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EFFECTS OF FERTILIZER NITROGEN ON A DENSE SWARD OF KIKUYU, PASPALUM AND CARPET GRASS. 3. NITROGEN SOURCE

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SUMMARY

Four sources of fertilizer nitrogen—ammonium nitrate, ammonium sulphate, sodium nitrate and urea—were tested for 1 year on a pure kikuyu sward at Millaa Millaa at rates of 0, 50, 100, 200 and 400 lb N/ac/yr. Cattle grazed the sward before trimming after harvesting.

The annual dry-matter and annual nitrogen yield responses to nitrogen rate were linear for all sources. At some harvests there were significant interactions between source and rate for dry-matter yield, nitrogen concentration and nitrogen yield. Generally, at 50 and 100 lb N/ac there were no differences between sources, but at 400 lb N/ac, ammonium nitrate produced 3,320 lb more dry matter per acre than urea.

Nitrogen recovery from ammonium nitrate was 92% as against 58% for urea.

I. INTRODUCTION

Maximum annual dry-matter yields from a kikuyu-paspalum-carpet grass sward fertilized with up to 400 lb N/ac/yr were 9,000–11,000 lb/ac in an experiment at Minbun, North Queensland (Gartner 1969*a*). An induced potassium deficiency limited yields from high-nitrogen treatments (Gartner 1969*b*). Other possible limiting factors were the efficiency of urea as a nitrogen source when broadcast (Burton and DeVane 1952; Volk 1959; Burton and Jackson 1962; Mees and Tomlinson 1964); the differing yield potential of the sward components; and the cut-and-remove harvesting technique.

A number of workers have reviewed the last problem (Hudson 1933; Giobel 1940; Sears 1944; Lynch 1947), but most worthwhile improvements suggested are impractical for district experimentation. Even so, the introduction of cattle to provide a grazing and trampling effect was desirable, since the sudden and complete defoliation of well-grown kikuyu in high-nitrogen treatments delayed regrowth. This raised the problem of fertility transference, particularly of nitrogen and potassium (B. W. Doak (1937), unpublished, quoted by Lynch 1947; Watkin 1957; Mundy 1961). However, Lotero, Woodhouse and Petersen (1966) found the effect of urination on nitrogen and potassium concentration to be much less prolonged than the effect on dry-matter yield, the duration of which was at most 10 months. Under the high-rainfall conditions of North Queensland, where grass growth and mineral depletion are rapid, the duration should be much less.

This paper describes a 1-year experiment to compare four nitrogen sources on a pure kikuyu sward, using cattle to remove most of the herbage before mowing after each harvest.

II. MATERIALS AND METHODS

Site.—The site was located on a dairy farm, 1 mile from Millaa Millaa. It lay on a north-easterly slope of 5%. An acre of pure kikuyu was cut off from an original paddock of 4 ac. Fertilizer history on this area was nil up to September 1962. To April 1964, the combined total was 100 lb N/ac, 60 lb P/ac and 2 oz Mo/ac.

The soil was a red-brown clay loam. Samples taken from control plots to a depth of 6 in. had a pH of 5·8 (1:2·5 H_2O), 69 p.p.m. of available P (B.S.E.S. method, Kerr and von Stieglitz 1938) and 0·61 m-equiv. % of K ($\frac{N}{20}$ HCl leach using an EEL flame photometer). At the conclusion of the experiment all treatments were sampled (3 cores to 6 in.) and analysed for these values.

Design.—A randomized split plot design was used with five main plots (60 lk x 30 lk) for nitrogen rate, each with four sub-plots for nitrogen source. There were four replicates.

Fertilizer.—Nitrogen rates were 0, 50, 100, 200 and 400 lb N/ac/yr applied in a split application, half at commencement on April 9, 1965, and half on June 18, after the second harvest. The nitrogen sources were urea, ammonium sulphate, sodium nitrate and ammonium nitrate. A basal dressing of superphosphate (22% P_2O_5) and muriate of potash (60% K_2O) was applied in the $N:P_2O_5:K_2O$ ratio of 2:1:2.

Data collection.—Each sub-plot was sufficient in size to give a 5 lk border surrounding 10 contiguous 5 lk x 2 lk sampling positions. One of these was cut with hand shears to the bottom of the "green layer" at each harvest. When growth was uneven an additional quadrat was cut. The whole sample was dried in a forced-draught oven at 160°F, weighed and analysed for N at each harvest and P and K at the final harvest.

Seven harvests were made over the 12-month period (April 9, 1965, to April 7, 1966), of which four were in the winter months April to September and three in the summer months October to March.

Management.—Cattle were excluded from the experimental area on March 2, 1965, and re-introduced on April 7 to observe their grazing behaviour. The weather was showery and wet, a common enough situation in Millaa Millaa.

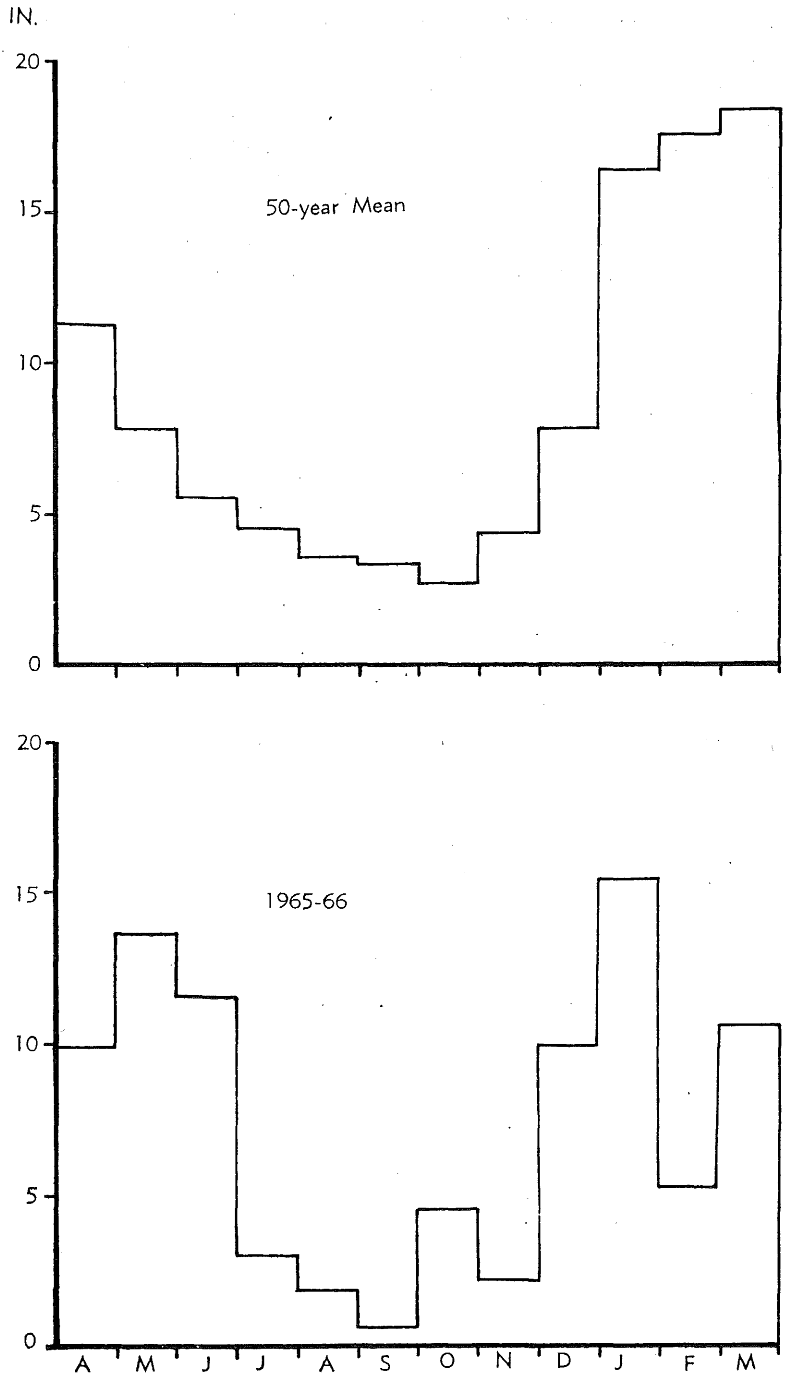

Fig. 1.—Rainfall at Millaa Millaa during the course of the experiment.

Under these conditions it took 26 head of milking cows 3 hr to remove the 5 weeks' growth of grass to a stage where only light trimming was necessary. All cows grazed for the first hour; 15% were lying down at the end of the second hour and 60% at the end of the third. Urination occurred mainly at the end of the first hour, while defecation occurred principally during the second hour. Thus for defoliation after harvesting, 40–45 head of cows were used for 1 hr to avoid flattening of the sward and excessive excretory activity. After grazing, dung pats were removed to prevent smothering of the grass, the remaining herbage was mown to 2–3 in., and the trimmings were removed.

Climate.—Monthly rainfalls for Millaa Millaa during the course of the experiment are shown in Figure 1 together with the 50-year means. July, August and September were exceptionally dry with only 5·45 in. as against the 50-year mean of 11·44 in.

Severe frosts occurred in the region from late June to August. The experimental site was not badly affected because it was located on top of a ridge. Nevertheless, black frosts on July 19 and 20 severely burnt the area.

Insects.—A heavy infestation of webworms (*Oncopera* spp.), apparent at the third harvest on July 26 (R. J. Elder, personal communication), necessitated the spraying of all plots with DDT at 1 lb a.i./ac on August 13. Prior to spraying, hole counts were made in the ammonium sulphate plots. The population build-up probably commenced in March, the middle of the moth flight period.

III. RESULTS

Table 1 shows dry-matter yields from each nitrogen source at each harvest.

TABLE 1

DRY-MATTER YIELDS (LB/AC) FROM EACH NITROGEN SOURCE AT EACH HARVEST

Nitrogen Source	Harvest							Annual Total†
	1 6.v.65	2 10.vi.65	3† 26.vii.65	4† 8.ix.65	5 2.xii.65	6 1.ii.66	7* 6.iv.66	
Urea	2,210	1,550	1,610	1,050	850	1,630	1,790	10,670
Ammonium sulphate	2,280	1,600	1,570	1,640	1,220	1,680	1,630	11,630
Sodium nitrate ..	2,390	1,530	1,640	1,600	900	1,560	1,860	11,470
Ammonium nitrate..	2,430	1,500	1,550	1,720	1,190	1,690	1,920	12,000
Coefficient of variation (%)	12	12	13	20	25	15	15	7
S.E.	73	48	52	74	64	62	66	201
L.S.D. .. 5%	..	..	..	211	185	..	188	576
L.S.D. .. 1%	..	..	..	283	247	..	252	772

* F test < 5%. † F test < 1%.

(a) Dry-matter Production

Annual dry-matter yields from urea were significantly less ($P<0\cdot01$) than those from ammonium nitrate, ammonium sulphate and sodium nitrate. This difference appeared at the fourth and fifth harvests. The yield from sodium nitrate also fell at the fifth harvest, when it was significantly less than the yields from ammonium nitrate and ammonium sulphate. At the seventh harvest the latter produced significantly less dry matter than ammonium nitrate and sodium nitrate.

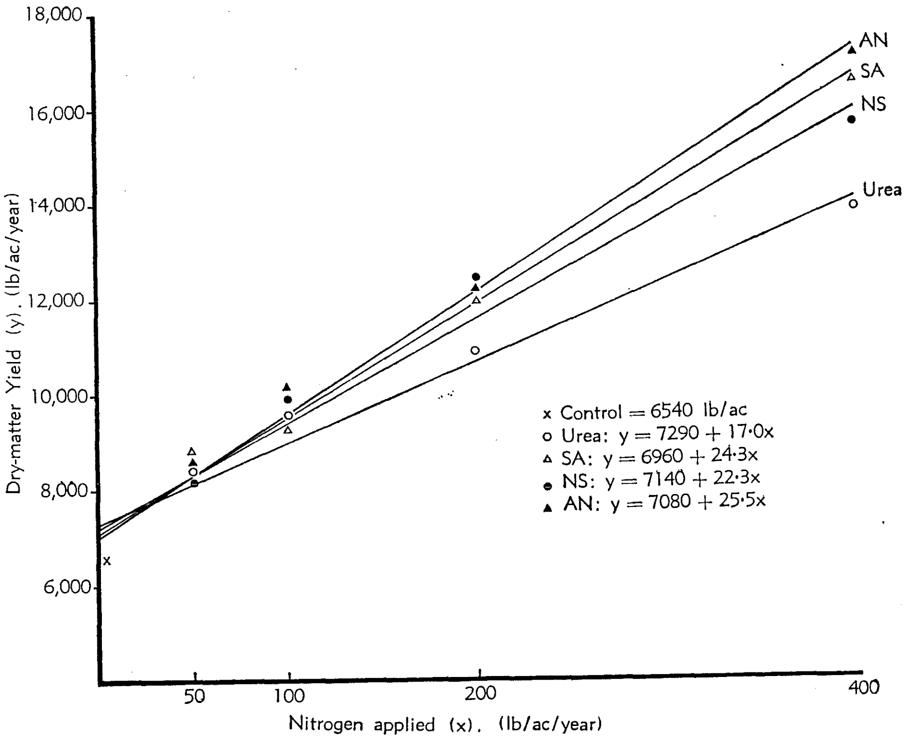

Fig. 2.—Annual dry-matter yield response of a pure kikuyu sward to different rates of nitrogen as urea, ammonium sulphate, sodium nitrate and ammonium nitrate.

The annual dry-matter yield response to different rates of nitrogen was significantly linear ($P<0\cdot01$) for all sources (Figure 2). Regression lines are of the form $y = a + bx$. The quadratic fit for sodium nitrate was also highly significant but the linear fit was a better one. Meaningful differences between the rates occurred at the fourth, fifth and sixth harvests. At these harvests the yields from 400 lb N/ac were significantly greater ($P<0\cdot01$) than those from 50, 100 and 200 lb N/ac. At the fourth harvest the yield from 200 lb N/ac was significantly greater ($P<0\cdot01$) than the yields from 50 and 100 lb N/ac and at the sixth harvest significantly greater ($P<0\cdot05$) than the yield from 50 lb N/ac.

TABLE 2

DRY-MATTER YIELDS (LB/AC) AT EACH HARVEST AND THE ANNUAL TOTAL FOR FOUR NITROGEN SOURCES AT FOUR NITROGEN RATES TOGETHER WITH THOSE FROM THE UNFERTILIZED SWARD

Nitrogen Rate (lb/ac)	Nitrogen Source	Harvest							Annual Total**
		1 6.v.65	2 10.vi.65	3** 26.vii.65	4** 8.ix.65	5** 2.xii.65	6 1.ii.66	7 6.iv.66	
0	..	1,270	1,310	710	440	560	1,090	1,160	6,540
50	U	1,520	1,650	1,170	580	630	1,270	1,590	8,410
	SA	1,670	1,450	1,050	730	820	1,350	1,710	8,770
	NS	1,760	1,430	1,160	590	560	1,080	1,560	8,140
	AN	1,730	1,510	1,070	660	840	1,060	1,750	8,620
100	U	2,350	1,470	1,430	740	840	1,350	1,360	9,540
	SA	1,850	1,560	1,500	810	880	1,220	1,450	9,270
	NS	2,290	1,370	1,480	980	650	1,500	1,630	9,890
	AN	2,440	1,280	1,380	1,000	640	1,550	1,760	10,050
200	U	2,340	1,600	1,500	1,050	710	1,700	2,010	10,910
	SA	2,530	1,590	1,930	1,530	960	1,640	1,640	11,820
	NS	2,740	1,550	2,060	1,470	840	1,510	2,060	12,220
	AN	2,780	1,590	1,740	1,450	1,060	1,680	1,890	12,190
400	U	2,610	1,480	2,330	1,820	1,200	2,180	2,190	13,820
	SA	3,080	1,800	1,790	3,490	2,240	2,500	1,740	16,640
	NS	2,770	1,760	1,870	3,370	1,540	2,150	2,170	15,620
	AN	2,770	1,620	2,000	3,770	2,220	2,490	2,290	17,140
S.E. ..	.. ..	145	96	105	147	129	124	131	401
L.S.D.	.. 5%	..	..	301	422	369	..	..	1,151
L.S.D.	.. 1%	..	..	403	566	495	..	..	1,544

** F test for interaction = 1%. U = urea; SA = ammonium sulphate; NS = sodium nitrate; AN = ammonium nitrate.

The interaction between nitrogen source and nitrogen rate was highly significant ($P<0\cdot01$) for annual dry-matter yields (Table 2). The effect occurred at the 200 lb N/ac level when the yield from urea was significantly less ($P<0\cdot05$) than the yields from sodium nitrate and ammonium nitrate; and at the 400 lb N/ac level when the yield from urea was significantly less ($P<0\cdot01$) than all other sources. As well, sodium nitrate yielded significantly less ($P<0\cdot05$) dry matter than ammonium nitrate at 400 lb N/ac. These differences occurred at the third, fourth and fifth harvests, when the interaction term was highly significant.

One anomaly in the interaction effect was the yield from urea at 400 lb N/ac at the third harvest. It was significantly greater than the yields from all other sources (Table 2). In the nitrogen source analysis (Table 1) this was cancelled by the significantly lower yield from urea at 200 lb N/ac.

After the second application of fertilizer on June 18, which preceded the third harvest by 38 days, top growth was "burnt" by all sources except urea in the 400 lb N/ac plots (i.e. 200 lb N/ac applied). The nitrate fertilizers caused a brown burn (ammonium nitrate severe, sodium nitrate medium). Ammonium sulphate caused a severe white burn.

TABLE 3

NITROGEN CONCENTRATIONS (%) IN THE HERBAGE FROM EACH NITROGEN SOURCE AT EACH HARVEST

Nitrogen Source	Harvest						
	1 6.v.65	2* 10.vi.65	3** 26.vii.65	4** 8.ix.65	5* 2.xii.65	6 1.ii.66	7** 6.iv.66
Urea	2·92	2·79	2·52	2·16	1·17	1·45	1·51
Ammonium sulphate	2·97	2·75	3·05	2·48	1·21	1·43	1·50
Sodium nitrate	2·98	2·94	2·97	2·48	1·25	1·47	1·56
Ammonium nitrate	3·05	2·90	2·99	2·57	1·18	1·45	1·48
Coefficient of variation (%) ..	6	6	5	7	7	4	4
S.E.	0·04	0·04	0·04	0·04	0·02	0·01	0·02
L.S.D. 5%	..	0·13	0·11	0·12	0·06	..	0·04
L.S.D. 1%	..	0·17	0·14	0·16	0·08	..	0·06

* F test < 5%. ** F test < 1%.

(b) Nitrogen Uptake

Nitrogen concentrations in herbage taken from the different sources of nitrogen were significantly different at five of the seven harvests (Table 3). Herbage from urea had a significantly ($P<0\cdot05$) lower concentration of nitrogen than that from all other sources at the third and fourth harvests. At the second, fifth and seventh harvests sodium nitrate produced herbage with significantly higher nitrogen concentrations than urea and one or both of the other sources.

Nitrogen concentrations increased with increasing rate of nitrogen fertilization at all harvests except the sixth and seventh (Table 4). Overall, this is demonstrated by the weighted annual percentages.

The interaction between nitrogen source and nitrogen rate was significant at the third and fourth harvests. Nitrogen concentrations in urea-fertilized herbage from the third harvest was significantly less ($P<0\cdot01$) than that in all other herbage at 100, 200 and 400 lb N/ac. This difference was repeated at the fourth harvest at 200 and 400 lb N/ac. As well, the nitrogen concentration at 400 lb N/ac in herbage fertilized with ammonium sulphate was significantly greater ($P<0\cdot01$) than that in herbage from sodium nitrate at the third harvest.

Nitrogen concentrations were highest in the winter period, April to September, when the nitrogen was applied. They ranged from 1·76% at nil nitrogen to over 4% at 400 lb N/ac. Concentrations were lowest at the fifth harvest, taken at the end of the dry season, when they ranged from little more than 1% at 0 and 50 lb N/ac to 1·39% at 400 lb N/ac. At the other summer harvests, concentrations ranged from 1·4 to 1·6%.

TABLE 4

NITROGEN CONCENTRATIONS (%) IN THE HERBAGE AT EACH HARVEST AND THE ANNUAL WEIGHTED PERCENTAGE CONCENTRATION FOR FOUR NITROGEN SOURCES AT FOUR NITROGEN RATES TOGETHER WITH THOSE FROM THE UNFERTILIZED SWARD

N Rate (lb/ac)	N Source	Harvest							Weighted Annual Percentage
		1 6.v.65	2 10.vi.65	3** 26.vii.65	4** 8.ix.65	5 2.xii.65	6 1.ii.66	7 6.iv.66	
0	..	2·31	2·15	1·76	1·91	1·07	1·42	1·53	1·79
50	U	2·47	2·22	1·85	1·98	1·12	1·46	1·47	1·85
	SA	2·42	2·14	2·01	1·94	1·05	1·41	1·50	1·80
	NS	2·46	2·21	2·01	2·05	1·10	1·45	1·50	1·90
	AN	2·62	2·18	1·99	2·02	1·01	1·46	1·43	1·86
100	U	2·58	2·50	2·13	2·07	1·09	1·41	1·54	2·00
	SA	2·73	2·44	2·43	2·13	1·16	1·43	1·58	2·08
	NS	2·70	2·77	2·52	2·19	1·28	1·45	1·62	2·15
	AN	2·66	2·57	2·50	2·18	1·10	1·45	1·55	2·08
200	U	2·84	2·82	2·67	2·13	1·21	1·48	1·57	2·36
	SA	3·06	2·81	3·41	2·46	1·25	1·47	1·52	2·42
	NS	3·10	2·93	3·31	2·45	1·25	1·51	1·60	2·45
	AN	3·08	2·92	3·25	2·52	1·21	1·52	1·49	2·38
400	U	3·77	3·60	3·42	2·44	1·25	1·46	1·46	2·50
	SA	3·67	3·62	4·34	3·39	1·39	1·40	1·40	2·80
	NS	3·65	3·85	4·05	3·21	1·35	1·48	1·53	2·80
	AN	3·83	3·92	4·23	3·57	1·39	1·39	1·45	2·84
S.E.	..	0·08	0·09	0·07	0·09	0·04	0·03	0·03	..
L.S.D.	5%	..	..	0·21	0·24	..	..	..	..
L.S.D.	1%	..	..	0·29	0·33	..	..	..	..

** F test for interaction < 1%. U = urea; SA = ammonium sulphate; NS = sodium nitrate; AN = ammonium nitrate.

Annual nitrogen yields in response to nitrogen rate were significantly linear ($P<0{\cdot}01$) for all sources (Figure 3). Regression lines are of the form $y = a + bx$. Percentage nitrogen recovery is equal to 100b. It ranged from 58% for urea to 92% for ammonium nitrate.

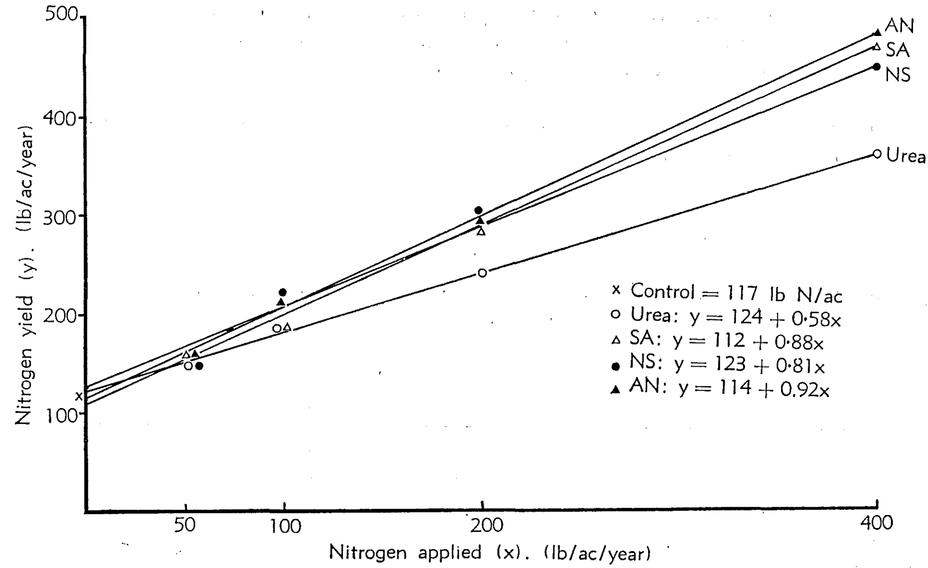

Fig. 3.—Annual nitrogen yield response of a pure kikuyu sward to different rates of nitrogen as urea, ammonium sulphate, sodium nitrate and ammonium nitrate.

TABLE 5

PHOSPHORUS AND POTASSIUM CONCENTRATIONS IN THE HERBAGE TAKEN AT THE SEVENTH HARVEST FOR EACH SOURCE AND EACH RATE OF NITROGEN

Nitrogen Source	P (%)	K (%)	Nitrogen Rate (lb/ac)	P (%)	K (%)
0*	0·33	1·21	0*	0·33	1·21
Urea	0·33	1·25	50	0·33	1·21
Ammonium sulphate	0·33	1·23	100	0·34	1·23
Sodium nitrate	0·34	1·30	200	0·34	1·29
Ammonium nitrate	0·32	1·26	400	0·32	1·31
Coefficient of variation (%)	5	4	..	4	5
S.E.	0·004	0·014	..	0·003	0·016
L.S.D. 5%	0·011	0·039	..	0·011	0·052
L.S.D. 1%	0·015	0·053	..	0·015	0·074

* Values for nil nitrogen were not included in the statistical analysis.

(c) Phosphorus and Potassium Uptake

F values for P and K concentrations in herbage taken at the seventh harvest were significant for both rate and source (Table 5). The interactions were not significant.

Phosphorus concentrations were significantly higher at 100 and 200 lb N/ac than at 50 and 400 lb N/ac. Potassium concentrations were significantly higher at 200 and 400 lb N/ac than at 50 and 100 lb N/ac.

Herbage fertilized with sodium nitrate contained more phosphorus and potassium than that from other sources.

TABLE 6

MEAN pH AND EXCHANGEABLE POTASSIUM IN SOIL TAKEN FROM EACH SOURCE AT EACH RATE AND THE UNFERTILIZED SWARD ON MAY 19, 1966

Nitrogen Source	pH	Exchangeable K (m-equiv. %)	Nitrogen Rate (lb/ac)	pH
0*	5·9	0·70	0*	5·9
Urea	5·6	0·64	50	5·3
Ammonium sulphate	5·5	0·60	100	5·7
Sodium nitrate	5·7	0·70	200	5·8
Ammonium nitrate	5·6	0·66	400	5·6
Coefficient of variation (%)	3	14	..	3
S.E.	0·036	0·022	..	0·046
L.S.D. 5%	0·103	0·065	..	0·146
L.S.D. 1%	0·138	0·087	..	0·210

* Values for nil nitrogen were not included in the statistical analysis.

(d) Soil Analysis

The F test for soil values was significant for pH ($P<0\cdot01$) for both rate and source and for exchangeable potassium ($P<0\cdot05$) for source (Table 6). It was not significant for total nitrogen and available phosphorus or the interactions.

At 5·3, the pH at 50 lb N/ac was significantly less ($P<0\cdot01$) than that for all other rates. The pH for ammonium sulphate was significantly less than that for all other sources. Although the interaction was not significant the greatest effect was at 400 lb N/ac, where the pH was 5·4. At nil nitrogen pH was 5·9.

The exchangeable potassium of soil under plots fertilized with sodium nitrate was significantly greater ($P<0\cdot01$) than that from plots fertilized with ammonium sulphate.

IV. DISCUSSION

Nitrogen source.—Clearly, the dry-matter (DM) yield potential of the kikuyu-paspalum-carpet grass sward in experiment 1 (Gartner 1969*a*) was limited by the use of urea as a nitrogen source. A pure sward of kikuyu fertilized with 400 lb N/ac as urea yielded 13,820 lb DM/ac. Ammonium nitrate at the same rate of nitrogen produced 17,140 lb DM/ac, a difference of 3,320 lb DM/ac. The difference was less for ammonium sulphate and sodium nitrate but still highly significant. At 92%, the recovery of nitrogen from ammonium nitrate was vastly superior to the 58% from urea, which is only slightly better than the 52% recovery rate recorded in the final year of experiment 1.

There were no differences between sources at 50 lb N/ac; differences in nitrogen concentration appeared at 100 lb N/ac, and differences in dry-matter yield appeared at 200 and 400 lb N/ac. The decline in nitrogen concentration and dry-matter yield from urea occurred after the second application of nitrogen. Under the conditions prevailing, gaseous loss of nitrogen from urea is thought to have occurred when 50 lb N/ac or more was applied in one application (Volk 1959).

The drop in nitrogen concentration preceded the drop in dry-matter yield. This confirms the belief that the anomaly in the interaction effect at the third harvest was caused by topgrowth "burning" by the nitrate fertilizers and ammonium sulphate at 400 lb N/ac. At this rate the nitrogen concentration in urea-fertilized herbage was 3·42%, significantly lower than that from the other sources, which had concentrations of greater than 4·0% (Table 4). Again, the lapse in yield at the fifth harvest by sodium nitrate at 400 lb N/ac was preceded by nitrogen concentrations which were lower at the third and fourth harvests than those from ammonium nitrate and ammonium sulphate (Table 4).

However, herbage from sodium nitrate often contained more nitrogen than that from other sources. As well, at the seventh harvest it contained more phosphorus and potassium, which was associated with higher exchangeable potassium in the soil.

The performance of ammonium sulphate was similar to that of ammonium nitrate. However, at the seventh harvest there was a significant fall in dry-matter yield (Table 1) which, allied with lower nitrogen concentrations, produced a highly significant interaction in the nitrogen yield data. The effects occurred at 200 and 400 lb N/ac (Tables 2 and 4) and were associated with lower soil pH and exchangeable potassium (Table 6) and lower concentrations of potassium in the herbage (Table 5).

Adequacy of phosphorus and potassium.—At the end of 1 year's production, the mean N, P and K contents of soil from fertilized plots were 0·46%, 55 p.p.m. and 0·65 m-equiv.% respectively. For unfertilized plots values were 0·43%, 49 p.p.m. and 0·70 m-equiv.%. This suggests an overall residue of N and P and a depletion of K.

All exchangeable potassium values were above the 0·4 m-equiv.% that appeared to be the threshold value for dry-matter response to potash fertilization in the second experiment in this series (Gartner 1969*b*). However, referring to the same paper, it should be noted that the $\frac{K\%}{N\%}$ values for the herbage in this experiment were all less than 1·0. They ranged from round 0·8 at 0, 50 and

100 lb N/ac to 0·9 at 400 lb N/ac. Even so, until the relationship between the concentrations of nitrogen and potassium in fertilized grass is more clearly defined, 1·0% is the only criterion available by which to assess adequacy of potassium for optimum grass growth. All concentrations were above this value.

All phosphorus concentrations, including those in unfertilized herbage, were greater than the critical percentage of 0·23% suggested for kikuyu by Andrew (1968). At round 50 p.p.m., soil levels of phosphorus were more than adequate.

Sward components.—The maximum dry-matter yield from the kikuyu-paspalum-carpet grass sward when fertilized with 400 lb N/ac as urea was 12,640 lb/ac. This figure is obtained by adding the 1964 dry-season yield of 1,590 lb DM/ac in experiment 1 to the 8-month yield of 11,050 lb/ac recorded in experiment 2 when the sward was adequately fertilized with phosphorus and potassium. At this stage kikuyu occupied 76% of the sward.

In the pure sward of kikuyu, urea at 400 lb N/ac yielded 13,820 lb DM/ac. The extra 24% of kikuyu increased DM yield by 1,180 lb/ac, or 49 lb per extra 1% of kikuyu in the sward. At the other end of the fertilizer scale, 6,540 lb DM/ac was produced by the unfertilized pure kikuyu sward; the mixed sward, containing on average 11% kikuyu, produced an average of 2,390 lb DM/ac. The difference is 4,150 lb DM/ac or 47 lb per extra 1% of kikuyu.

Thus the presence of paspalum and carpet grass in the sward limited the yield potential of the environment over the range of nitrogen treatments. The replacement of 1% of these components by kikuyu appears to be worth almost 50 lb DM/ac.

Frost damage on kikuyu was much less severe at 200 and 400 lb N/ac than at the lower rates. Further, at 400 lb N/ac the very dry weather (Figure 1) following the frosts did not diminish the yield or quality of the grass at the fifth harvest.

Management.—Grazing control did not occur exactly according to plan. Several times cattle were left on the plots for longer than the scheduled hour. However, cattle tended to concentrate on the high-nitrogen treatments, which were the main cause of concern with the cut-and-remove harvesting technique.

Even so, trampling and lodging were a problem in these treatments after the first harvest when wet weather interfered with the grazing-trimming-removal process. Smothering effects were still evident in the regrowth 3 weeks after harvesting. At other harvests this did not present a problem.

Where urination effects were obvious another sampling position was selected. This was seldom the case.

The use of cattle to provide a grazing and trampling effect did not affect the accuracy of this experiment in comparison with experiments 1 and 2. It served the purpose of overcoming the undesirable effects of sudden and complete defoliation of well-grown kikuyu. However, strict control must be kept over the length of time the cattle graze. Urine spots were obvious where cattle had been left on for longer than 1 hr, particularly in the summer season when rainfall was below average (Figure 1) and the plots became nitrogen-deficient. As well, when grass in high-nitrogen treatments was allowed to grow too tall its attractiveness to cattle and its lax nature made for excessive trampling and lodging with subsequent smothering of regrowth.

Accuracy.—The accuracy of dry-matter data collection in this experiment (experiment 3) compared favourably with that of the first two experiments (Table 7). In all experiments, coefficients of variation for individual harvests were above 10%. However, for annual dry-matter yields, coefficients of variation were satisfactory, particularly in experiment 3. In this experiment the coefficients of variation for herbage concentration of N, P and K were below 10% (Table 3).

TABLE 7

COEFFICIENTS OF VARIATION FOR DRY-MATTER YIELD AND SOIL ANALYSES IN EXPERIMENTS 1, 2 AND 3

Parameter	Range in Coefficients of Variation				
	Experiment 1	Experiment 2		Experiment 3	
		Main Plots	Subplots	Main Plots	Subplots
Dry-matter yield					
Annual	17 to 29	19	10	15	7
Individual harvests**	15–66 (14)	26–43 (4)	17–21	19–37 (7)	12–25
Soil analysis					
pH	3	..	..	3	3
P_2O_5 (p.p.m.)	41	..	..	45	30
Exch. K (m-equiv. %)	29	..	..	22	14
Total N (%)	..	..	..	11	7

* Coefficient of variation $= \dfrac{\text{Standard deviation}}{\text{General mean}} \times 100.$

** Figure in brackets = No. of harvests.

The coefficients of variation for soil analyses were consistent for experiment 1 and experiment 3. They were low for pH, satisfactory for total N, intermediate for exchangeable K and high for available P (Table 7).

Insects.—It is apparent from the dry-matter data in Table 2 that grass yields at the third harvest were diminished by the heavy infestation of webworms. Further, rate of regrowth was retarded, since the normal harvest interval after fertilizing at this time of year is 4 weeks. There was no obvious effect on nitrogen rate differences even though there were significantly more webworm holes in plots fertilized with 100 and 200 lb N/ac than in other treatments, particularly 400 lb N/ac (R. J. Elder, personal communication).

Conclusion.—Nitrogen deficiency is a major barrier to high levels of dry-matter production from kikuyu in the Millaa Millaa environment. At high rates of nitrogen the effect of variable seasons is secondary.

Maximum yields in this experiment were diminished by abnormal frosts, webworms, smothering and fertilizer burning. In experiments 1 and 2 they were diminished by the use of urea as a nitrogen source, the presence of paspalum and carpet grass in the sward, the cut-and-remove harvest technique and an induced potassium deficiency. Therefore, yields of up to 20,000 lb DM/ac of high quality can be expected from a pure sward of kikuyu fertilized with ammonium nitrate at 400 lb N/ac if phosphorus and potassium levels are maintained, webworms are controlled, grazing management is aggressive and the total nitrogen application is made in more than two dressings.

However, since the response up to 400 lb N/ac is linear, still higher yields might be obtained from higher rates of nitrogen before the efficiency of dry-matter production falls off.

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