Nitrogen-fertilised grass in a subtropical dairy system 2. Effect of level of nitrogen fertiliser on animal production

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Summary. The response in yield of milk and milk components to level of nitrogen (N) fertiliser applied to a tropical grass pasture was measured over 6 years. Pasture (*Chloris gayana* cv. Callide) was stocked at 2 Holstein–Friesian cows/ha and received annual basal dressings of phosphorus (250 kg superphosphate/ha) and potassium (63 kg KCl/ha), and treatments of urea at 0, 150, 300, 450, and 600 kg N/ha.year. Fertiliser was applied in 3 equal applications in September, December, and February. Cows were maintained on the pasture throughout the year, and 0.4 ha grazing oats/cow (100 kg N/ha.year) and 0.8 t cracked grain/cow were given as supplements. Hay or silage supplements were given when green grass yield was <0.5 t dry matter (DM)/ha. The amount of hay and silage given annually averaged 755, 437, and 529 kg DM/cow at 0, 300, and 600 kg N/ha.

Mean milk response over the 6 years was high (8 kg milk/kg N) for 0–150 kg applied N/ha.year. The difference between fertilised and unfertilised pastures increased with time, and this was associated with degradation of pasture, excessive liveweight loss during lactation, and premature drying off of cows at nil applied N. At 150–600 kg N/ha.year, response was consistent across years (4.5 kg milk/kg N.year).

Yields of milkfat and lactose reflected changes in milk yield, although milk protein percentage decreased significantly (P<0.05) with increased level of applied N. Conception rate increased with rate of applied N, from 58 to 92% at 0 and 600 kg N/ha.year (P<0.01).

The results suggest a maximum margin over feed costs at 334 kg applied N/ha over the total grazed area. We conclude that there will be a large milk response to applying about 150 kg N/ha.year; beyond that, the milk response would be consistently about 4.5 kg/kg N to at least 600 kg N/ha.year.

Introduction

Tropical grass pastures fertilised with nitrogen (N) can sustain high stocking rates (Colman and Kaiser 1974; Davison *et al.* 1985) and greater milk production per ha than grass and legume mixed pastures (Caro Costas and Vicente Chandler 1979; Davison *et al.* 1982). These results were obtained in relatively high rainfall zones, and it is of interest to determine whether results could be extended to areas receiving <1000 mm annual rainfall.

A 6-year study examined milk production responses to N fertiliser applied to a tropical grass pasture, and effects on pastures and soils (Cowan *et al.* 1994). This paper reports the effects of 5 levels of applied urea on animal productivity at a stocking rate comparable to that used on district farms.

Materials and methods

The experiment was conducted over 6 years at Mutdapilly Research Station, south-eastern Queensland (27°45'S, 152°40'E; alt. 40 m), in a subtropical environment of predominantly summer rainfall. Details of rainfall, experimental site, and establishment and management of pastures are given in Cowan *et al.* (1995). There were 2 replicates of a Rhodes grass (*Chloris gayana*) cv. Callide pasture, and the present data were obtained at a stocking rate of 2 cows/ha on these pastures. Treatment levels of urea fertiliser supplied 0, 150, 300, 450, and 600 kg N/ha.year to the pasture. During winter, each treatment group also had access to a separate area of grazing oats, giving a mean stocking rate over the year of 1.17 cows/ha. Fifteen Holstein–Friesian cows and 5 Holstein–Friesian heifers were used in each year, and each animal was given 3 kg cracked barley or sorghum daily during lactation, or 1 kg daily when dry. Second-quality lucerne (*Medicago sativa*) hay or maize silage supplements were given to cattle at about 9 kg DM/cow.day when green dry matter (DM) on offer to cows was visually assessed at <0.5 t/ha.

Cows were milked twice daily. Milk yield was recorded weekly and a composite sample of milk analysed for fat, protein, and lactose (Fossomatic-

Table 1. Effect of level of nitrogen fertiliser (kg/ha.year) on annual and seasonal milk yields for cows grazing Rhodes grass pasture at 2 cows/ha

Regression coefficients in parentheses are not significant (P<0.10) but are included to show the level of consistency in the response

Period and year	Milk yield (kg/cow) N applied: 0	150	300	450	600	Linear regression coeff. 0–600	150–600
Annual							
1983–84	2180	2664	2651	3058	3339	1.81**	1.62*
1984–85	2351	2741	3184	3489	4083	2.81**	2.89**
1985–86	2443	3263	3560	3378	4492	2.81*	(2.34)
1986–87	—	4049	4530	4029	4805	—	(1.18)
1987–88	—	3446	4305	4371	4896	—	2.94*
1988–89	—	3556	4001	4024	4724	—	2.35*
Means							
Years 1–3	2325	2889	3132	3308	3971	2.47**	2.28*
Years 4–6	—	3684	4279	4141	4808	—	2.16†
Years 1–6	—	3286	3705	3725	4390	—	2.22*
Spring							
Years 1–3	676	851	847	860	1215	0.72*	(0.74)
Years 4–6	—	1329	990	1517	1538	—	(0.77)
Summer							
Years 1–3	831	1106	1175	1273	1435	0.92**	0.72*
Years 4–6	—	1351	1642	1449	1832	—	(0.83)
Autumn							
Years 1–3	538	711	792	854	993	0.70**	0.61*
Years 4–6	—	806	1211	913	1191	—	(0.57)
Winter							
Years 1–3	281	223	319	322	330	n.s.	n.s.
Years 4–6	—	198	436	264	247	—	n.s.

† P<0.10; * P<0.05; ** P<0.01.

Milkoscan 203). Cows were weighed fortnightly following morning milking.

Effects of level of N fertiliser on milk yield and composition over 6 years were analysed by regression. Annual totals were analysed, and totals for spring (1 September–12 December), summer (13 December–12 March), autumn (13 March–7 June), and winter (8 June–31 August). After 3 years the nil applied N treatment was discontinued (see Results). For analyses of means across years, data have been grouped into years 1–3 and 4–6.

Results

Milk yield

Pastures receiving the nil applied N treatment did not form the basis of a stable system. Milk yield did not increase during the first 3 years (Table 1), and this production was maintained through increased supplementary feeding (see Table 3) and large losses in liveweight of cows during autumn (Fig. 1). On the basis of these results and observations of pasture degeneration (Cowan *et al.* 1995), we discontinued this treatment after 3 years.

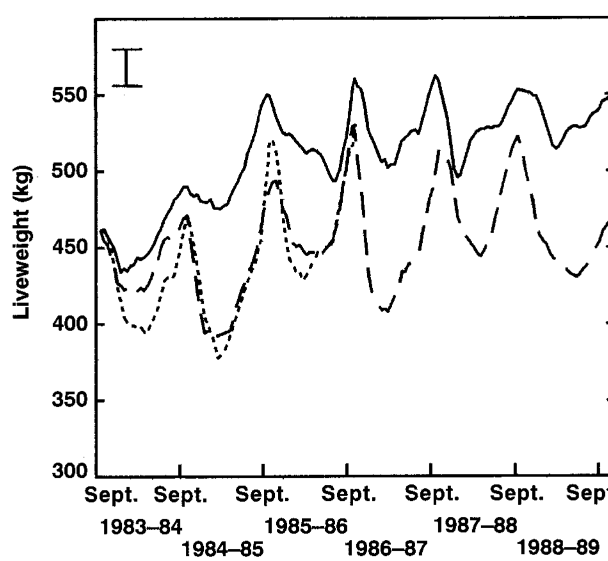

Figure 1. Pattern of liveweight change over six years for cows grazing Rhodes grass pasture fertilised with 0 (- - -), 150 (— — —), and 600 (———) kg/ha.year of applied nitrogen. Vertical bar indicates approximate s.e.m.

Milk yield per cow increased significantly with level of N fertiliser in 5 of the 6 years (Table 1). In years 1–3 the response was linear from 0 to 600 kg N/ha.year. In years 4–6, when the nil N treatment had been discontinued, the linear response was very similar to that measured during years 1–3, although the intercept was markedly increased (3420 *v.* 2470 kg). The incremental increase in milk yield per cow with level of N fertiliser at the stocking rate of 2 cows/ha on Rhodes grass pasture averaged 2.22 kg milk/kg N and was reasonably consistent over years (Table 1). The milk yield of all cows on fertilised paddocks increased with time.

The response in milk yield to level of N fertiliser occurred in spring, summer, and autumn and was of a similar magnitude in each of these seasons (Table 1). As occurred for annual yield, the response was similar in years 1–3 and 4–6. There was no response in winter, but at this time cows were either dry or in late lactation and were grazing oats at a common stocking rate and level of applied N.

At the stocking rate of 1.17 cows/ha there was a linear increase in milk yield with level of fertiliser, described by the following equation:

$$M = 3067 + 4.46\,(\pm\,1.11)N \quad (n = 4;\ \text{r.s.d.} = 146) \qquad (1)$$

where M is milk yield (kg/ha.year) and N is level of N applied over the total area (i.e. 128–377 kg N/ha.year).

Milk components

Yield of milkfat increased ($P<0.05$) linearly with level of applied N. As occurred for milk yield, the response was reasonably consistent across years, although there was a tendency for the incremental response to be less in years 4–6 (0.057 kg/kg N) than in years 1–3 (0.082 kg/kg N). In each of years 1–3 the regression coefficient was greater (0.097 kg/kg N) when the nil applied N treatment was used in the equation than in equations using only 150–600 kg N/ha.year (0.082 kg/kg N). The increase in fat yield with level of applied N occurred in each season and was consistent during spring, summer, and autumn (0.025, 0.032, 0.031 kg/kg N).

Milkfat percentage averaged 3.78%. Milkfat yield per ha from the total grazed area for those 4 groups grazing pastures receiving applied N is described by the equation

$$F = 129 + 0.077\,(\pm\,0.011)N \quad (n = 4;\ \text{r.s.d.} = 2.8) \qquad (2)$$

where F is milkfat yield (kg/ha.year) and N is as defined in equation 1.

Milk protein percentage tended ($P<0.10$) to decrease with level of applied N from 150 to 600 kg N/ha.year. This effect was most marked in spring and was greater in years 4–6 than years 1–3 (Table 2).

Yield of milk protein increased ($P<0.05$) with level of applied N; the increase was greater in years 1–3 than years 4–6 (0.057 *v.* 0.041 kg/kg N). As with milkfat this

Table 2. Effect of level of nitrogen fertiliser (kg/ha.year) on annual and seasonal protein percentages in milk from cows grazing Rhodes grass pasture at 2 cows/ha

Regression coefficients in parentheses have probabilities of $P<0.25$ and are included to show the level of consistency in the response

Period and year	Milk protein (%)					Linear regression coeff.	
	N applied: 0	150	300	450	600	0–600	150–600
Annual							
1983–84	3.03	3.21	3.21	3.22	3.00	n.s.	(–0.0004)
1984–85	2.98	3.30	3.19	3.30	3.06	n.s.	(–0.0004)
1985–86	3.11	3.18	3.08	3.14	2.96	n.s.	(–0.0005)
1986–87	—	3.30	3.17	3.26	3.00	—	(–0.0005)
1987–88	—	3.17	2.90	2.87	2.85	—	(–0.0007)
1988–89	—	3.35	3.14	3.15	3.02	—	–0.0007†
Means							
Years 1–3	3.04	3.23	3.16	3.22	3.00	n.s.	(–0.0004)
Years 4–6	—	3.27	3.07	3.09	2.96	—	–0.0006†
Years 1–6	—	3.25	3.12	3.16	2.98	—	–0.0005†
Spring							
Years 1–3	3.05	3.08	2.96	3.01	2.85	–0.0003†	(–0.0004)
Years 4–6	—	3.17	3.08	2.94	2.84	—	–0.0008**
Summer							
Years 1–3	2.87	3.06	2.91	3.00	2.83	n.s.	(–0.0004)
Years 4–6	—	3.16	2.93	2.98	2.79	—	–0.0007†
Autumn							
Years 1–3	3.23	3.51	3.39	3.58	3.25	n.s.	(–0.0004)
Years 4–6	—	3.60	3.21	3.46	3.26	—	(–0.0005)

† $P<0.10$; ** $P<0.01$.

increase occurred throughout lactation, being 0.019, 0.025, and 0.024 kg/kg N in spring, summer, and autumn, respectively.

For cattle grazing pastures receiving 150–600 kg N/ha.year, there was a linear increase in milk protein yield per ha total grazed area with level of applied N, described by the following equation:

$$P = 106.2 + 0.096\,(\pm\,0.021)N \quad (n = 4;\ \text{r.s.d.} = 2.7) \qquad (3)$$

where P is milk protein yield (kg/ha.year) and N is as defined in equation 1.

Lactose percentage in milk averaged 4.71%, declining from an average of 4.80% in spring to 4.23% in winter. There was an increase in lactose percentage with level of applied N, from 4.72 to 4.91% at 0 and 600 kg N/ha.year, respectively (regression coefficient = 0.0003; $P<0.01$), and this increase was similar and significant ($P<0.05$) over the ranges 0–600 and 150–600 kg N/ha.year in years 1–3.

Lactation length

Mean lactation length increased ($P<0.05$) with the application of N fertiliser (0.045 days/kg N), mean values being 248 days at nil N to 276 days at 600 kg N/ha.year.

Liveweight

During the first 4 years, there was a general increase in mean liveweight of cows, from about 430 kg postcalving in year 1 to 510 kg in year 4. Since heifers were usually used to replace cows not retained in the experiment, the age structure of the herd was reasonably consistent. Values in years 5 and 6 were similar to year 4 (Fig. 1). Within years the annual fluctuation in liveweight, from a peak before calving to a low at about April, was greater for cows at the nil or low levels of applied N than at higher levels. The extent of liveweight loss from calving through to autumn was significantly ($P<0.05$) inversely related to level of applied N. This was particularly evident for cows grazing pastures at nil applied N, where minimum mean liveweight in April–May was about 80 kg less than for cows grazing pastures at the 600 kg N/ha level. By contrast, the precalving weights were much less variable. This effect was associated with earlier drying-off of cows at the low levels of applied N and subsequent rapid weight gains while grazing oats during winter.

Conception rate

Over the 6 years of the experiment, 12 cow-mating seasons were observed at nil applied N and 24 seasons at 150–600 kg N/ha.year. Although numbers are small, regression analysis showed that total conception rate increased ($P<0.01$) with level of applied N, the values being 58, 63, 67, 87, and 92%, respectively.

Table 3. A summary of production criteria for dairy cows seasonally calved in a dryland farming system using a tropical grass pasture fertilised with five rates of applied N (kg/ha.year)

The system consists of 0.5 ha tropical grass pasture, 0.4 ha grazing oats, and grain and roughage supplements (see Materials and methods) Prices for 1992 are: milk $A0.30/kg, urea $360/t, superphosphate $300/t, potassium chloride $400/t, concentrate $150/t, hay and silage $150/t DM

N applied to total area:	44	128	211	294	377
	(kg/ha.year)				
Milk output	2581	3647	4113	4135	4873
Inputs					
Nitrogen	44	128	211	294	377
Phosphorus	12.5	12.5	12.5	12.5	12.5
Potassium	17.3	17.3	17.3	17.3	17.3
Concentrate	955	955	955	955	955
Hay and silage (DM)	755	525	437	448	529
	($/ha.year)				
Milk output	774.3	1094.1	1233.9	1240.5	1461.9
Inputs					
Nitrogen	34.3	99.8	164.6	229.3	294.1
Phosphorus	41.7	41.7	41.7	41.7	41.7
Potassium	13.8	13.8	13.8	13.8	13.8
Concentrate	143.3	143.3	143.3	143.3	143.3
Hay and silage	120.8	84.0	69.9	71.7	84.6
Margin (output – input)	420.4	711.5	800.6	740.7	884.4

Hay and silage supplements

In each year all cows received hay or silage from October to December. During this period grazing oats was no longer productive and storm rains were usually insufficient to stimulate substantial growth of the tropical grass. Following storm rains, cows at 600 kg N/ha.year continued to receive hay for about 4 weeks longer than other groups, as the high trash levels on the ground delayed regrowth of the Rhodes grass (Cowan *et al.* 1995*a*). During autumn and winter, before oats became available for grazing, cows at the lower levels of applied N required more hay. In particular, cows at nil applied N were heavily dependent on hay from about March to June. The average amounts of hay and silage given are shown in Table 3.

Economics

The mean milk output and levels of input of fertiliser, concentrate and hay or silage for the 5 treatments are shown in Table 3, together with the financial values. The increase in hay inputs at low levels of applied N had the effect of increasing the response in financial margin. By contrast the higher hay input at 600 kg N/ha.year had the effect of reducing the financial margin. The maximum financial margin per ha occurred at a mean

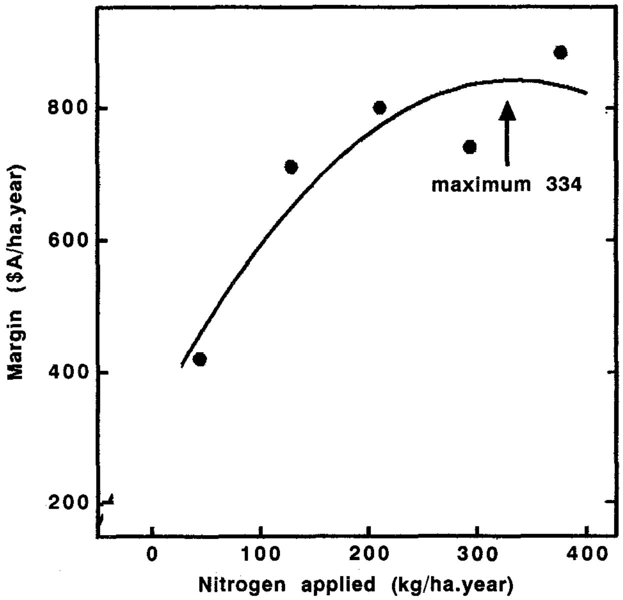

Figure 2. Relationship between financial margin above feed and fertiliser costs and average level of nitrogen application over the total grazed area. Calculations used to determine the margins are shown in Table 3.

input of 334 kg applied N/ha (Fig. 2), equivalent to 520 kg N/ha.year on the Rhodes grass pasture.

Discussion

Without applied N, the Rhodes grass pastures degenerated in yield and botanical composition (Cowan *et al.* 1995) and supported only low levels of milk production, about 1000 kg/ha.year if adjustment is made for the amount of supplementary feed. With low levels of fertiliser N applied, the pastures remained Rhodes grass dominant and there was a substantial increase in DM yield (Cowan *et al.* 1995). The combination of these effects results in a high milk response. At higher levels of applied N (>150 kg N/ha.year in our study), pastures are very stable and the milk response reflects the additional DM grown and that proportion subsequently harvested by the cow. Consequently, we measured a milk response of about 8 kg/kg N over 0–150 kg N/ha.year, and 4.5 kg/kg N over 150–600 kg N/ha.year. The response at 150–600 kg N/ha.year was consistent over the 6 years of our study.

Previous experiments using N-fertilised grass pastures for dairy production used 1 or 2 levels of applied N and did not allow a description of a response curve. With temperate pastures receiving N fertiliser at rates of 400–700 kg N/ha.year, milk responses ranged from –1.3 to 3.8 kg/kg N (Wilson and Dolby 1969; Gordon 1973). King and Stockdale (1980) measured almost no increase in milk production when a *Trifolium repens* based pasture was fertilised with 224 kg N/ha.year. With tropical pastures, the milk response at levels of applied N <150 kg N/ha.year have been about 7.2–16 kg/kg N in controlled experiments (Cowan and Stobbs 1976; G. D. Chopping, quoted by Cowan *et al.* 1993) and in studies of input–output relationships across several farms (Rees *et al.* 1972; Kerr and Chaseling 1992). At higher levels of application the response has been 4–7 kg milk/kg N (Davison *et al.* 1985; Reason *et al.* 1989; Davison 1992; Cowan *et al.* 1993). In a survey of farm inputs and outputs in the UK, Hawkins and Rose (1979) measured an average level of N use of 263 ± 75 kg N/ha.year and an increase of 4.9 kg milk/kg N when stocking rate was held constant, although in practice, the net response was double this due to concomitant increases in stocking rate with increases in applied N. Beef response models show a linear increase in liveweight gain per ha with increases in applied N to about 200 kg N/ha.year, but little or no response beyond this level (Martin and Berry 1970; McMurphy and Tucker 1979; Jones 1990; Tallowin *et al.* 1990).

Our experiment was done in a relatively low rainfall environment (800 mm annually) and supports previous work showing a similar pasture DM response to N across a relatively wide range of rainfall zones (Buchanan and Cowan 1990). In northern Australia, dairying is carried out in annual rainfall zones 700–2500 mm, and it is unlikely that lack of rainfall would limit responses to less than those recorded in our study.

Milk production and cow liveweight increased during the first 3 years of our study, indicating that cows took some time to adapt to this system of feeding; this is consistent with the results of Davison *et al.* (1985). This adaptation occurred in both animal and pasture. Precalving liveweights of cows increased with years, from 480 kg in year 1 to 575 kg in year 3. An increase in liveweight of this magnitude has been associated with an additional 850 kg milk/cow.lactation (Brown *et al.* 1982), similar to the increase over time in the present experiment of 950 kg. These results emphasise the long-term nature of the response by cows to feeding systems, and the need to obtain this information before making an economic assessment.

The response in milk yield to level of applied N was consistent in spring, summer, and autumn for our spring-calving cows. By contrast, Davison *et al.* (1985; 1988) measured a response in milk yield only during autumn and winter. This difference in response may, in part, reflect the difference in environment, as those experiments were done in an upland tropical environment of relatively high rainfall (1250 mm), but with dry spring weather. Our cows were maintained on pasture throughout the year, whereas those of Davison *et al.* (1985; 1988) were removed from pasture during spring. Davison (1992) showed that if, rather than destocking paddocks, cows were maintained on paddocks during spring and given supplementary roughage, then a milk response to N was observed earlier in the year. In our study, differences in liveweight between levels of applied N were greatest in late autumn and early winter, reflecting the cumulative effects of treatment from calving in spring through to autumn. Cows grazing pasture without applied N lost >100 kg liveweight during this period but, following premature drying-off, made very rapid gains in liveweight during late winter and spring.

There was a decrease in protein percentage in milk as level of applied N increased. Other studies have shown milk protein percentage to increase (Gordon 1973; Cowan *et al.* 1976; Davison *et al.* 1988) or to be unchanged (King and Stockdale 1980; Davison 1992) in response to level of applied N. Protein percentage in milk reflects the relative rates of secretion of milk volume (lactose, chloride) and delivery of protein into the udder (Schmidt 1971); it is likely that forages of different composition, and supplemented with different rates of concentrate, will have variable effects on protein percentage. The application of N fertiliser to grassland reduces the soluble carbohydrate content of grass (McIlroy 1967), yet increases the total yield of grass on offer to cows. The net effect on milk protein levels will depend on the relative changes in grass intake by the cow, and in the proportions of soluble carbohydrate, digestible DM, crude protein, and rumen-degradable protein in the pasture.

In our experiment, increasing the level of applied N during summer increased conception rate, perhaps reflecting a higher DM intake by cows during the mating period. By contrast, Norton *et al.* (1989) observed a negative association between conception rate and level of applied N during summer on several dairy farms with year-round calving. There are differences in rainfall, pastures species, and supplementary feeding between that study and ours, further demonstrating the difficulty of ascribing a simple response to a change in the level of applied N. Reason *et al.* (1989) measured a decrease in the calving–conception interval for cows grazing pastures receiving a higher level of applied N.

We conclude that the milk production response to level of N fertiliser will be high at low levels of application where fertiliser is effective in preventing decline of an introduced grass pasture. Optimum economic response occurs in the range 150–300 kg N/ha.year.

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