An evaluation of kikuyu-clover pastures as a dairy production system.
1. Pasture and diet

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Abstract

An experiment used 42 lactating Holstein-Friesian cows to evaluate kikuyu (*Pennisetum clandestinum*) cv. Whittet, Haifa white clover (*Trifolium repens* cv. Haifa) and Safari clover (*T. semipilosum* cv. Safari) pastures at 3 stocking rates (2.5, 3.75 and 5 cows/ha) and a range of nitrogen fertiliser levels (0, 150, 300 and 600 kg/ha N). These perennial pastures were compared with an annual ryegrass (*Lolium* spp.) production system stocked at 5 cows/ha that received 400 kg/ha N. All pastures were irrigated over the 3 years of the experiment. The diet selected from pasture was evaluated using oesophageally fistulated cows and the botanical and chemical composition of their diets related to botanical and chemical components in the pasture on offer. The experiment was conducted in a tropical upland environment, where the average annual rainfall is 1279 mm and summer dominant.

Total pasture on offer was generally highest in late spring and summer and lowest in late winter. Clover on offer was always highest in November (520 ± 29) kg/ha DM with means of 280 (± 20), 230 (± 13) and 290 (± 12) kg/ha DM in February, May and August. Clover yields were highest at 2.5 and 3.75 cows/ha where no nitrogen fertiliser was applied and Haifa was the dominant clover throughout. Clover on offer declined over the 3 years. Annual ryegrass pastures yielded approximately 14 t/ha DM from May–December. Pasture quality was high with the crude protein % of kikuyu increased by stocking rate and level of N fertiliser (range 12–18%). The crude protein % of ryegrass averaged 24%, while that of clover ranged from 23–26%.

Clover % in the diet (CLD) was positively related to both clover % in the pasture (CLP) and clover DM on offer (CLY, kg/ha DM): CLD = 0.91 + 1.725 CLP (May and November) and CLD = 7.92 + 1.725 CLP (August) (r^2 = 0.44; P<0.05). In August, clover % in the diet was related to clover on offer by the equation: CLD = 5.69 + 0.058 CLY (r^2 = 0.42; P<0.05). The conversion rate of kikuyu in the pasture to kikuyu in the diet was similar for all treatments (regression coefficient 0.6), but where 600 N was applied, there was a higher overall kikuyu % in the diet. The best predictor of crude protein % in the diet (CPD) included kikuyu leaf % (KLD) + clover % (CLD) in the equation: CPD = 6.34 + 0.199 (KLD + CLD) (r^2 = 0.60; P<0.01).

Dietary clover % declined over the 3 years in all treatments and seasons except for treatments 2.5/0N and 3.75/0N in spring when clover in the diet was 30–40%. This decline over time was related to a reduction in clover on offer in the pastures over the same period. In general, season had the dominant effect on the relationships between pasture and diet parameters.

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Introduction

Irrigated annual temperate pastures based on ryegrass (*Lolium* spp.) have played a large role in increasing the quantity and quality of grazed forage available on dairy farms in the tropics and subtropics (Chopping *et al.* 1982a; Moss *et al.* 1985). This system is called 'High-N Rye' and is based on ryegrass-dominant pasture planted in autumn at high seeding rates and grazed 6–9 times until early summer, with annual fertiliser applications of up to 500 kg/ha N. During summer and autumn, cows graze tropical grass pastures. Milk yields as high as 15 000 L/ha have been recorded from this system (Chopping *et al.* 1982b; 1982c).

It is a simple system to manage as the pastures tolerate high stocking rates and frequent grazings. This simplicity has led to a rapid increase in its adoption amongst dairy farmers (Lowe and Hamilton 1985). Despite the benefits of the 'High-N Rye' system, it is an expensive system to operate due to the high inputs of nitrogen fertiliser and the need to reseed each year (Chopping and Cuda 1991). The annual nature of the system demands a high labour input at the time of establishment, there is a risk of delayed sowing in wet autumns and in some situations it can lead to soil erosion prior to establishment of new pasture.

Naturalised white clover has long been considered a potential source of high quality forage for pasture systems in the subtropics. Research has shown productivity is limited by rainfall variability and distribution, with large annual fluctuations in yield (Ostrowski 1972; Jones 1982). Raingrown Safari clover (*Trifolium semipilosum* cv. Safari) has also been used and has shown some promise as an alternative to white clover in certain areas (Jones and Rees 1972; Garden 1977; Shaw and Quinlan 1978). Stobbs (1976) compared Safari and white clover pastures in combination with *Paspalum dilatatum* over 3 seasons. The clover pastures demonstrated similar milk production per cow and higher production than rhodes grass (*Chloris gayana*) cv. Pioneer pastures.

The philosophy behind the present experiment was to integrate both white clover (*T. repens*) cv. Haifa and Safari clover into a kikuyu (*Pennisetum clandestinum*) cv. Whittet pasture as a low-cost alternative to the 'High-N Rye' system. Kikuyu was chosen as the companion grass because of its prostrate growth habit and its wide use on dairy farms in northern Australia (Lowe and Hamilton 1985). Pastures were irrigated year-round to remove soil moisture as a limiting factor to productivity. A range of stocking rates and nitrogen fertiliser levels were employed to determine the potential of this combination of pasture species and to compare the quantity and quality of both the pasture and the diet with that of the ryegrass system. The second paper in the series (Davison *et al.* 1997) discusses the milk production and liveweight responses of the two pasture systems.

Materials and methods

Location and climate

The experiment was conducted at Kairi Research Station, north Queensland (17° 14'S, 145° 34'E; altitude 700 m). Rainfall and temperatures over the long term and during the experiment are presented in Table 1. The climate is typically tropical with 79% of rain falling over the December–April period. Notable climatic features during the experiment were severe frosts in July 1984 and extended periods of overcast weather in March and May 1985.

Table 1. Climatic data for 1984–1986, including the extreme daily maximum and minimum temperatures recorded for July and December in each year, compared with the long-term (54-year) mean.

Year	Annual rainfall	Total no. wet days	Evaporation	Maximum/minimum temperature July	Maximum/minimum temperature December
	(mm)		(mm)	(°C)	
1984	872	123	1667	25.0/0.5	35.0/16.0
1985	1107	160	1624	22.4/1.0	33.5/10.3
1986	1053	160	1642	24.5/6.5	35.0/15.6
Long-term mean	1279	160	1555	20.9/10.9	28.9/18.3

Pasture establishment

An area of 11.6 ha of krasnozem soil was ploughed and prepared in late 1982 and early 1983 and sown in the summer to millet (*Panicum* spp.). In April 1983, the area was ploughed, sprayed for weed control, and superphosphate (8.8% P; 0.02% Mo) at 500 kg/ha and muriate of potash at 250 kg/ha were applied. These fertilisers were applied at the same rates in March in each subsequent year.

Perennial pastures were sown in late May 1983. Whittet kikuyu, Haifa white clover and Safari clover were each sown at 2 kg/ha. Saia oats (*Avena sativa* cv. Saia) was included in the mixture at 20 kg/ha to act as a cover crop and help reduce competition from weeds. Paddocks in the experimental area designated to be annual pastures were sown only to oats. At sowing, all pastures were fertilised with 50 kg/ha N, and irrigation was applied as deemed necessary. Establishment was excellent and grazing commenced in September 1983. The pastures were slashed in October and December 1983 to help reduce the grass component and promote clover content in spring and summer. From late January 1984–late March 1984, pastures were grazed at 5 dry cows/ha.

In 1984, 1985 and 1986, annual pasture areas were ploughed in early March and sown at commercially used sowing rates (40–50 kg/ha) to *Lolium multiflorum* cv. Midmar, *Lolium perenne* cv. Ellet, *Trifolium subterraneum* cv. Clare and *Trifolium repens* cv. Haifa, between March 19 and April 9. Urea was applied at 50 kg/ha N before planting and once each month after grazing commenced to give an annual input of 400 kg/ha N. Weeds were controlled 3 weeks post-planting with Dinaseb (1.5 L/ha a.i.) and 2, 4, D-B (1.5 L/ha a.i.).

Treatments and animal management

The experimental design was a randomised complete block with 7 treatments arranged as an incomplete factorial. Experimental pastures consisted of 28 paddocks of perennial and annual pastures in 4 pasture replicates. Cows on the 5/ANN treatment also grazed an adjacent perennial kikuyu-clover pasture from mid-December to May each year. These perennial pastures were fertilised as for the remaining perennial pastures and were grazed at 5 cows/ha with mature cows during the period, June–December.

Stocking rate (cows/ha)	Treatments				
	Kikuyu-clover				Annual ryegrass
	N fertiliser (kg/ha/yr)				
	0	150	300	600	400
2.5	2.5/0N	—	—	—	
3.75	3.75/0N	3.75/150N	—	—	
5.0	—	5/150N	5/300N	5/600N	5/ANN

All nitrogen fertiliser was in the form of urea. In the 150N treatments, applications were 50 kg/ha N in March and 100 kg/ha N in May. For 300N and 600N treatments, fertiliser was applied equally in 6 split dressings at approximately 8-week intervals. Muriate of potash (125 kg/ha) was applied to all pastures in September 1985.

A total of 42 cows calved between mid-March and mid-May each year and were allocated to 7 groups of 6 cows on the basis of milk yield, liveweight and calving date. A group was allocated to each treatment and grazed the 4 paddocks in that system on a 1-week grazing, 3-week spelling regime. Pastures were grazed on this rotation from the start (April 18, 1984) to the completion (February 26, 1987) of the experiment. Cows in all treatments received molasses (75.5% DM, 6% crude protein, 1.1% Ca, 0.6% Mg, 0.5% S) at the rate of 3.5 kg/d, fortified with dicalcium phosphate (23.7% Ca, 18.8% P) and coarse salt (NaCl) to supply 60 and 30 g/d, respectively. Further details on animal management are given in the second paper in this series (Davison *et al.* 1997).

Pasture measurements

Pasture on offer and its botanical and chemical composition were determined in February, May, August and late October–early November each year. Sampling took 2 days on each occasion for 4 consecutive weeks. Pre-grazing and post-grazing pasture yields were determined on each occasion, by cutting pasture in 8 randomly placed quadrats (0.4 m^2) to ground level with hand shears. Subsamples were taken for dry matter (DM) determination, while 500–750 g was sorted into green kikuyu, Haifa, and Safari clover, dead material and weeds for perennial pasture, and green ryegrass and clover, dead material and weeds for annual pasture. Weeds were defined as any species other than those sown. All pasture samples were dried at 80°C for 24 h in a forced-draught oven.

Samples of kikuyu, Haifa, Safari, ryegrass and annual clovers were ground to pass through a 1 mm screen and retained for chemical analysis. In Years 1 and 2 (May 1984–May 1986), each pasture component was analysed for N in individual replicates and for Ca, P, Mg, K and S (AOAC 1980) pooled across replicates. Despite this pooling of samples, there was often insufficient Safari and annual clover to complete the analyses.

In addition to the seasonal pasture sampling of annual ryegrass pastures, each ryegrass replicate was sampled as previously outlined on the day before grazing commenced from May 15–December 26, 1984. In 1986, 2 of the 4 pasture replicates were sampled pre-grazing from May 7–November 19.

Soil measurements

Soil samples were taken in June 1984 and March 1987. In each paddock, 20 core samples (5 cm diameter) were taken to a depth of 10 cm, bulked, subsampled and dried at 40°C for 48 h, then analysed for pH (soil:solution ratio of 1:5), electrical conductivity, phosphorus (bicarbonate), organic carbon, total nitrogen, calcium, magnesium, sodium and potassium (Bruce and Rayment 1982).

Diet measurements

The botanical and chemical composition of the diet were measured in each season, on all treatments, using oesophageally fistulated Holstein-Friesian cows (Davison *et al.* 1985). Animals were adapted to kikuyu-clover pastures adjacent to the experiment for 7 days prior to sampling. Animals were fasted overnight with access to water and used for sampling between 0800 and 1030 h. Pre-grazing samples were taken 1 day prior to experimental cows entering their paddocks, and post-grazing samples on the day cows left their paddocks, in the same week that pasture samples were taken. All 4 replicates were sampled with 2 or 3 oesphageally fistulated cows used to sample each paddock. Samples from cows in each paddock were pooled and squeezed through muslin. A subsample (200–300 g) was frozen, and for perennial pastures, sorted (Chacon *et al.* 1977) into green kikuyu leaf, green kikuyu stem, clover, dead material and weeds. Annual pastures were sorted into green ryegrass, clover, dead material and weed components. Another subsample (500 g) was dried at 70°C for 24 h and ground to pass through a 1 mm screen. In Years 1 and 2, this sample was analysed for crude protein (N% x 6.25) in each replicate and for Ca, Mg and S pooled across replicates (AOAC 1980). In Year 3, only crude protein was analysed for pre- and post-grazing paddocks.

Statistical analysis

Analysis of the botanical and chemical composition of pasture and diet isolated the effects of 7 treatments which included different combinations of nitrogen fertiliser, stocking rate and pasture type (Genstat 5 1989). The error term for pasture data was estimated from the paddock-to-paddock variation after allowing for replicates and treatments. The analyses were done within years, across years and within seasons. Seasonal analyses were done separately for each season using a split-plot design, with year as a subplot. An analysis of variance for each soil chemical attribute was done for both 1984 and 1987. The error term for the diet botanical analyses was estimated from the animal-to-animal variation after allowing for replicates and treatments. Analyses were done within years and across years. For the analysis across years for seasonal and treatment effects on the diet botanical percentages, the design was treated as a split plot in time, with years as a second factor applied to each treatment.

Genstat 5 (1989) was used to derive all prediction equations. In general, all results were pooled and season and treatment and their interactions were introduced as factors into the regression model. If the factor or its interaction with any term did not contribute significantly to a decrease in the residual error, the term was not included in the final model.

Results

Pasture — botanical composition

Total pasture on offer. Within the kikuyu-clover treatments, total pasture on offer was similar from November–May. Overall means were 3840 (± 69, s.e.), 3960 (± 75) and 3740 (± 78) kg/ha DM for February, May and November, respectively, and 2690 (± 51) kg/ha DM in August (Figure 1). Treatment yields were generally highest at 2.5/0N and lowest at 5/150N (Figure 1). Maximum and minimum yields for 5/150N were 3050 kg/ha DM in May and 1790 kg/ha DM in August, and for 2.5/0N, they were 4870 kg/ha DM in February and 4000 kg/ha DM in August.

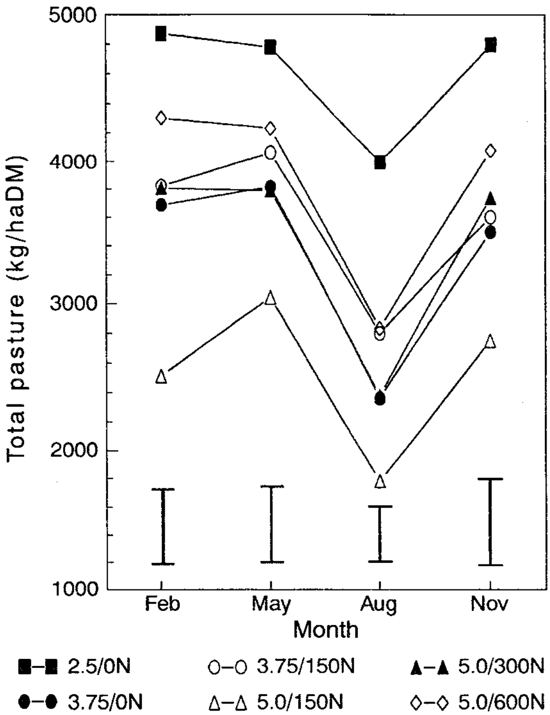

Figure 1. Total pasture on offer in kikuyu-clover pastures in 4 seasons at a range of stocking rates (cows/ha) and nitrogen fertiliser levels (kg/ha N) averaged over 3 years. The vertical bars represent LSD (P = 0.05) values.

Clover. Total clover (Haifa + Safari) on offer was always highest in November (mean 520 ± 29 kg/ha DM). Overall means in February, May and August were 280 (± 20), 230 (± 13) and 290 (± 12) kg/ha DM, respectively (Figure 2). Haifa was the dominant of the 2 clovers in the perennial pastures. The ratios of Haifa:Safari on offer (DM basis) were 2.0, 2.2, 5.2 and 9.2 for February, May, August and November, respectively.

There were differences (P<0.01) in clover on offer between years and these are presented for 4 treatments for 4 seasons in Figure 3. Total clover on offer showed a general decline from Year 1 to Year 3 with the lowest yields recorded in Year 2 in all seasons.

Kikuyu. The amount of green kikuyu DM on offer in each season is shown in Figure 2. Over all treatments, mean yields were 2070 (± 49) in February, 2450 (± 69) in May, 1450 (± 36) in August and 1950 (± 36) kg/ha DM in November. Kikuyu as a % of total pasture on offer decreased (P<0.01) from Year 1 to Year 3 in each season except August (Figure 4). In August, green kikuyu % increased (P<0.05) across years only for treatments 2.5/0N (43 to 54%), and 3.75/0N (40 to 51%).

Dead material and weeds. Dead pasture material was higher (P<0.01) for 2.5/0N than for all other kikuyu-clover treatments in August and November and most other treatments (P<0.05) in February and May, and for 5/150N was lower (P<0.05) than for all other treatments in each season. Over all treatments, mean yields in February, May, August and November were 1360 (± 36), 1130 (± 28), 910 (± 26) and 1160 (± 29) kg/ha DM, respectively, and dead material as a % of total pasture on offer increased (P<0.01) from Year 1 to Year 3 in May (22 to 33%) and November (27 to 38%) (Figure 4).

Most of the DM yield attributed to weeds included grass species such as couch (*Cynodon dactylon*) and *Brachiaria decumbens,* which were readily eaten by cows. Weed yields over all treatments were 130 (± 22), 150 (± 23), 50 (± 8) and 100 (± 19) kg/ha DM in February, May, August and November, respectively, and were generally highest at 5/300N and 5/150N and lowest at 2.5/0N. At 5/150N, weeds increased from 1984 to 1986 with the ingress of nutgrass

(*Cyperus rotundus*), pigweed (*Portulacca* sp.) and crowsfoot (*Eleusine indica*). Over all treatments and seasons, weeds as a % of total pasture on offer increased (P<0.01) from Year 1 to Year 3 (Figure 4).

Annual pasture. Annual ryegrass-clover pastures (5/ANN) over 8 grazings yielded 14.2 t/ha DM in 1984 (May–December) and 14.4 t/ha DM in 1986 (May–November). Over the 2 years of the study, mean DM on offer was 6.1 t/ha in winter and 7.3 t/ha in spring.

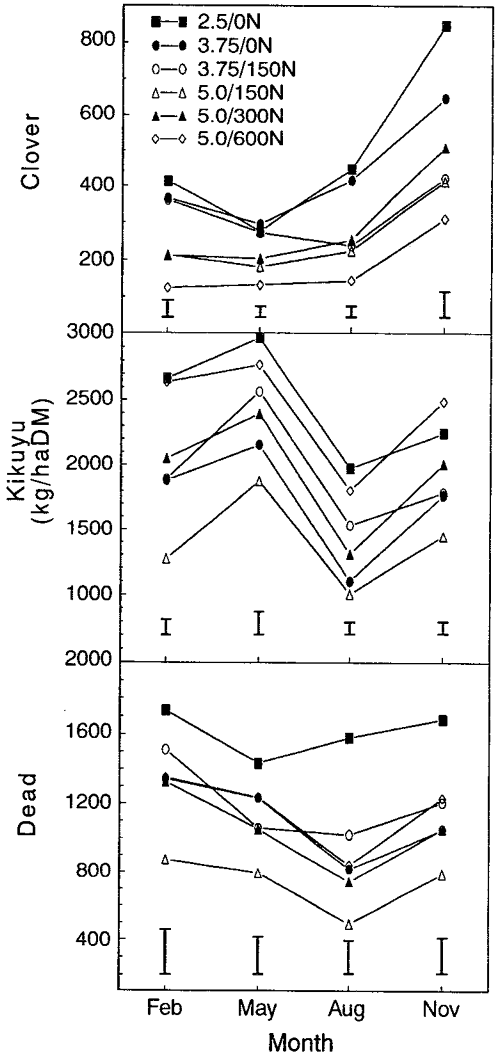

Figure 2. Clover (Haifa and Safari), kikuyu and dead material on offer in kikuyu-clover pastures in 4 seasons at a range of stocking rates (cows/ha) and nitrogen fertiliser levels (kg/ha N) averaged over 3 years. The vertical bars represent LSD (P = 0.05) values.

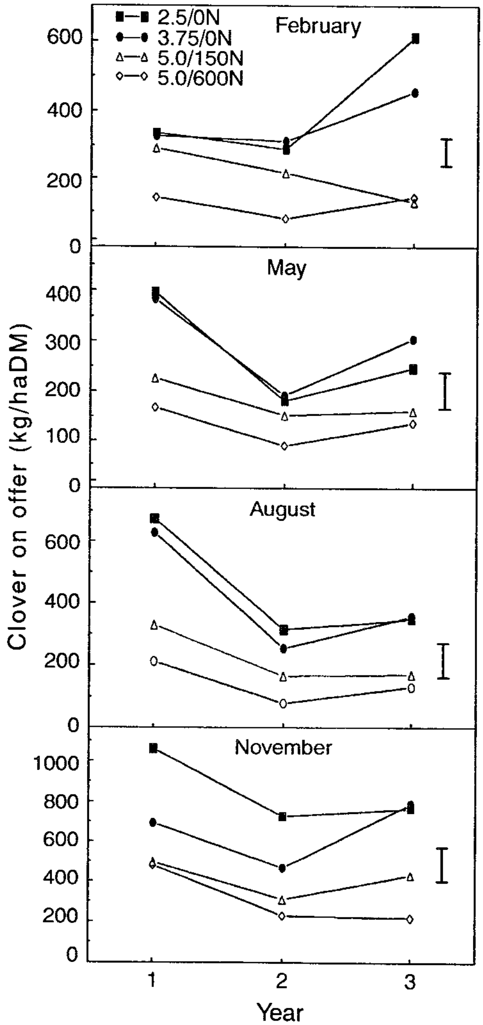

Figure 3. Clover on offer in perennial kikuyu-clover pastures over 3 years for treatments indicated. The vertical bars represent LSD (P = 0.05) values for year effects.

Pasture — chemical analyses

Crude protein (CP) concentration of kikuyu tended to increase with both stocking rate and level of nitrogen fertiliser (Figure 5). The CP concentration of ryegrass was significantly higher (P<0.01) than that of kikuyu in each season (Table 2). In the kikuyu-clover pastures, CP concentration of clovers was highest in August and November (Table 2) and generally increased with stocking rate (Figure 5).

The Ca % of Haifa was always well above that of ryegrass, which in turn was higher than that of kikuyu. The concentrations of P, Mg and S were similar in all species, while K concentration in ryegrass was always above that in kikuyu and clover (Table 2).

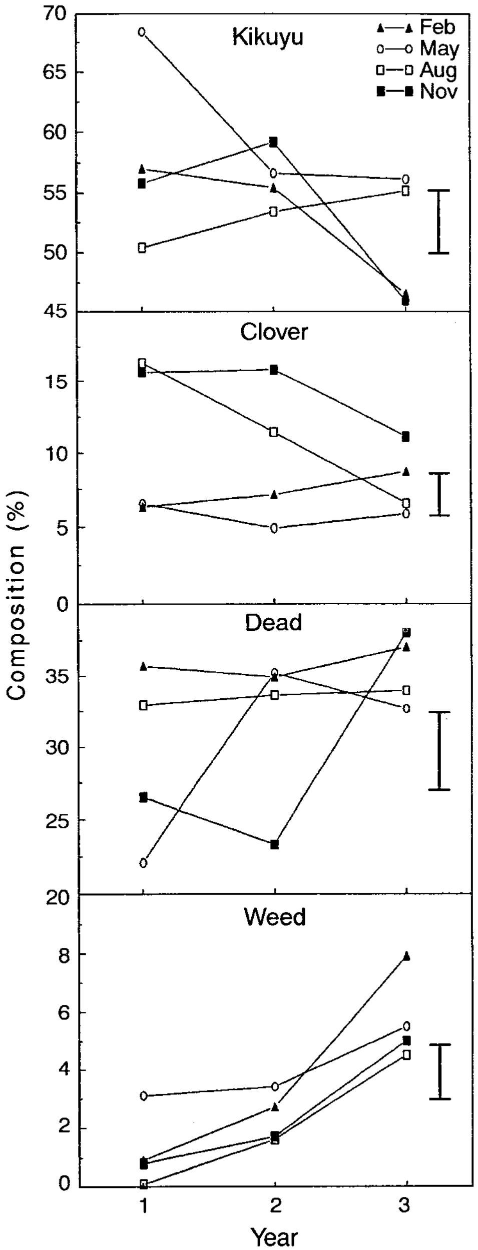

Figure 4. Green kikuyu, clover, dead material and weeds (% DM) over Years 1–3 of the experiment. The vertical bars represent LSD (P = 0.05) values for year effects.

Soil fertility

There was no significant effect (P>0.05) of treatments on the change in soil chemical parameters from 1984–1987. Mean values were pH 6.24 (±0.03), P 63.4 (±2.7) ppm, organic C 2.53 (±0.04)%, total N 0.302 (±0.005)%, Ca 9.06 (±0.21), Mg 2.30 (±0.17), Na 0.12 (±0.01) and K 1.72 (±0.06) m-equiv/100g.

Diet —botanical composition

Perennial pasture. Clover % in the diet was highest in November (overall mean 29%), followed by August (24%), May (11%) and February (10%), and tended to be higher at the lower stocking rates (Figure 6). The addition of 150 kg/ha N at 3.75 cows/ha decreased dietary clover % in August by 14% (P<0.05) and in November and May by 4% (P>0.05). At 5 cows/ha, dietary clover level was similar at 150N or 300N, and consistently greater (P<0.01) than that at 600N. Dietary clover was lower (P<0.01) in Year 3 than in Year 1 for all samplings and treatments except 2.5/0N in November (Figure 7). The decrease in clover content of the diet over years was countered by an increase in kikuyu stem % and dead % in the diet. In May, dead material in the diet increased from 7% in Year 1 to 13% in Year 3 (P<0.05), while kikuyu stem % increased from 7% to 20% (P<0.01).

Mean kikuyu leaf % in the diet was 63, 64, 43 and 48% in February, May, August and November, respectively (Figure 6), with no decrease across years in any season (P>0.05). Cows at 5/600N selected more (P<0.01) kikuyu leaf than those on any other treatment, with a mean value of 68%. Kikuyu stem comprised 10–18% of the diet, while dead material in the diet was highest in August (15–21%) and lowest in November (7–18%). Broad-leaf weeds comprised less than 2% of the diet, with none detected in August of any year.

Annual pasture. In the annual pasture, ryegrass comprised 89 and 82% and dead material 6 and 16% of the diet in August and November, respectively, while the balance of the diet was clover.

Table 2. Chemical analyses for kikuyu, Haifa clover and ryegrass averaged across treatments and years.

Month	Species	Crude protein	Ca	P	Mg	K	S
					(%DM)		
February	Kikuyu	12.7	0.27	0.43	0.31	4.67	0.28
	Haifa	23.1	1.04	0.36	0.28	4.25	0.19
May	Kikuyu	14.3	0.30	0.39	0.32	4.64	0.27
	Haifa	23.5	1.07	0.33	0.29	5.00	0.21
	Rye	24.1	0.61	0.42	0.28	5.83	0.33
August	Kikuyu	16.7	0.35	0.43	0.35	5.07	0.32
	Haifa	26.9	1.13	0.38	0.30	4.56	0.24
	Rye	23.6	0.43	0.39	0.23	5.95	0.29
November	Kikuyu	14.8	0.30	0.43	0.33	4.88	0.26
	Haifa	26.1	1.11	0.33	0.29	4.58	0.21
	Rye	25.2	0.49	0.37	0.29	5.11	0.31

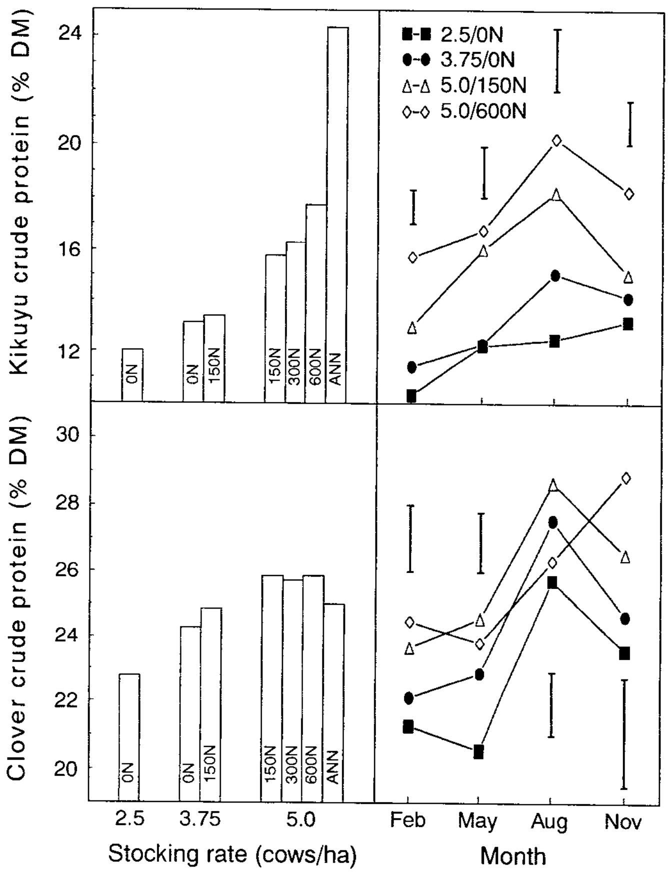

Figure 5. Crude protein concentration (% DM) in green kikuyu and clover meaned for each treatment across years and for 4 treatments in each season (ANN = annual rye-clover pastures). The vertical bars represent LSD (P = 0.05) values.

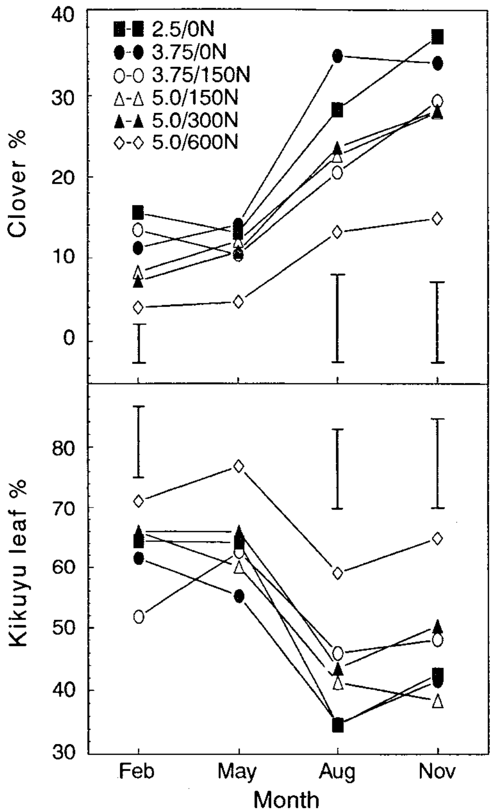

Figure 6. Clover and kikuyu leaf (% DM) in the diet in different months of cows on perennial kikuyu-clover pastures. The vertical bars represent LSD (P = 0.05) values.

Diet — chemcial analyses

The average crude protein in the diet for all 7 treatments was 17 (±0.4)% in February, 20 (±0.5)% in May, 21 (±0.4)% in August and 20 (±0.3)% in November. The crude protein % in the diet of cows on annual pastures was 23, 24 and 22% for May, August and November, with only the August figure significantly higher (P<0.05) than for perennial treatments.

Seasonal changes in Ca, Mg and S concentrations of the diet selected are shown in Figure 8. Within the kikuyu-clover pastures, the diet selected from 5/600N was lower in Ca due to the higher proportion of kikuyu in the diet. On the other hand, in perennial pasture in winter and spring, the higher proportion of clover in the diet resulted in higher Ca levels. The S level in the diet of cows on 5/ANN was higher than for perennial pasture treatments in both August and November.

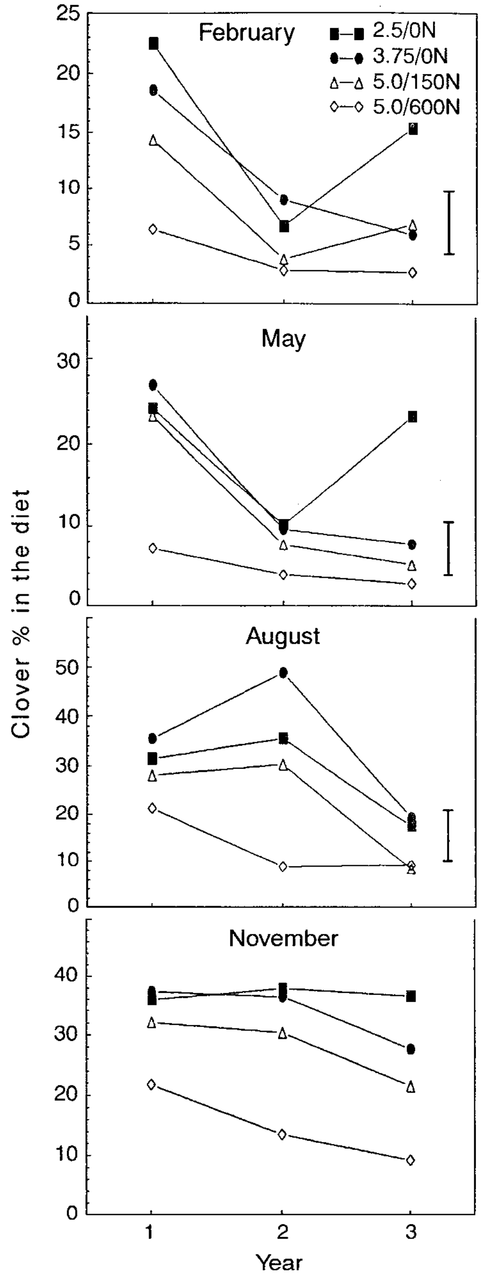

Figure 7. Changes in clover % in the diet selected from perennial kikuyu-clover pastures over 3 years. The vertical bars represent LSD (P = 0.05) values for year effects.

Prediction of dietary crude protein

Dietary CP% (CPD) was related to clover % in the diet (CLD) across all seasons and all 7 treatments. The equations for each treatment are presented in Table 3.

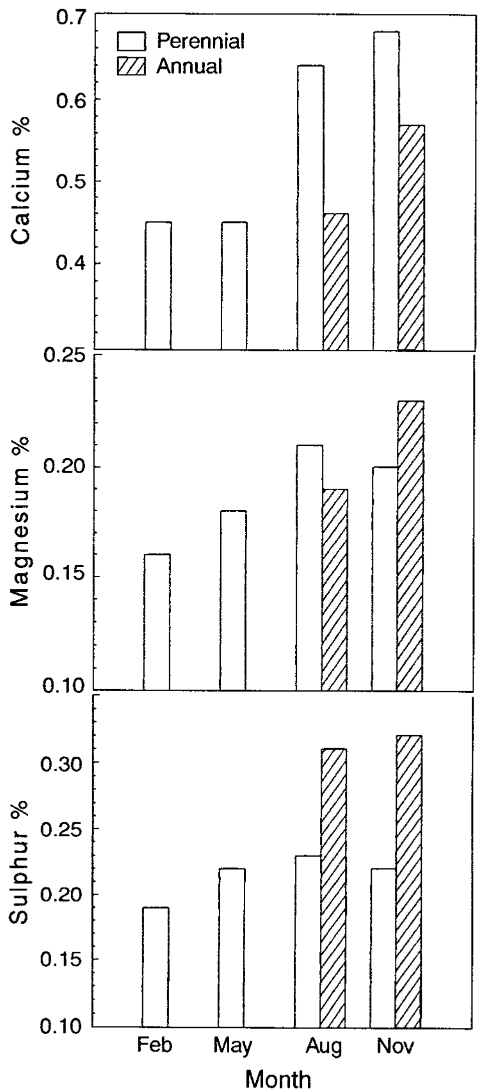

Figure 8. The concentration of calcium, magnesium and sulphur selected from pasture by cows on perennial kikuyu-clover and annual ryegrass pastures.

Kikuyu leaf percentage in the diet (KLD) was a poor predictor of CPD. The best model included season as a term and had the following form: CPD = a + 0.106 (± 0.013) KLD ($r^2 = 0.25$; $P<0.05$). The "a" values for each season were 13.44 (±1.03) for February and May, 17.99 (±0.87) for August and 17.31 (±0.88) for October.

The overall best predictor of CPD combined both clover % and kikuyu leaf % in the diet (KLD + CLD). The relation between CPD and the kikuyu leaf % + clover % across all treatments and all seasons gave the following equation: CPD = 6.34 (± 0.75) + 0.199 (±0.010) (KLD + CLD) ($r^2 = 0.60$; $P<0.01$). When season was incorporated into the regression as a factor, the r^2 increased to 0.69 ($P<0.01$). Equations for each season had different ($P<0.05$) regression coefficients.

February and May: CPD = 6.55 (±0.66) + 0.180 (±0.009) (KLD + CLD)

August: CPD = 6.55 (±0.66) + 0.227 (±0.010) (KLD + CLD)

October: CPD = 6.55 (±0.66) + 0.211 (±0.009) (KLD + CLD).

Table 3. Regression equations predicting dietary crude protein % (CPD) from clover % in the diet (CLD) for each treatment.

		Regression equation[1]	
Stocking rate	Nitrogen level	Constant	Coefficient
(cows/ha)	(kg/ha N)		
2.5	0	14.99 (±0.98)	0.209 (±0.031)
3.75	0	15.10 (±0.99)	0.212 (±0.029)
3.75	150	16.20 (±0.96)	0.197 (±0.035)
5.0	150	17.21 (±0.96)	0.198 (±0.035)
5.0	300	17.85 (±0.94)	0.176 (±0.034)
5.0	600	20.61 (±0.86)	0.224 (±0.058)
5.0	400 (annual)	24.36 (±0.81)	−0.095 (±0.067)

[1] General form: CPD = a + b CLD ($r^2 = 0.43$; $P<0.01$).

Pasture — diet relationships

Clover percent in the diet (CLD) was related to both clover % in the pasture (CLP) and clover yield on offer (kg/ha DM) in the pasture (CLY). Treatments made no difference to the regression equations developed, though there were significant effects due to season. For the equations in Table 4, data across all treatments within seasons were pooled. There was no linear relationship between CLD and CLP in February.

The association between KLD and green kikuyu in the pasture was significant ($P<0.05$) but regression coefficients were low. All treatments had the same regression coefficient but 5/600N had a higher intercept in each season. The general forms of the regression equations relating KLD to all green kikuyu % in the pasture (KP) and all kikuyu on offer in the pasture (KY, kg/ha DM) are set out below:

KLD = a + 0.6 (±0.104)KP
(r^2 = 0.31; P<0.05)

KLD = a + 0.0044 (±0.0015) KY
(r^2 = 0.27; P<0.05).

Examples of constants (a) for KP in February and May were 25.78 (±6.88) and 36.89 (±7.24) for Treatments 1–5 and 5/600 N, respectively, and in November were 13.22 (±6.26) and 24.33 (±6.56). Examples of constants for KY in February and May were 48.03 (±5.51) and 64.72 (±5.46) and in November were 33.65 (±4.92) and 50.34 (±4.07) for Treatments 1–5 and 5/600N, respectively.

Table 4. Regression equations relating clover % in the diet (CLD) to clover % (CLP) and clover yield (CLY; kg/ha DM) on offer in the pasture.

Clover % in pasture	
May and November:	CLD = 0.91 (±3.76) + 1.725 (±0.586) CLP
August:	CLD = 7.92 (±2.79) + 1.725 (±0.586) CLP (r^2 = 0.44; P<0.05)
Clover on offer in pasture (kg/ha DM)	
February and May:	CLD = 5.69 (±1.53) + 0.0283 (±0.008) CLY
August:	CLD = 5.69 (±1.53) + 0.0579 (±0.010) CLY
November:	CLD = 5.69 (±1.53) + 0.0433 (±0.010) CLY (r^2 = 0.42; P<0.05)

Discussion

Total pasture on offer for most treatments was high and in the range of 3–5 t/ha DM for all samplings except August. Based on other work, soil pH, phosphorus and mineral concentrations were not considered limiting to pasture production (Bruce and Rayment 1982). The absolute yields of clover on offer and clover % in the kikuyu-clover pastures were not high. At 2.5/0N and 3.75/0N, yields of clover on offer were less than 500 kg/ha DM from February–August and were above 600 kg/ha DM only in November. In May, there was less than 10% of clover DM in any treatment, while in November it ranged from 11%–23% for 2.5/0N and 3.75/0N, respectively. Despite these low figures, clover on offer and clover % in the pasture were major determinants of diet quality and milk yield (Davison *et al.* 1997).

Clover selection

Both clover yield on offer and clover % in the pasture had similar impacts on clover % in the diet indicating both need to be considered when managing pastures for dairy cows. Hodgson (1990) used the term selection index (defined as % clover in the herbage eaten ÷ % clover in the sward) to help explain selection for clover in mixed swards. Using this definition, the selection index was approximately 1.7 in May, August and November. Hodgson (1990) also made the point that, while selection can be measured, 'preference' for a particular species is much harder to measure. The high selection pressure observed in autumn, winter and spring, when clover % in the pasture, total pasture on offer and structure of the pasture differed markedly, suggests there may have been both selection and preference for clover.

Clover decline

The selection of a higher proportion of clover in the diet than that on offer would have been one cause of the decline in clover yield from Year 1 to Year 3 of the experiment. The decline in clover in the diet was more apparent at 5 cows/ha and in treatments that received nitrogen fertiliser, suggesting that competition from kikuyu and selective grazing were contributing factors. The greatest decline occurred in late summer and autumn, where Year 3 levels decreased to 30–50% of the levels in Year 1. Jones (1982) showed that survival of clover stolons over summer and seedling regeneration in winter were inversely related to companion grass yields. In summer, green kikuyu and dead pasture material, most of which was kikuyu, on offer ranged from 3.3–4.2 t/ha DM. It is likely that removal of some of this material through higher grazing pressure or cutting over summer may have stimulated clover growth in summer and autumn. In a flexible stocking rate experiment, Sproule *et al.* (1983) showed that Safari clover responded to increased summer grazing with increased yields, stolon length and growing points due to reduced competition from the companion grasses.

Jones (1982) suggested total pasture on offer above 3 t/ha DM would depress both stolon survival over summer and seedling regeneration in winter. On irrigated kikuyu-clover pastures, this figure could be revised upwards to approximately

4 t/ha DM. Total pasture on offer in this experiment was above 3 t/ha DM in November and February for all treatments except 5/150N. At 5/150N, the production system was unstable due to the ingress of both grass and broadleaf weeds, lower milk production per cow and liveweight loss (Davison *et al.* 1997). It was noticeable at 2.5/0N, where total pasture on offer was above 4 t/ha DM all year round, that regrowth of clover in winter and spring was slower than at 3.75/0N. Pasture on offer did not exceed 4 t/ha DM in November or February at 3.75/0N and pastures had similar yields of clover on offer to 2.5/0N in all seasons except November, when 2.5/0N was higher (Figure 2). This work indicated a stocking rate of 3.75 cows/ha without nitrogen fertiliser provided an excellent pasture sward and the capacity for clover to regenerate each winter, representing the best compromise between stocking rate, clover on offer and maintenance of a reasonable clover % in the diet.

Haifa and Safari

Haifa was the dominant clover throughout the experiment. Lowe and Bowdler (1984) demonstrated annual yields of Haifa of 4.7–6.5 t/ha DM in irrigated pasture mixtures at Gatton in south-east Queensland. In the same experiment, Safari clover gave annual yields of 0.6–2 t/ha DM and Whittet kikuyu 3.3–6.3 t/ha DM. There was no evidence of a decline in clover or kikuyu yields in their study over 3 years, although plots were mown and not grazed. Safari clover performed well in a cutting trial on the Atherton Tableland (Shaw and Quinlan 1978), but on-farm observations of Safari (L. Cook, personal communication) confirmed the low productivity that was recorded in our experiment.

Response to nitrogen fertiliser

The effect of nitrogen fertiliser on pasture composition varied with stocking rate. At 5/600N, there were substantially depressed clover yields in favour of kikuyu. At 5/150N and 5/300N, although there were only small differences in clover on offer between treatments, there was a large increase in kikuyu production and total pasture on offer in all seasons at 300N. These results indicate that, at 5 cows/ha, clover is tolerant of annual nitrogen fertiliser applications up to 300 kg/ha N. At 3.75 cows/ha, the use of 150 kg/ha N depressed clover yields in August and November and boosted kikuyu yields in August, but not in the other 3 seasons. When nitrogen fertiliser was applied in winter by Chopping *et al.* (1982b) at Ayr, they demonstrated a similar reduction in yield of white clover (*T. repens*) cv. Ladino, but an increase in subterranean clover (*T. subterraneum*) cv. Clare. This suggests clover types respond differently to nitrogen fertiliser applied in winter. A long-term beef experiment by Mears and Humphreys (1974) on N-fertilised kikuyu pastures in northern New South Wales showed that, with 0 or 134 kg/ha N, there was invasion by naturalised white clover. At these fertiliser levels, increasing the stocking rate from 3.3 to 7.4 steers/ha favoured the development of white clover, which comprised up to 25% of these pastures. However, when 336 or 672 kg/ha N was applied, little clover was present at any stocking rate.

Diet quality

The higher clover levels in the diet from winter to late spring meant that cows on kikuyu-clover pastures consumed a high quality diet at the time of year when annual ryegrass pastures are used on dairy farms (Lowe and Hamilton 1985; Chopping and Cuda 1991). During summer and autumn, the quality of the diet was maintained as kikuyu leaf replaced the loss of clover in the diet. The proportion of leaf in the diet was between 55–75% in summer and autumn and between 35–65% in winter and spring. Kikuyu leaf and clover together made up the bulk of the diet throughout the year. The actual proportions in the diet were dependent on the yield and % of clover and kikuyu leaf on offer.

Dietary crude protein level was unlikely to have been a limiting factor as it was above that required to support the milk yields recorded in this experiment (NRC 1989). The concentration of Ca in the diet was below the recommended level [0.5% for cows producing 20 kg/d (NRC 1989)] for cows grazing kikuyu-clover pastures in February and May and the annual pastures in August. Magnesium % in the diet on perennial pastures was also below that recommended (0.2%) in February and May, as it was in the diet of animals grazing annual pasture in August. Sulphur was below the recommended level of

0.2% (NRC 1989) in February for perennial pastures. It is unlikely cows in this experiment were deficient in these elements due to the feeding of molasses and dicalcium phosphate, which together would have provided an additional 52 g/d of Ca, 21 g/d of Mg and 18 g/d of S. Based on NRC (1989) recommendations, Ca, Mg and S supplementation would be necessary in late summer and autumn for cows grazing kikuyu-clover pastures, whereas cows on ryegrass-dominant pastures would need additional Ca and Mg in winter and spring.

Conclusions

We conclude that clover on offer is maximised at either 2.5 or 3.75 cows/ha. At 3.75 cows/ha, nitrogen fertiliser should not be used on these pastures in autumn or winter if clover on offer is to be maximised. At 5 cows/ha, nitrogen fertiliser can be used up to 300 kg/ha N without depressing clover production. A stocking rate of 3.75 cows/ha without nitrogen fertiliser gave consistently high pasture yields with the exception of winter and provided the best compromise between stocking rate, clover on offer and a high quality diet.

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