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Strategic use of nitrogen fertilizers on pasture grasses in the humid tropics of Queensland

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Summary

Strategic use of nitrogen fertilizers to increase pasture growth in winter–spring was studied between 1972 and 1975 on two sites on the humid tropical coast of Queensland. Site 1 was representative of free draining fertile soils. Site 2 was representative of infertile soils with drainage problems during summer rains.

At site 1, bimonthly yields of *Brachiaria decumbens* cv. Basilisk and *Digitaria decumbens* (pangola) fertilized with 0 to 600 or 672 kg ha^{-1} yr^{-1} N in single, three or five split applications as ammonium nitrate or urea and with a single application of Osmocote at 336 kg ha^{-1} N in the first year were studied.

At site 2, bimonthly yields of these grasses, *D. pentzii* CQ911 and *Setaria sphacelata* var. *splendida* with 0 to 600 kg ha^{-1} yr^{-1} N in three split applications are reported; *Panicum maximum* cv. Hamil established poorly from seed and *D. decumbens* CPI 8385 grew too slowly .

Mean cumulative yields from May to November for *B. decumbens* were 1.4 to 1.7 times those of *D. decumbens* and 1.1 to 1.2 times those of other grasses. However, in July, mean yields were *D. pentzii* $>$ *S. sphacelata* $\geqslant$ *B. decumbens* $\geqslant$ *D. decumbens.*

Near maximum yields were obtained from 300 to 336 kg ha^{-1} yr^{-1} N at both sites, irrespective of frequency. Apparent nitrogen recoveries were highest with 100 to 112 kg ha^{-1} yr^{-1} N and three split applications in 1972 and 1974. 'Slow release' Osmocote gave similar yields to ammonium nitrate in 1972. Water, phosphorus and potassium are discussed in relation to grass growth; responses to nitrogen fertilizer were dependent on rainfall. Yields and apparent N recoveries by *B. decumbens* at both sites were similar in similar seasons.

1. Introduction

The seasonal pattern of pasture growth is one of the greatest problems confronting pasture managers in the humid tropics of Queensland. Summer, from December to April, is characterized by high temperatures and rainfall; winter, from June to August, is characterized by low night temperatures; both winter and spring, from September to November, have periods of moisture shortage (Teitzel and Middleton 1978). Rapid growth of pasture species in summer is followed by slow growth in winter and spring, even with the grass-legume mixtures recommended for the area (Teitzel and Middleton 1979).

To increase pasture growth, Teitzel, McTaggart and Hibberd (1971) suggested that nitrogen fertilizer be applied in winter and spring to grass pastures on heavier soils. Signal grass (*Brachiaria decumbens* cv. Basilisk) was the most productive of several grasses in a clipping experiment receiving 224 kg ha^{-1} N (Grof and Harding 1970). In a grazing experiment, Harding and Grof (1978) measured a mean annual live-weight gain of 950 kg ha^{-1} by steers on a signal grass pasture receiving 196 kg ha^{-1} yr^{-1} N. Their experiments used untested sequences of nitrogen fertilizer application on a well drained, heavy textured soil at the South Johnstone Research Station. Pangola grass (*Digitaria decumbens*) was, however, the grass most commonly planted and available for use with nitrogen fertilizer in the early 1970s.

There was, therefore, a need to examine rates and frequencies of nitrogen fertilizer application, to compare signal and pangola grasses and to extend the evaluation to other soil types. We decided to include grasses that might prove superior on the large areas of infertile soils with drainage problems during the wet season. The paper reports the results of two clipping experiments, the first on a free draining, naturally fertile soil which tends to dry out more in spring than the South Johnstone soil, the second on a naturally infertile soil subject to waterlogging. Experiment 1 studied the effects of four rates and three sequences of nitrogen fertilizer on signal and pangola grasses. In the first year, a 'slow release' fertilizer was included. Experiment 2 studied the effects of four rates and one sequence of nitrogen fertilizer on six grasses.

2. Materials and methods

Sites

Experiment 1 was conducted on a mesophyll forest/basalt soil-vegetation unit (Teitzel and Bruce 1971) at Utchee Creek, approximately 10 km from South Johnstone (17° 35′S, 146° 00′E). This inherently fertile, free draining krasnozem had a Principal Profile form of Gn 3.11 (Northcote 1971). Experiment 2 was conducted on a *Melaleuca* woodland/mixed alluvial soil-vegetation unit at Silkwood, approximately 20 km from South Johnstone. This soil was infertile with poor drainage during the wet season and had a Principal Profile Form of Um 6.34.

Nutrient deficiencies at Utchee Creek and Silkwood have been studied by Teitzel and Bruce (1972, 1973). Standley and Moody (1979) documented phosphorus sorption curves for soils 2673 from Utchee Creek, 2600 from Silkwood and 2088 from the site of the grazing experiment by Harding and Grof (1978) at South Johnstone and reported respective phosphorus sorption indices of 23.3, 40.8 and 26.4. The available water ranges (0 to 15 cm) for the sites were 24, 29 and 19 mm at Utchee Creek, Silkwood and South Johnstone respectively (Standley, unpublished data).

Nitrogen fertilizers and treatment abbreviations

Ammonium nitrate was the cheapest granular fertilizer until 1974. Then limited availability and a price increase prompted a change to urea. A slow release source, Osmocote (Anon. 1969), was included in experiment 1 in 1972. Osmocote is a mixture of ammonium nitrate and ammonium sulphate encapsulated in a polymeric material (Allen and Mays 1974) through which the nitrogen sources are expected to pass by osmosis.

Rates of nitrogen were 0, 112, 336 and 672 kg ha^{-1} yr^{-1} N in experiment 1 in 1972 and 0, 100, 300 and 600 kg ha^{-1} yr^{-1} N in both experiments subsequently. They will be abbreviated as N0, N112, . . . N600 in this paper.

Experiment 1

This experiment consisted of a partial factorial array of four nitrogen rates, two nitrogen sources and three sequences of application to signal and pangola grasses in 40.5-m^2 plots in three completely randomized blocks. The factorial was complete for four nitrogen rates (N0, N112, N336 and N672 as ammonium nitrate in 1972; N0, N100, N300 and N600 as ammonium nitrate in 1973 and as urea in 1974) and two sequences of equal split applications.

For the first sequence, fertilizer was broadcast in mid-April, late May, mid-July, late August and mid-October; for the second, fertilizer was broadcast in mid-April, mid-June and mid-August. A third sequence, one annual broadcast application in mid-April, was included at N336 in 1972 and N300 in 1973 and 1974. Osmocote was applied only once, broadcast at 336 kg ha^{-1}N in mid-April 1972.

The grasses were planted vegetatively on a 0.4-m grid in July 1971 and were mown periodically to 15 cm during the summer. Superphosphate (10% P) and muriate of potash (50% K) were broadcast over the site annually. In May 1972, April 1973 and April 1974 the rates of application were respectively 448, 448 and 400 kg ha^{-1} superphosphate and 168, 168 and 150 kg ha^{-1} muriate of potash. Nitrogen treatments began on 20 April 1972.

Grass dry matter yields were measured bimonthly between May 1972 and March 1975. Total nitrogen was determined for all samples and nitrogen yields were calculated. Grass from N672/N600 in five split applications was analysed for total phosphorus and potassium.

Soil samples (0 to 15 cm) were taken after each harvest from N672/N600 in five split applications. Ten cores 2.5 cm in diameter from each plot were combined for analysis for pH, acid extractable phosphorus and exchangeable potassium.

Replicate means for soil and grass phosphorus and potassium were calculated for each sampling between July 1972 and March 1975. The general mean and standard deviation for the 11 samplings during the May to November periods from 1972 to 1974 were calculated.

By October 1972, pangola grass was suffering from heavy infections of rust (*Puccinia oahuensis*) and weeds had invaded the plots. The grass survived but did not recover in 1973 and sampling was abandoned in September 1973.

Signal grass with N300 and N600 began to appear retarded in November 1973. Damage by nematodes (*Pratylenchus brachyurus*) was confirmed on root samples dug from plots on 27 February 1974. Nematodes were controlled by the nematicide 'Nemacur' (phenamiphos) sprayed at 11.2 kg a.i. ha^{-1} on 10 March 1974. A further attack by nematodes in November 1974 was controlled by spraying on 4 December 1974.

Experiment 2

This experiment consisted of a full factorial array of four nitrogen rates (N0, N100, N300 and N600 as ammonium nitrate in 1973 and as urea in 1974 and 1975) applied to five grasses in 40.5-m^2 plots in three randomized blocks. Equal split applications of nitrogen fertilizer were broadcast in the mid-April–mid-June–mid-August sequence comparable with the second sequence in experiment 1. The grasses planted in 1972 were Hamil (*Panicum maximum* cv. Hamil), splendida (*Setaria sphacelata* var. *splendida* CPI 15899), pangola (*D. decumbens*), signal (*B. decumbens* cv. Basilisk), and *D. decumbens* CPI 8385. *D. pentzii* CQ911 replaced CPI 8385 in 1973.

Hamil seed (2.24 kg ha^{-1}) was planted in February and again in April. Other grasses were planted vegetatively; splendida and pangola in February, signal in April and CPI 8385 in March in plots subsequently replanted with *D. pentzii* in March 1973. Basal fertilizers were 2.8 kg ha^{-1} Cu as copper sulphate pentahydrate and 560 kg ha^{-1} lime in April–May 1972 and 56 kg ha^{-1} N as ammonium nitrate in August 1972. In April 1972, April 1974 and July 1975 superphosphate at 503, 400 and 400 kg ha^{-1} respectively and muriate of potash at 188, 150 and 150 kg ha^{-1} respectively were broadcast over the site. Nitrogen treatments began in 1973.

Grass dry matter yields were measured bimonthly from each plot between July 1973 and November 1975. Samples from July 1973 to March 1975 were analysed for total nitrogen and nitrogen yields were calculated. Splendida from N0 and N600 and composite samples of grasses from these treatments were analysed for phosphorus and potassium. Replicate means for each sampling were calculated. Then means and standard deviations for analyses of splendida and the composite for both nitrogen treatments from May to November 1974 were calculated.

Soil samples (0 to 15 cm) were taken in April 1972, September 1973, July 1974, March 1975 and November 1975. Thirty cores 2.5 cm in diameter were combined for each composite sample. The first series, in 1972, was taken at random across a replicate to give a composite for each replicate. Subsequently, from N0 and N600, six samples were taken from plots of each of the five grasses to give composite samples corresponding to two nitrogen rates by three replicates. Soils were analysed for exchangeable potassium and acid extractable phosphorus. Replicate means for each sampling from September 1973 to November 1975 were calculated. Then means and standard deviations for the four sampling times were calculated.

Grass sampling

Whereas stoloniferous grasses such as pangola can survive low cutting, erect grasses such as splendida can be severely checked or killed. Teitzel, Wilson and Abbott (unpublished data) investigated the effect of different cutting heights on the grasses. Then they selected heights to minimize bias in favour of the stoloniferous or of the erect types. In experiment 1, cutting heights of 6 cm for pangola and 11 cm for signal were chosen. For experiment 2, heights of 7.6 cm for the *Digitaria* species, 12.7 cm for signal and 20.3 cm for splendida and Hamil were selected in July and September 1973. Thereafter a common height of 12.7 cm was adopted for all except the *Digitaria* species.

Grass from 4.05 m^2 within each plot was taken for dry matter yield determination and a sub sample was retained for chemical analysis. The grasses were cut by rotary mower from May 1972 to January 1973, a technique suited to short, dry samples. The greater bulk of material in March 1973 was collected by forage harvester. Subsequent harvests in experiment 1 and those in experiment 2 were by a motor mower with reciprocating blade (Jari). After each sampling the entire experimental area was mown to the requisite height for each grass and the cut grass was removed.

Chemical analyses

The total nitrogen contents of grasses were determined by a microkjeldahl procedure. Phosphorus and potassium contents were measured by a colorimetric method and flame photometry respectively, after dry ashing at 550°C (Cavell 1954).

Composite soil samples were air dried and sieved (2 mm). They were analysed for acid extractable phosphorus (Kerr and von Stieglitz 1938) and for potassium exchangeable in 1M ammonium chloride pH 8.4 (Beckwith 1964).

3. Results

The principal aim of this paper is to report species performance during the winter-spring period with various nitrogen fertilizer treatments. Therefore yields and chemical analyses for samplings from May to November are considered. Water, phosphorus and potassium are additional factors that may limit growth.

Rainfall and soil water potential

Monthly rainfalls (to the nearest mm) recorded at South Johnstone Research Station appear in table 1. From May to November, cumulative rainfalls (to the nearest mm) were 946, 1276, 932 and 1219 mm for 1972, 1973, 1974 and 1975 respectively, of which only 423, 605, 262 and 829 mm fell from June to October. During the 156 days following August 1972, 93 days of water potential below –0.2 bars and only 17 days of water potential above –0.3 bars were recorded in the soil at a depth of 10 cm in experiment 1 (Standley 1979).

Experiment 1

Comparison of grasses and nitrogen responses. Signal grass outyielded pangola grass at all times. Mean yields for all nine treatments from May to November 1972 were 6 454 and 3 853 kg ha^{-1} respectively. Rust, moisture stress and weeds in pangola plots invalidated any subsequent comparison of the grasses.

The effects of nitrogen treatments on signal grass yields from May to November are given in table 2. Cumulative yields for a given rate of nitrogen were highest in 1973 and lowest in 1974: with N300 and N600 yields in 1973 were about twice those in 1972 and 1974. The greatest separation of treatments was in 1973, the order of increasing yields being N0 $<$ N100 $<$ N300 and N600.

Table 1. Monthly rainfall (mm) at South Johnstone, 1972 to 1975

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total
1972	847	864	813	240	408	207	18	45	151	2	116	88	3 798
1973	229	494	1 019	575	389	228	117	24	145	91	284	1 049	4 642
1974	542	765	610	140	572	59	4	62	94	43	99	147	3 138
1975	428	749	418	495	354	134	116	127	347	105	38	878	4 187
Long term average* . .	491	576	662	363	246	164	104	83	83	91	123	233	3 202

* Climatic mean for South Johnstone (Teitzel and Middleton 1978).

Table 2. Dry matter yields of signal grass harvested at 2-monthly intervals and apparent nitrogen recoveries from May to November in Experiment 1 at Utchee Creek

Nitrogen rate (kg ha^{-1})	Nitrogen sequence*	Grass yield (kg ha^{-1})					Apparent N recovery (%)
		May	Jul	Sep	Nov	Total	
		1972—ammonium nitrate applied					
0		2 529	769	84	68	3 450	
112	1	3 311	993	436	287	5 027	40.4
112	2	4 157	1 119	525	474	6 275	66.2
336	1	3 614	1 139	1 419	688	6 860	32.0
336	2	3 383	1 103	1 389	797	6 672	32.9
336	3	3 294	1 269	1 763	853	7 179	39.2
336	3†	3 277	1 319	1 488	833	6 917	35.3
672	1	3 692	1 407	1 616	1 086	7 801	21.5
672	2	3 646	1 158	1 676	1 423	7 903	24.0
L.S.D. 5%	3	606	318	363	316	971	9.2
		1973—ammonium nitrate applied					
0		2 082	207	10	287	2 586	
0	3†	2 791	281	103	787	3 962	
100	1	3 555	812	456	1 042	5 865	45.4
100	2	4 023	1 028	659	1 036	6 746	66.5
300	1	5 349	2 203	1 899	2 878	12 329	70.4
300	2	4 702	1 444	1 746	2 544	10 436	69.3
300	3	4 933	1 616	1 718	2 792	11 059	75.2
600	1	3 935	1 694	2 226	3 646	11 501	43.2
600	2	4 244	1 410	2 324	4 680	12 658	48.7
L.S.D. 5%		926	461	574	855	1 901	10.0
		1974—urea applied					
0		1 440	30	31	47	1 548	
0	3†	1 689	20	47	63	1 819	
100	1	2 491	112	335	224	3 162	35.3
100	2	2 759	300	440	223	3 722	50.3
300	1	2 482	580	1 066	838	4 966	34.6
300	2	2 757	602	764	408	4 531	35.7
300	3	2 752	841	1 045	713	5 351	45.7
600	1	2 760	502	619	660	4 541	18.7
600	2	2 829	479	637	607	4 552	19.8
L.S.D. 5%		673	356	297	216	830	10.5

*Sequence 1: 5 applications 6 weeks apart beginning mid-April.
Sequence 2: 3 applications 8 weeks apart beginning mid-April.
Sequence 3: 1 application in mid-April.
Sequence 3†: Osmocote only in 1972.

$$\text{Apparent N recovery: } \frac{(\text{N yield of treatment} - \text{N yield N}_0)}{\text{N applied in current year}} \times 100$$

In May, nitrogen treatments outyielded N0 but there were no significant ($P < 0.05$) differences between rates. By September, yields increased according to treatments in the order N0 < N100 < N300 and N600, an effect pronounced in 1973. Only in November 1972 and 1973 did N600/672 give yields generally significantly higher than those from N300/336.

The frequency of application of nitrogen, 5 x 6 weeks or 3 x 8 weeks from mid-April, had no consistent effect on grass yields. Moreover, N300/336 in one application was as effective as either series of split applications at this rate. Osmocote gave similar yields to the corresponding rate of ammonium nitrate. Granules of Osmocote lay on the soil surface in April 1972 and subsequently burst. Its residual effect in terms of increased grass yields in 1973 was not significant ($P < 0.05$).

Apparent nitrogen recoveries from May to November are included in table 2. Recoveries from N300 and N600 in 1973 were approximately twice those in 1972 and 1974. With N300/336 recoveries were higher than with N600/672 (except for N336 sequence 1 and N672 sequence 2 in 1972) and frequency of application produced no significant ($P < 0.05$) differences in recoveries at either rate. However, with N100/112 higher recoveries were obtained from three than from five split applications in all years. Moreover, in 1972 and 1974, highest recoveries were obtained from N100/112 in three split applications. Osmocote gave the same recovery as the corresponding rate of ammonium nitrate.

Treatment N600/672 raised the nitrogen concentration of signal grass about 1% above the control. With N600/672 the concentration was lowest in March (1.4 to 1.7% N) and highest in September (2.9 to 3.4% N).

Phosphorus and potassium. Signal grass phosphorus from N600/672, sequence 1, was $0.216 \pm 0.047\%$, highest in July or September, lowest in November. Soil phosphorus showed little variation, 12.6 ± 2.5 ppm P. For the periods from May to March 1972–73, 1973–74 and 1974–75 phosphorus removed in grass corresponded to 0.71, 0.69 and 0.51 times that applied in superphosphate in the current year.

The potassium concentrations in the grass were $1.28 \pm 0.63\%$, highest in May (following fertilizer application), and lowest in November. Exchangeable potassium, 0.093 ± 0.021 m. equiv. per 100 g, was not significantly ($P < 0.05$) increased by fertilizer applications. For the periods from May to March 1972–73, 1973–74 and 1974–75 potassium removed in grass corresponded to 3.42, 1.98 and 1.36 times that added as muriate of potash in the current year.

Nematodes. Symptoms of nematode damage, stunted growth and brown coloration of the leaf tips of signal grass, first appeared late in 1973 on treatments N300 and N600. By February 1974, the mean and standard deviations for nematode counts per 100 g of roots were 21524 ± 17824 for N100, N300 and N600 compared with 4050 and 1630 for two replicates of N0. Populations varied according to seasonal conditions: counts in May for N100, N300 and N600 were 3583 ± 1816. Nematicide applied in March 1974 to split plots of these treatments reduced the counts in May to 823 ± 788. However, control of nematodes did not result in significantly ($P < 0.05$) higher yields of signal grass between May and November 1974 compared to yields from untreated split plots.

Experiment 2

Comparison of grasses. Mean yields for splendida, *D. pentzii,* signal and pangola grasses are presented in table 3. Mean cumulative yields from May to November for signal grass were 1.4 to 1.5 times those of pangola grass; signal grass produced significantly ($P < 0.05$) more dry matter than pangola grass for all individual harvests except those in May and November 1975. However, mean cumulative yields for signal grass were only 1.1 to 1.2 times those of splendida and *D. pentzii*. In July, mean yields were significantly different in the order *D. pentzii* $>$ splendida $\geqslant$ signal $\geqslant$ pangola. By September, yields of *D. pentzii* were not significantly different from those of signal grass. Splendida yields were not significantly different from those of *D. pentzii* in May 1974 and in September and November of both years. For each grass, cumulative yields in 1975 were 1.6 to 1.8 times those in 1974.

Nitrogen responses. Responses to nitrogen treatments are given in table 4. For the cumulative period May to November 1974 and 1975, yields increased in the order N0 $<$ N100 $<$ N300 and N600. In the second year, more grass was produced from each treatment, 3.2 times for N0 and 1.5 times for N300 to N600. Yields were significantly higher with N300 than with N600 for harvests in July and September of both years and in November 1974. However, N300 gave yields only significantly higher than those with N100 in July 1974, September of both years and in November 1974.

Table 3. Dry matter yields (kg ha^{-1}) averaged over all nitrogen rates for grasses harvested at 2-monthly intervals in Experiment 2 at Silkwood

Sampling	Grass	Yield 1974	Yield 1975
May	Signal	1 673	1 775
	Splendida	1 254	1 541
	Pangola	879	1 617
	D. pentzii CQ911	887	1 123
	L.S.D. 5%	479	267
July	Signal	312	299
	Splendida	615	229
	Pangola	173	155
	D. pentzii CQ911	802	549
	L.S.D. 5%	128	96
September	Signal	1 198	3 599
	Splendida	1 165	2 840
	Pangola	1 000	2 286
	D. pentzii CQ911	1 111	3 380
	L.S.D. 5%	167	564
November	Signal	1 289	1 824
	Splendida	906	1 729
	Pangola	894	1 376
	D. pentzii CQ911	956	1 318
	L.S.D. 5%	137	485
Total	Signal	4 472	7 497
	Splendida	3 940	6 349
	Pangola	2 946	5 434
	D. pentzii CQ911	3 765	6 433
	L.S.D. 5%	396	1 122

Table 4. Effect of fertilizer rates (kg ha^{-1} yr^{-1} N) on the mean dry matter yields (kg ha^{-1}) and nitrogen recoveries (%) of four grasses in Experiment 2 at Silkwood

Sampling	Grass yield				L.S.D. 5%
	Nitrogen fertilizer rate				
	0	100	300	600	
1974					
May	878	1 168	1 168	1 479	479
July	87	384	843	587	128
September	144	1 112	1 868	1 351	167
November	331	889	1 178	1 657	137
Total	1 440	3 553	5 057	5 074	396
1975					
May	1 484	1 548	1 622	1 403	267
July	255	339	418	219	96
September	1 136	3 248	4 160	3 561	564
November	1 684	1 038	1 374	2 223	485
Total	4 559	6 173	7 574	7 406	1 122
1974	Apparent N recovery				
May–Nov		39.8	36.1	22.2	6.0

Apparent nitrogen recoveries in 1974 were significantly higher with N100 than with N300 and N600. Nevertheless, at a particular rate of nitrogen, recoveries by the four grasses were not significantly ($P < 0.05$) different.

Signal grass yields and apparent nitrogen recoveries for the same nitrogen sequence are compared for both experiments in table 5a. In 1974, yields at Silkwood were 1.2 to 1.3 times those at Utchee Creek and apparent nitrogen recoveries were 0.9 to 1.2 times those at Utchee Creek. Mean cumulative signal grass yields for N0, N100, N300 and N600 in three equal split applications were 7 497 kg ha^{-1} in 1975 at Silkwood compared with 8 107 kg ha^{-1} in 1973 at Utchee Creek. Ratios of signal grass yields for each rate and frequency of nitrogen application compared with the control have been compiled in table 5b. The proportion of the yield increase attributable to the first 100 to 112 kg ha^{-1} N was higher in 1972 and 1974 than in 1973 and 1975.

Phosphorus and potassium. Means and standard deviations for various phosphorus and potassium analyses are given in table 6.

Table 5a. Signal grass yields (kg ha^{-1}), nitrogen recoveries (%) and rainfall (mm) from May to November in Experiment 1 at Utchee Creek and Experiment 2 at Silkwood

Expt	Year	Signal grass yield				Rainfall†	
		Treatment (kg ha^{-1} yr^{-1} N)*				Jun–Oct	May–Nov
		0	100	300	600		
1	1973	2 586	6 746	10 436	12 658	605	1 276
2	1975	4 856	6 579	8 470	10 080	829	1 219
1	1974	1 548	3 722	4 531	4 552	262	932
2	1974	1 904	4 400	5 776	5 800	262	932
		Apparent N recovery					
1	1974		50.3	35.7	19.8		
2	1974		43.4	38.6	23.7		

* 3 equal split applications at 8 weekly intervals commencing mid-April.

† South Johnstone Research Station.

Table 5b. Increases in signal grass yields from May to November by nitrogen treatments in Experiment 1 at Utchee Creek and Experiment 2 at Silkwood

Year	Expt	Grass yield ratio and treatments*	
		$\frac{N100/112}{N0}$	$\frac{N300/336}{N0}$ and $\frac{N600/672}{N0}$
1972	1	1.5 to 1.8	1.9 to 2.3
1973	1	2.3 to 2.6	4.0 to 4.9
1974	1	2.0 to 2.4	2.9 to 3.5
	2	2.3	3.0 to 3.1
1975	2	1.4	1.7 to 2.1

* Calculated for each frequency of application in Experiment 1.

Phosphorus and potassium analyses of splendida and of the composite sample were lowest in the samples taken in November from N600. Splendida potassium analyses were higher than N0 and lower for N600 than those of the corresponding composite samples. Phosphorus removal from May 1974 to March 1975 with N600 was almost half that applied in superphosphate and more than twice that removed from N0. Potassium removal for both splendida treatments and for the composite samples at N600 was 1.1 to 1.2 times that added. Soil analyses for exchangeable potassium were significantly ($P < 0.05$) lower for N600 than for N0, whereas phosphorus analyses were not different.

Table 6. Mean phosphorus and potassium analyses of samples from the experiment at Silkwood

Sampling	Analysis	Treatment		
		Fertilizer (kg ha^{-1} yr^{-1} N)	Grasses	
			Splendida	Composite*
May–Nov 1974	Grass P	0	0.248 ± 0.040	0.238 ± 0.043
	(%) (± s.d.)	600	0.249 ± 0.030	0.215 ± 0.044
	Grass	0	2.53 ± 0.44	1.91 ± 0.24
	(%) (± s.d.)	600	1.17 ± 0.55	1.23 ± 0.42
May 1974 to Mar 1975	Grass P removed / Fertilizer P†	0	0.21	0.17
		600	0.49	0.41
	Grass K removed / Fertilizer K†	0	1.16	0.79
		600	1.11	1.17
Sep 1973 to Nov 1975	Soil P	0		32.4 ± 5.5
	(ppm) (± s.d.)	600		29.0 ± 6.2
	Soil K	0		0.130 ± 0.020
	(meq per 100 g)	600		0.096 ± 0.015

* Signal, splendida, pangola and *D. pentzii* CQ911.

† Applied in April 1974.

4. Discussion

The principal interest of this study is the performance of grasses in the winter–spring period. Nitrogen fertilizer application began in April and ended in August for experiment 2 and in October for experiment 1. Therefore harvests from May to November are considered, with particular interest in those from July and September.

The sites of the experiments were representative of different soil-vegetation units and had been included in soil fertility studies by Teitzel and Bruce (1972, 1973). The sites were complementary to those at South Johnstone for the experiments of Grof and Harding (1970) and Harding and Grof (1978), but the Silkwood soil had a higher available water range and phosphorus sorption index. However, differences between the sites had little effect on signal grass yields and apparent nitrogen recoveries from May to November 1974 (table 5). Moreover, the comparison of yields from Utchee Creek in 1973 and Silkwood in 1975 (both seasons of good rainfall) also indicates minimal effect of site on grass performance.

There were periods of obvious moisture stress during late winter and spring in 1972 and 1974. Although cumulative rainfall from May to November indicated little difference between years, closer examination of the proportion received from June to October reflects the dry season in 1972 and even drier season in 1974. Grass with the high nitrogen treatments was the most severely stressed during these periods. At Utchee Creek, the importance of water as a factor limiting responses to fertilizer may be illustrated by mean signal grass yields from May to November: in 1972 with N336 they were only 61% of those with N300 in 1973; likewise in 1972 with N672 they were only 65% of those with N600 in 1973. Similarly, at Silkwood yields in 1974 were much lower than those in 1975 (tables 3 and 4).

In both experiments, significant ($P < 0.05$) increases in cumulative yields peaked at N300/336. Most of the yield increase was attributable to the first 100 to 112 kg ha^{-1} N in the drier seasons of 1972 and 1974 whereas the higher rates of nitrogen produced twice as much grass in the wetter season of 1973 (table 5b).

The frequency of nitrogen application did not significantly ($P < 0.05$) influence grass yields. In particular, N300/336 applied once in April was as effective as split applications. Apparent nitrogen recoveries indicated most efficient use of 300 to 336 kg ha^{-1} N at one application in mid-April and of 100 to 112 kg ha^{-1} N as three split applications 8 weeks apart. Less efficient recovery of five split applications (the last two in late August and mid-October) than of three split applications (the last in mid-August) was indicated for all rates and was significant ($P < 0.05$) for N100/112 in 1972, 1973 and 1974 (table 2).

Ammonium nitrate, urea and Osmocote were, apparently, equally effective sources of nitrogen. For a particular treatment, apparent recoveries from ammonium nitrate at Utchee Creek in 1972 and from urea at both sites in 1974 were similar (tables 2, 4 and 5a). Osmocote showed no advantage as a 'slow release' fertilizer in 1972. However, the granules split open on the soil surface during the weeks following application. If they had been placed at depth in the soil they might have remained intact in a relatively moist environment, thereby enabling the slow release mechanism of osmosis to operate.

Signal grass proved superior to pangola grass at both sites. However, at Silkwood *D. pentzii* gave highest yields in July and yields equal to those of signal grass in September. Indeed, for the cumulative period May to November signal grass yields were only 1.1 to 1.2 times those of *D. pentzii* and splendida and all three show promise for infertile, relatively poorly drained country. Splendida yields in particular may have been limited by potassium availability at N300 and N600.

The experiments demonstrated disadvantages of some of the grasses, disadvantages that were exacerbated by high rates of nitrogen fertilizer and prolonged periods of moisture stress. When the experiments were being planned, pangola grass was the species most commonly planted and available for nitrogen fertilization. However, on the humid tropical coast during the dry winter–spring periods of 1971 and 1972, it was decimated by rust and aphids (*Schizaphis* spp.). Other grasses appeared resistant and were included in the Silkwood experiment (Teitzel and Wilson 1974). However, the initial germination of Hamil seed was poor and attempts to re-establish it failed due to preferential grazing by marsupials. *D. decumbens* CPI 8385 grew very slowly and was replaced by *D. pentzii*. By the onset of the wet season in December 1973, signal grass with N300 and N600 proved susceptible to attack by nematodes.

Phosphorus probably did not limit growth at either site. Even at N600/672, phosphorus concentrations in the grasses were not low. Moreover, annual removal corresponded to no more than 71% of phosphorus applied in superphosphate that year. However, soil analyses were always below 20 ppm at Utchee Creek whereas they had mean values of about 30 ppm at Silkwood. The failure of superphosphate to raise the soil tests accords with the high sorption of phosphorus shown by these soils (Standley and Moody 1979).

Induced potassium deficiency may have limited nitrogen responses at both sites. Although potassium deficiency had never been found on basaltic soils in this area (Teitzel and Bruce 1972) and although the Utchee Creek site received 243 kg ha^{-1} K from 1972 to 1974, far more potassium was removed than was applied. Also, potassium concentrations in grasses at both sites were low by the time of the November harvests. In both experiments, exchangeable potassium analyses of soils were low.

Hacker and Jones (1969) commented on high potassium uptake by *Setaria sphacelata* cv. Nandi and the association between high yields and high potassium contents. The opportunity was taken in the Silkwood experiment to examine this proposition for *S. sphacelata* var. *splendida.* For N0, potassium analyses of splendida were higher than those of the corresponding composite of all grasses whereas, for N600, analyses were lower (table 6). Removal of potassium by splendida was almost identical for both treatments, indicating that potassium limited the response by splendida to the high nitrogen treatment.

The experiments provide guidelines for graziers intending to increase their pasture production in winter and spring by using nitrogen fertilizer. Signal grass may be recommended for both soil types. However, *D. pentzii* should give most growth in winter on poorly drained, relatively infertile country; splendida is also suitable and both grasses have been resistant to aphids, rust and nematodes. The original recommendation (Teitzel *et al.* 1971) of split fertilizer applications in winter and spring apparently confers no advantage over a single application of 300 kg ha^{-1} N at the end of the wet season. A single application of 100 kg ha^{-1} N was not tested but results show that less efficient use is made of five split applications extending to October than by three split applications extending to August. Although highest yields were produced by 300 kg ha^{-1} N as ammonium nitrate or urea, the most economical return may be obtained with 100 to 200 kg ha^{-1} N, especially in dry seasons.

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