and time on the botanical composition of the sward. The positive linear response by kikuyu to nitrogen rate increased with time. There was a corresponding increase in the negative response by carpet grass. Paspalum showed no significant direction of movement. A small positive response to rate in 1962 and 1964 balanced a negative response in 1963.

After 3 years of nitrogen fertilization the crossover point between the superior species, kikuyu and paspalum, and the inferior species, carpet grass, occurred at approximately 150 lb nitrogen per acre (Figure 3). However, more than 200 lb nitrogen per acre was required to develop kikuyu dominance. The implied curvature in the response by paspalum in Figure 3 is considered to be a better representation of the position of this species in the fertility scale than a linear one.

(b) Growth

Maximum dry-matter yields recorded ranged from approximately 9,000 to 11,000 lb/ac at the 400 lb nitrogen level (Table 2). The response to nitrogen rate was significantly linear ($P < 0{\cdot}01$) in each of the three years of measurement. Regression lines of the form $y = a + bx$ are shown in Figure 4A.

The time trend in the slope "b" was upward. This was significant ($P<0{\cdot}05$) in the final season relative to the first two, when the response was better maintained at the 400 lb level ($P<0{\cdot}01$). As well, the yield from 100 lb nitrogen had improved considerably relative to 50 lb nitrogen (Table 2).

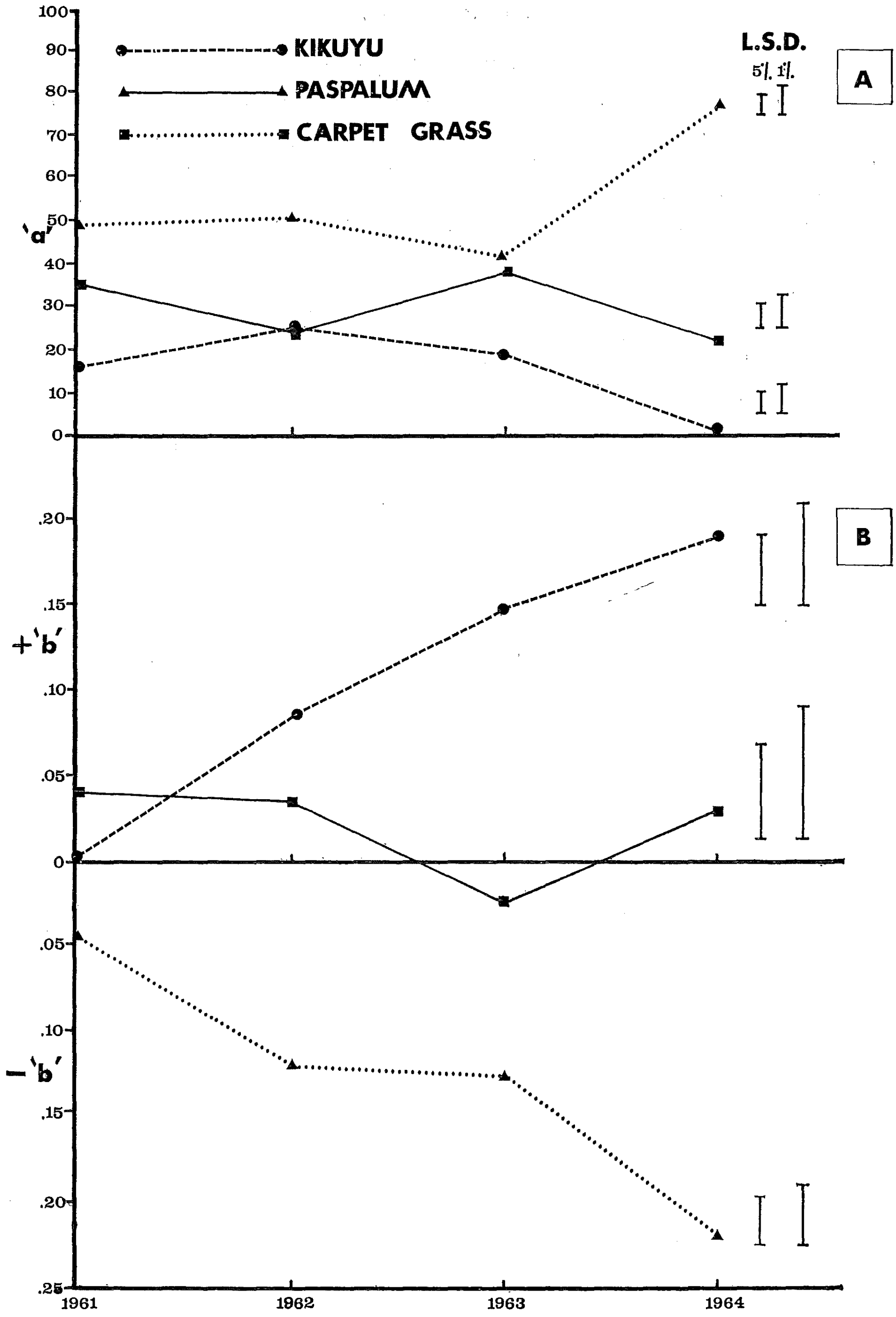

Fig. 2.—Values for the linear regression of species composition on nitrogen rate in each of four years. A. The constant "a", showing the response to season by species in unfertilized plots. B. The linear coefficient "b", showing the dynamic interaction of rate of nitrogen and time on botanical composition.

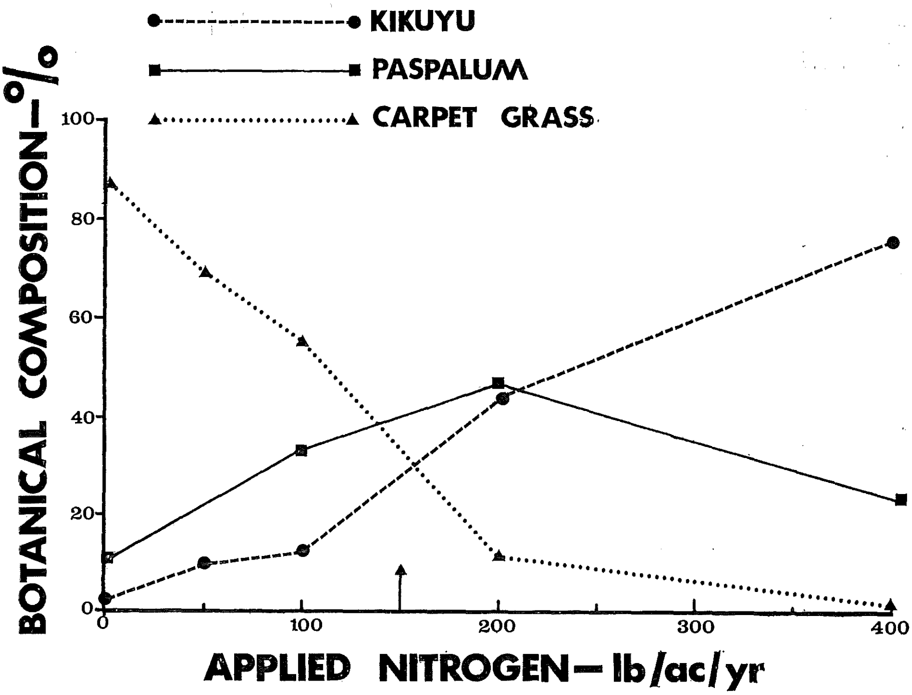

Fig. 3.—Effect of 3 years' nitrogen fertilization at different rates on the botanical composition of a mixed sward of kikuyu-paspalum-carpet grass; estimates made in November, 1964.

TABLE 2

DRY-MATTER PRODUCTION: ANNUAL YIELD, EFFICIENCY OF THE RESPONSE AND DRY-SEASON YIELD FROM A MIXED SWARD OF KIKUYU-PASPALUM-CARPET GRASS

Nitrogen Rate (lb/ac/yr)	Annual Yield (lb/ac)			Efficiency of Response (lb dry-matter/lb applied nitrogen)			Dry-season Yield (lb/ac)		
	1961–62	1962–63	1963–64	1961–62	1962–63	1963–64	1962	1963	1964
0	1,960	3,690	1,510				240	210	170
50	3,140	4,700	2,070	24	20	11	300	240	260
100	3,420	5,190	3,520	15	15	20	390	300	540
200	6,670	8,810	6,070	24	26	23	770	700	690
400	8,820	10,870	10,050	17	18	21	830	1,430	1,590
S.E.	560	550	330				120	130	110
L.S.D. 5%	1,650	1,620	980				350	390	320
L.S.D. 1%	2,260	2,210	1,330				480	530	430

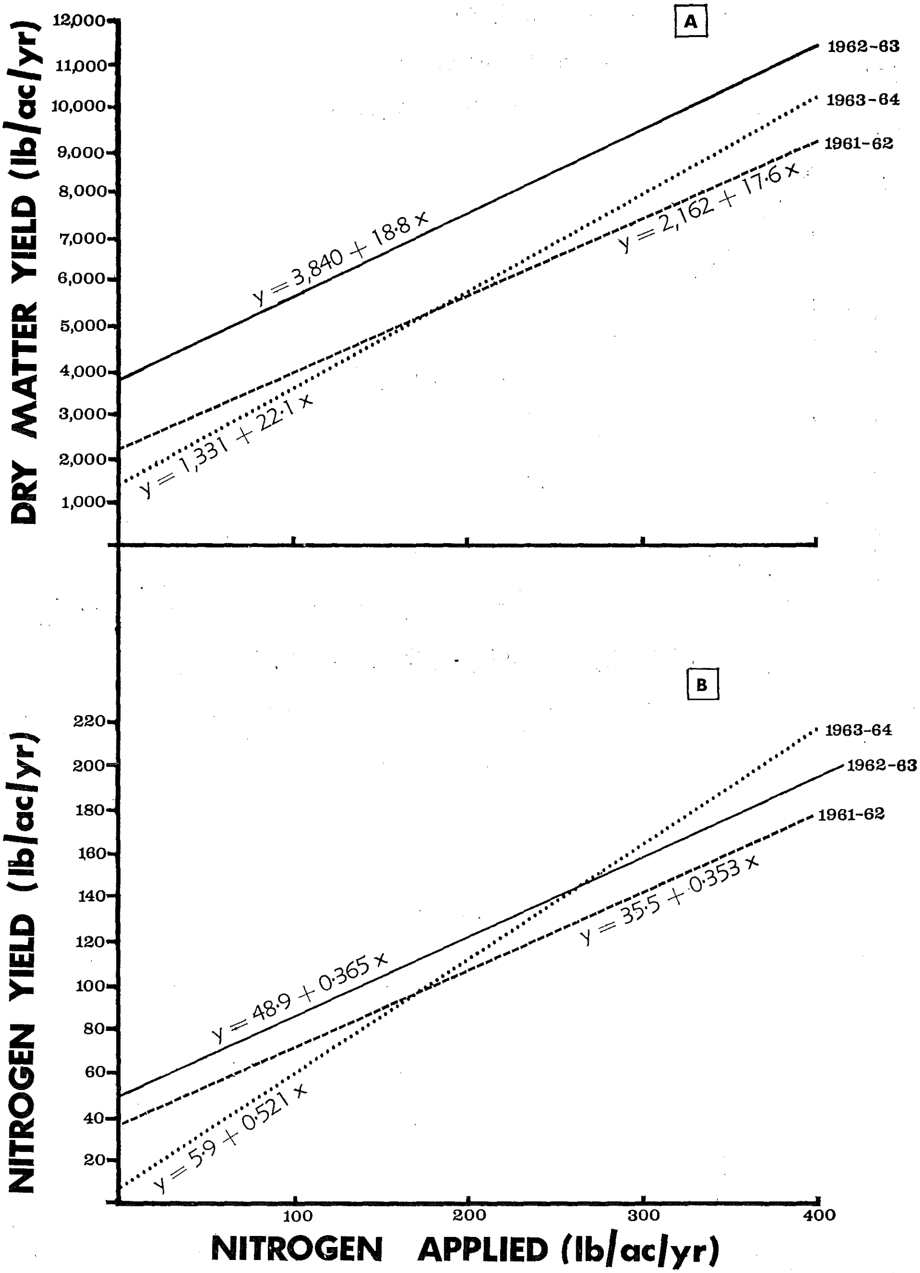

Fig. 4.—Effect of different rates of urea nitrogen on the yield of dry matter and nitrogen from a mixed sward of kikuyu-paspalum-carpet grass. A. Linear response in annual dry-matter yield. B. Linear response in annual nitrogen yield.

Differences in the constant "a" (dry-matter yield at nil nitrogen) indicate seasonal variations in dry-matter yield. Production in 1962-63 over the whole range of nitrogen rates was at a significantly higher level ($P<0\cdot01$) than in 1961-62. In 1963-64, "a" was almost significantly less than the value for 1961-62 at the 5% level, but this difference was not extended due to the increase in the response to nitrogen.

There was no significant evidence of curvature in the regression analysis. However, a suggestion exists in the data that the most efficient response occurred at the 200 lb level. In the first, second and third years respectively, 24, 26 and 23 lb extra dry matter per lb nitrogen applied were produced (Table 2).

Differences due to treatment were generally maintained throughout each year, even in the harvest taken at the end of each dry season (Table 2). This was particularly so at the 400 lb level, which was significantly greater ($P<0\cdot01$) than all other treatments in November 1963 and November 1964.

(c) Nitrogen Uptake

Nitrogen percentages of herbage taken at each harvest are shown in Table 3. Broadly, nitrogen content increased with each increment of fertilizer. However, this trend was affected by harvest interval and length of time after fertilizing. It became more certain with time as the species composition of the sward changed. Of particular importance is the maintenance of this quality response in the November harvests of each year. The highest nitrogen values were recorded after the winter application of fertilizer in April or May.

TABLE 3

EFFECT OF NITROGEN RATE ON PERCENTAGE NITROGEN CONTENT OF HERBAGE HARVESTED FROM A MIXED SWARD OF KIKUYU–PASPALUM–CARPET GRASS

Date Fertilized	Date of Harvest	Treatment (lb N/ac/yr)					Harvest Interval (days)
		0	50	100	200	400	
6.x.61 ..	12.i.62 ..	1·40	1·47	1·49	1·58	1·48	98
	6.iv.62 ..	1·52	1·71	1·54	1·75	1·74	84
7.iv.62 ..	14.v.62 ..	1·76	2·03	2·21	2·46	3·04	38
	26.vii.62 ..	1·93	1·93	2·08	2·24	2·21	73
	7.xi.62 ..	1·23	1·22	1·33	1·42	1·29	104
9.xi.62 ..	4.iii.63 ..	1·37	1·30	1·37	1·27	1·35	116
	23.iv.63 ..	1·46	1·47	1·67	1·74	1·97	50
14.v.63 ..	3.vii.63 ..	1·22	1·57	2·13	2·02	2·60	71
	12.xi.63 ..	1·14	1·26	1·23	1·33	1·41	132
7.xii.63 ..	21.i.64 ..	0·78	1·26	1·39	1·76	2·16	70
	24.iii.64 ..	1·06	1·20	1·39	1·60	1·81	63
	28.v.64 ..	1·07	1·24	1·39	1·68	1·67	64
28.v.64 ..	20.vii.64 ..	1·33	1·74	2·02	2·51	3·36	53
	4.xi.64 ..	1·04	1·17	1·36	1·55	1·56	107

Nitrogen yields were significantly linear ($P<0{\cdot}01$) in each of the three years. Regression lines of the form $y = a + bx$ are drawn in Figure 4B. Percentage nitrogen recovery is equal to 100b.

The time trend in the slope "b" was again upwards, with a significant increase ($P<0{\cdot}01$) in 1963-64. This raised nitrogen recovery to 52% from approximately 36% in previous years. However, there is a suggestion in the data that the recovery of nitrogen in that year was more efficient at the 200 and 400 lb nitrogen levels than at 50 and 100 lb.

When the constant "a" (nitrogen yield from unfertilized plots) is examined, seasonal differences are evident. The nitrogen content in the 1963 harvests was lower than that in other years (Table 3). Despite this, the higher level of dry-matter production in that season maintained nitrogen yields at a higher level than in the 1962 harvest period. As well, the yield at nil nitrogen for the 1964 harvests was significantly less ($P<0{\cdot}01$) than that recorded in the other two seasons (Figure 4).

(d) Soil Analysis

Analyses presented in Table 4 show no significant differences in pH and P_2O_5 content due to nitrogen treatments. However, the trend towards lower levels of exchangeable potassium was significant ($P<0{\cdot}05$) at the 200 and 400 lb levels.

TABLE 4

Some Soil Values at the Conclusion of the Experiment in November, 1964

Treatment (lb N/ac/yr)	pH	P_2O_5 (p.p.m.)	K^+ (m-equiv. %)
0	5·33	114	0·50
50	5·28	81	0·54
100	5·22	106	0·41
200	5·25	116	0·37
400	5·15	83	0·32
S.E.	0·06	17	0·05
L.S.D. 5%	N.S.	N.S.	0·15
L.S.D. 1%	..	..	0·20

IV. DISCUSSION

(a) Nitrogen Utilization

Grasses with potential to use fertilizer nitrogen efficiently are sought to produce large quantities of dry-matter of sufficient quality for animal production.

The botanical response to a range of nitrogen rates by the three species in this experiment (Figures 1-3) indicates that carpet grass is at the bottom end of the scale of potential and kikuyu at the top end, with paspalum somewhere in between.

This fact is strengthened by the subsequent effect of the proportion of each species in the sward on annual dry-matter yields and nitrogen contents. For example, in the final year of the experiment kikuyu occupied 76% of the sward (Figure 1) fertilized with 400 lb nitrogen per acre, from which was harvested 10,050 lb dry-matter per acre (Table 2) containing 1·56 to 3·36% nitrogen (Table 3). In contrast, unfertilized plots contained 87% carpet grass. These yielded only 1,510 lb dry-matter per acre, ranging from 0·78 to 1·33% nitrogen. At 200 lb nitrogen per acre, the sward contained 46% paspalum, 44% kikuyu and 10% carpet grass. It yielded 6,070 lb dry-matter per acre ranging from 1·55 to 2·15% nitrogen.

Since the dry-matter response was linear, it is probable that sub-optimal quantities of nitrogen were used and maximum potential yields were not reached. However, factors other than the nitrogen supply and the environment may have limited the top yields to around 10,000 lb dry-matter per acre per year. Possibilities considered were nutrient imbalance as indicated by the decline in available potassium in the soil (Table 4) under the high-nitrogen treatments (probably aggravated by the cut with no-return harvesting technique), the mixture of grasses of differing yield potential, and the efficiency of urea as a carrier of nitrogen to the sward.

Nitrogen contents of herbage fertilized with 100, 200 and 400 lb nitrogen per acre are generally well above the level of 1·2% stated by Milford (1960) as being necessary to achieve positive nitrogen balance in sheep. Herbage from 50 lb nitrogen per acre was satisfactory during the winter months but of marginal quality in the summer. Unfertilized herbage was often below the stipulated figure. Such values are important when assessing the overall results for potential animal production particularly as the quantity response was maintained during the dry season at the upper levels of nitrogen fertilization.

Lower nitrogen percentages in 1962-63 are attributed to the very heavy summer rains in that period and the longer time interval between harvests.

The major increase in carpet grass in 1963-64 (Figure 1) caused the significant reduction in dry-matter and nitrogen yield from unfertilized plots in that year (Figure 4). Concomitantly, kikuyu and paspalum held their dominant positions well at 200 and 400 lb nitrogen per acre. The combination of both factors resulted in the significant rise in the dry-matter response and nitrogen recovery.

(b) Kikuyu Decline

Nitrogen rate induced the major changes in species composition, dry-matter yield and nitrogen content. However, the significant differences in the constant value "a" in the linear functions for botanical composition (Figure 2) and dry-matter yield (Figure 4A) suggest that underlying these effects were seasonal differences which either supported or reduced them.

The significantly higher dry-matter yield in 1962-63 was probably due to the consistently high rainfall in that season (Table 1), which followed below-average rainfall in 1961 and 1962. A significant increase in paspalum was also recorded at the end of that year.

The rainfall in 1964 was again above average and well distributed. However, the natural build-up of nitrogen in the dry season following a year of high plant production and heavy leaching rains may have been insufficient to maintain the balance between the species in the following growing season. Hence, carpet grass made a major advance in unfertilized plots, the underlying effect of which was arrested only when 400 lb nitrogen per acre was applied. The consequences of this have been discussed previously.

It is suggested that this short-term seasonal effect mirrors the long-term ingress of carpet grass in unfertilized grass swards with the concomitant regress of first kikuyu and then paspalum.

The general symptoms of yellowness and unthriftiness of the kikuyu in the sward disappeared at 200 and 400 lb nitrogen per acre. However, the specific symptom of apical dwarfing could be observed occasionally amongst well-grown kikuyu in these plots. The reason for this has not been clarified.

Thus, in the broad scheme of things it is possible to arrest the decline in the productivity of kikuyu-based pastures by the judicious use of adequate amounts of nitrogen fertilizer.

V. ACKNOWLEDGEMENTS

I wish to acknowledge the assistance of Mr. C. G. Wilkinson, who managed the experiment during my absence in 1963. Thanks are due to Dr. L. R. Humphreys for advice in the planning of the experiment and throughout its duration; to Mr. W. J. McDonald and other Departmental officers for field assistance; to the Agricultural Chemical Laboratory Branch for soil and plant analyses; and to the Biometrics Branch for statistical analysis of experimental data.

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(Received for publication October 30, 1967).

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