An evaluation of kikuyu-clover pastures as a dairy production system.
3. Dynamics of pasture composition and diet selection

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Abstract

A dairy system based on irrigated, perennial kikuyu (*Pennisetum clandestinum*) cv. Whittet — white clover (*Trifolium repens*) cv. Haifa pasture was compared at various stocking rates and nitrogen (N) fertiliser rates in a 3-year experiment. In the final year, observations were taken on 4 treatments comprising: 2.5 cows/ha, 0 kg/ha N; 3.75 cows/ha, 150 kg/ha N; 5 cows/ha, 150 kg/ha N; and 5 cows/ha, 600 kg/ha N. Daily milk yield, and pasture on offer, pasture composition and diet selection on Days 0, 2, 5 and 7 of a 7 day grazing, 21 day spelling rotation were measured.

Milk yields ranged from 10.6–15.5 kg/d in May ($P<0.01$) and from 16.9–21.7 kg/d in October ($P<0.05$). Peak milk yield occurred on Day 3 of the grazing cycle in May and Day 4 in October, with increases of 1.85 and 0.75 kg/d, respectively, relative to milk yield at the start of the cycle.

Clover % in the diet (DCLOV%) on the first day of the grazing cycle was the factor most closely related to milk yield (MY; kg/d). The across-seasons equation, where MONTH = 0 for May and 1 for October, was:

$$\text{MY (kg/d)} = 11.77 + 3.94\ \text{MONTH} + 0.069\ \text{DCLOV}\ \%$$
$$(R^2 = 0.84;\ P<0.001).$$

Clover % in the diet (DCLOV%) was most related to pasture clover yield on offer (PCLOVY) with declining coefficients of selection for each day of the rotation. Dietary crude protein % declined linearly with day of the rotation at approximately 1.4% per day, and calcium and magnesium selected from pasture were also observed to decrease with day of the grazing cycle.

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Introduction

Previous papers in this series (Davison *et al.* 1997a; 1997b) described an irrigated kikuyu (*Pennisetum clandestinum*) cv. Whittet — clover (*Trifolium repens*) cv. Haifa pasture system suitable for dairy production in subtropical areas. The 3-year study demonstrated the importance of clover and kikuyu leaf in the diet on milk production. It also showed that clover on offer decreased with increased stocking rate and with increased nitrogen fertiliser. As one objective of grazing management is to maximise the intake of high quality components such as legume and leaf (Chacon *et al.* 1978), this study aimed: firstly, to gain a better understanding of the botanical selection undertaken by cows; and secondly, to document the pattern of selection as the pasture on offer changed over a 7-day grazing period and to relate this to milk yield.

Four treatments were chosen from the long-term study that encompassed extremes of stocking rate and nitrogen fertiliser levels. Pasture composition and the diet selected on these treatments were monitored in both late autumn and spring of the third year of the experiment.

Materials and methods

Location

The experiment was conducted in May and October-November 1986 at Kairi Research Station, north Queensland (17°14′S, 145°34′E;

altitude 700 m). Average annual rainfall is 1285 mm. Maximum and minimum temperatures range from 28.9°C and 18.3°C in December to 20.9°C and 10.9°C in July. Annual rainfall in 1986 was 1053 mm. Rainfall in May and October was 25 mm and 24 mm, compared with long-term averages of 61 mm and 34 mm, respectively. Mean monthly maximum and minimum temperatures in 1986 were 23.4°C and 14.9°C for May and 28.3°C and 16.8°C for October.

Pastures and treatments

An experiment described by Davison *et al.* (1997a; 1997b) was established to measure pasture and milk production by Holstein-Friesian cows grazing irrigated, perennial pastures consisting of kikuyu, Haifa clover and Safari clover (*T. semipilosum*) cv. Safari. The 4 treatments chosen for detailed observations were: 2.5 cows/ha with 0 kg/ha N (2.5/0N); 3.75 cows/ha with 0 kg/ha N (3.75/0N); 5 cows/ha with 150 kg/ha N (5/150N); and 5 cows/ha with 600 kg/ha N (5/600N).

The treatments were allocated at random to each of 4 blocks of pasture. Throughout the experiment, these blocks of pasture were grazed on a 7 day grazing, 21 day spelling rotation. At the 150 kg/ha N level of nitrogen fertiliser, 50 kg/ha N as urea (46% N) was applied in March and 100 kg/ha N in May, while at 600 kg/ha N, fertiliser was applied equally in 6 dressings at 8-week intervals. Irrigation was applied to pastures at approximately 9 Ml/ha annually.

Four multiparous cows and 2 heifers that had calved between mid-March and mid-May were blocked on milk production and parity and randomly allocated to each treatment. Cows were offered 3.5 kg/d of molasses mixed with 60 g/d of dicalcium phosphate and 30 g/d of sodium chloride. The supplement was fed in the paddock 3 times a week on a group basis.

Measurements

Observations on the pasture and diet were made from May 7–21 (autumn–early lactation) and October 22–November 5 (spring–mid-lactation). During each week of grazing, the pasture on offer was measured just prior to grazing on Days 0, 2, 5 and 7. Eight × 0.4 m^2 quadrats were cut with hand shears to ground level, bulked and weighed. Two subsamples were taken for dry matter (DM) determination (400 g) and a third (300 g) was separated into green kikuyu leaf and stem, green Haifa, green Safari, dead material and weed. Weeds were defined as species not planted and included couch (*Cynodon dactylon*) and *Brachiaria decumbens*, which were readily eaten by cows. Material was dried for 24 h at 80°C and weighed. Material from Day 0 was bulked across blocks for each treatment, and kikuyu leaf and stem and clovers were ground through a 1 mm screen before being analysed for crude protein (N% × 6.25), P, Ca, Mg and K (AOAC 1980).

The diet selected from pastures was sampled using 8 oesophageally fistulated cows on Days 0, 2, 5 and 7 of each sampling week in both seasons. The 8 animals were lactating and of similar liveweight to the experimental animals. They were maintained on an adjacent perennial kikuyu-clover pasture for 7 days prior to each sampling period. On the night before sampling, these animals were confined to yards with water only. Diet samples were collected from 0730–0930h with 2 cows grazed in each paddock for approximately 30 minutes. The order in which paddocks were sampled and the animals used to sample each paddock were changed at each sampling. A foam rubber sponge was inserted into the lower oesophagus to ensure complete collection of the sample. Samples of 1–3 kg were collected in canvas bags with gauze bottoms to allow excess saliva to drain away. Samples from both animals were bulked and squeezed through muslin cloth and a subsample taken. One-half of this material was frozen and later sorted into kikuyu leaf, kikuyu stem, clover, dead material and weed using the technique of Chacon *et al.* (1977). The remainder of the sample was dried at 70°C for 24 h, ground through a 1 mm screen and analysed for CP, Ca and Mg.

Milk yields of individual cows were measured at each milking for the 2 weeks in each season.

Statistical analyses

For milk yields, the seasons were analysed separately using analysis of variance. The two grazing cycles were treated as paddock replicates with animal and day of cycle effects nested within paddocks. With diet and pasture data, a similar approach was used, except that no animal terms were involved. Where appropriate, the day-of-cycle term was separated into linear and quadratic terms using orthogonal polynomials. Pooling results over seasons was examined, but the differing levels of variability and the differing patterns in treatment response made it advisable not to proceed with this approach in most instances.

The relationships between diet and pasture composition were examined using general linear models allowing for the effects of treatment, month and day of cycle on both model intercepts and slopes (Genstat 5 1989).

Results

Milk yield

Treatment milk yields were significantly different (P<0.01) in May, with mean yields of 15.5, 12.7, 11.6 and 10.6 kg/d (s.e. ±0.07) for 2.5/0N, 3.75/0N, 5.0/150N and 5.0/600N, respectively. The corresponding values in October were 21.7, 18.8, 18.1 and 16.9 kg/d (P<0.05; s.e. ±0.5).

The effect of day of the grazing cycle was significant (P<0.05) in both May and October with the effect being independent of treatment. The largest change in milk yield occurred from Day 1 to Day 2 of the cycle, with an increase of 1.85 (±0.30) kg/cow in May, and an increase of 0.75 (±0.34) kg/cow in October (Figure 1). In May, peak milk yield was on Day 4 with no difference (P>0.05) between Days 3–5. In October, peak milk yield was on Day 5 with no difference (P>0.05) between Days 2–5 (Figure 1).

Botanical composition

Pasture on offer. Mean total pasture on offer across all treatments was generally higher in October than in May (Table 1). All treatments carried more dead material and less weed in October than in May, while kikuyu stem and dead material were the major components in each treatment and season. In October, clover on offer was similar to leaf on offer in all treatments except 5/600N (Figure 2). Clover on offer at 5/600N was the lowest of all treatments in both May and October (P<0.01).

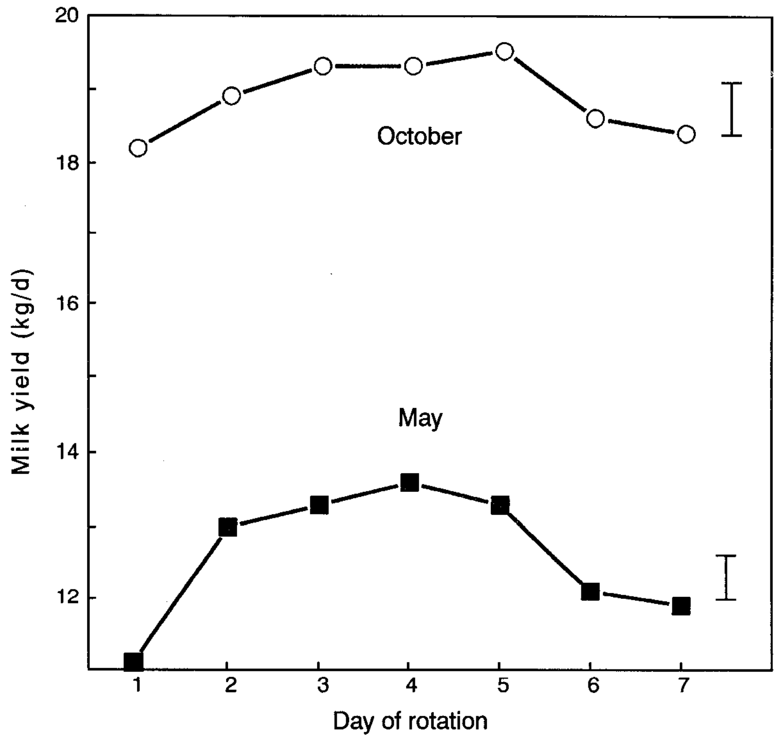

Figure 1. Milk yield averaged across treatments for each day of the grazing cycle in autumn (May) and spring (October). LSD bars (P = 0.05) represent between-day effects.

Table 1. Mean yields on offer of pasture components in May and October for perennial kikuyu-clover pastures.

		Treatments					
Stocking rate (cows/ha)		2.5	3.75	5.0	5.0	s.e.	LSD
N fertiliser (kg/ha N)		0	0	150	600	mean	(P=0.05)
				(kg/ha DM)			
Total	May	5941	4164	3342	4637	313	1407
	Oct	6872	5034	3342	5523	174	782
Kikuyu leaf	May	1062	789	657	933	73	326
	Oct	810	799	495	1184	6	26
Kikuyu stem	May	2600	1653	1341	2139	149	670
	Oct	1739	1478	1089	2163	68	308
Clover	May	265	278	179	76	12	54
	Oct	1013	851	536	194	12	54
Dead	May	1941	1384	871	1302	75	337
	Oct	3256	1854	1066	1842	129	579
Weeds	May	73	59	293	187	66	ns
	Oct	54	51	156	140	13	56

Across treatments, kikuyu leaf on offer (and % on offer) declined significantly (P<0.01) from Day 0 to Day 7 of grazing from 1315 (29%) to 533 (12%) kg/ha DM in May and from 1185 (21%) to 501 (10%) kg/ha DM in October. Yield of kikuyu stem did not change significantly during the grazing week. Dead material on offer showed an apparent increase (P<0.01) over the grazing week in May (1039 to 1618 kg/ha DM; s.e. ±97), but there was no change in October except at 5/600 N (P<0.05).

Diet. Average diet composition in May and October was 5 and 24% clover, 58 and 44% kikuyu leaf, 24 and 19% kikuyu stem and 13 and 13% dead material, respectively. Overall means for kikuyu leaf % were 74, 74, 51 and 32% for Days 0, 2, 5 and 7 (P<0.01; ±3.7), and for clover % were 12, 3, 4 and 2% (P<0.01; ±1.2), with no differences (P>0.05) between treatments (Table 2). Corresponding values for kikuyu stem were 10, 15, 29 and 40% (P<0.01; ±3.1), and for dead material 4, 7, 15 and 26% (P<0.01; ±2.8). There were no significant differences between treatments for either stem or dead material (Table 2). However, dead material increased from 4% to 10% over the 7 days for 2.5/0N and from 4% to 32% for the other 3 treatments (P>0.05). Similarly, kikuyu stem % increased from 7% to 28% at 2.5/0N and from 16% to 44% for the other 3 treatments (P>0.05).

The general pattern of selection

In October, cows selected for clover initially, then kikuyu leaf, leading to an increase in kikuyu stem and dead material later in the grazing week (Figure 3). In contrast to May, kikuyu leaf % was the highest component in the diet on Day 7 in all 4 treatments (Figure 3). There was a large difference between treatments in the decline of clover % in the diet over Days 0 to 7: for 2.5/0N (66% to 14%); for 3.75/0N (61% to 12%); for 5/150N (46% to 6%); and for 5/600N (13% to 4%). For kikuyu leaf %, there were both significant treatment differences (P<0.01; Table 2) and significant differences (P<0.01) in the change of leaf % in the diet across the week. Leaf percentages for Days 0 and 7 were 22% and 43% for 2.5/0N, 32% and 33% for 3.75/0N, 42% and 35% for 5/150N and 81% and 52% for 5/600N [±4.8; LSD (P=0.05) 14.7]. Kikuyu stem and dead material increased (P<0.01) from Day 0 to Day 7 with across-treatment means of 6, 18, 22 and 30% for stem % and 4, 9, 19 and 20% for dead material %. There were no treatment differences (P>0.05) for stem or dead matter (Table 2).

Chemical composition of the diet

Dietary crude protein % (DCP) was higher in October than in May (means 18.9% and 16.4%), but most of this was due to differences within 2.5/0N and 3.75/0N (Table 3). The rate of decrease in DCP from Day 0 to Day 7 was similar for all treatments in both seasons and could be represented by the following equations:

$$\text{May DCP\%} = 21.43\ (\pm 0.44) - 1.442\ (\pm 0.099)\ D \quad (P<0.01)$$

$$\text{Oct DCP\%} = 23.49\ (\pm 0.44) - 1.309\ (\pm 0.099)\ D \quad (P<0.01)$$

where D = day of grazing cycle.

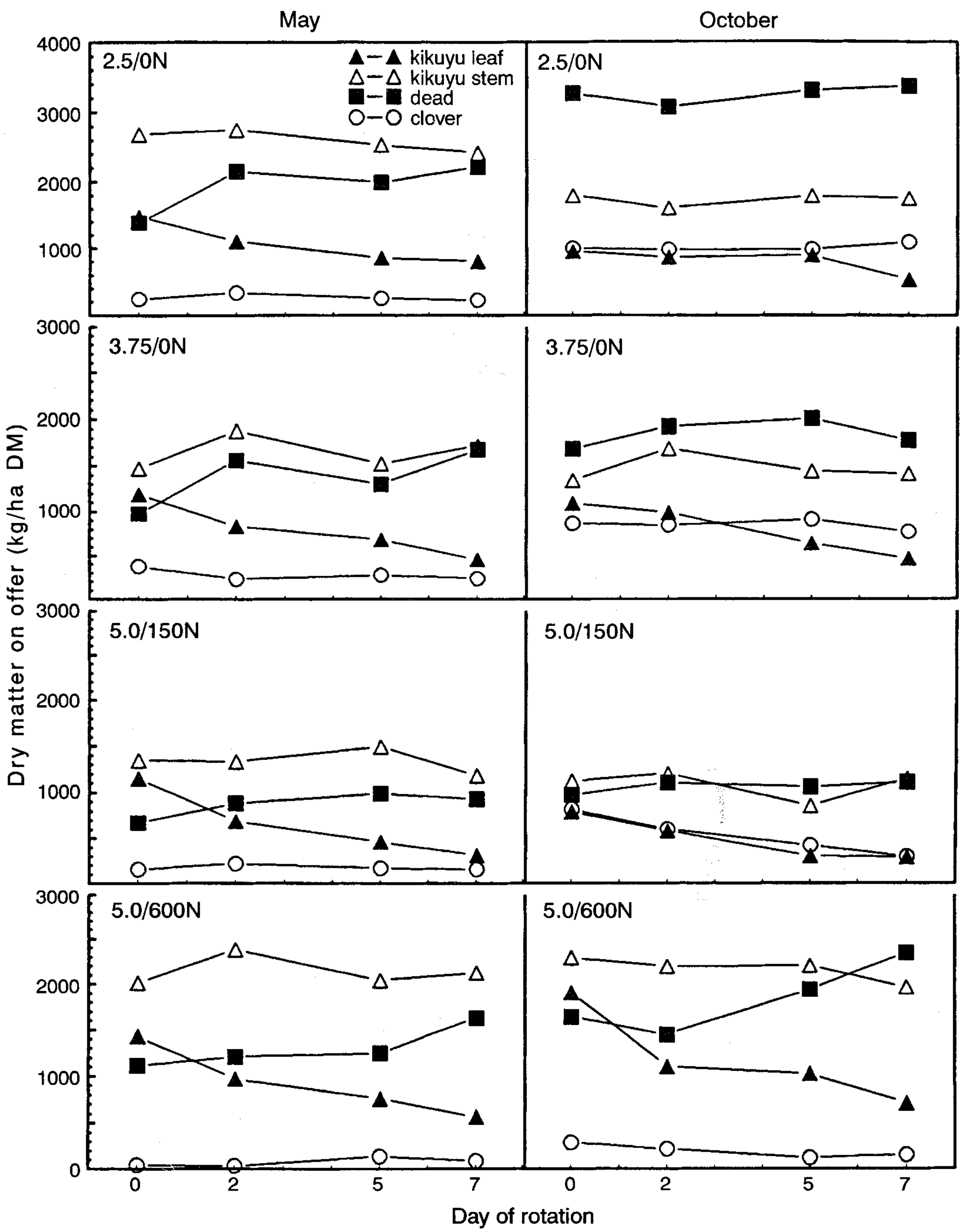

Figure 2. Changes in the botanical composition of kikuyu–clover pastures on offer to cows in autumn (May) and spring (October).

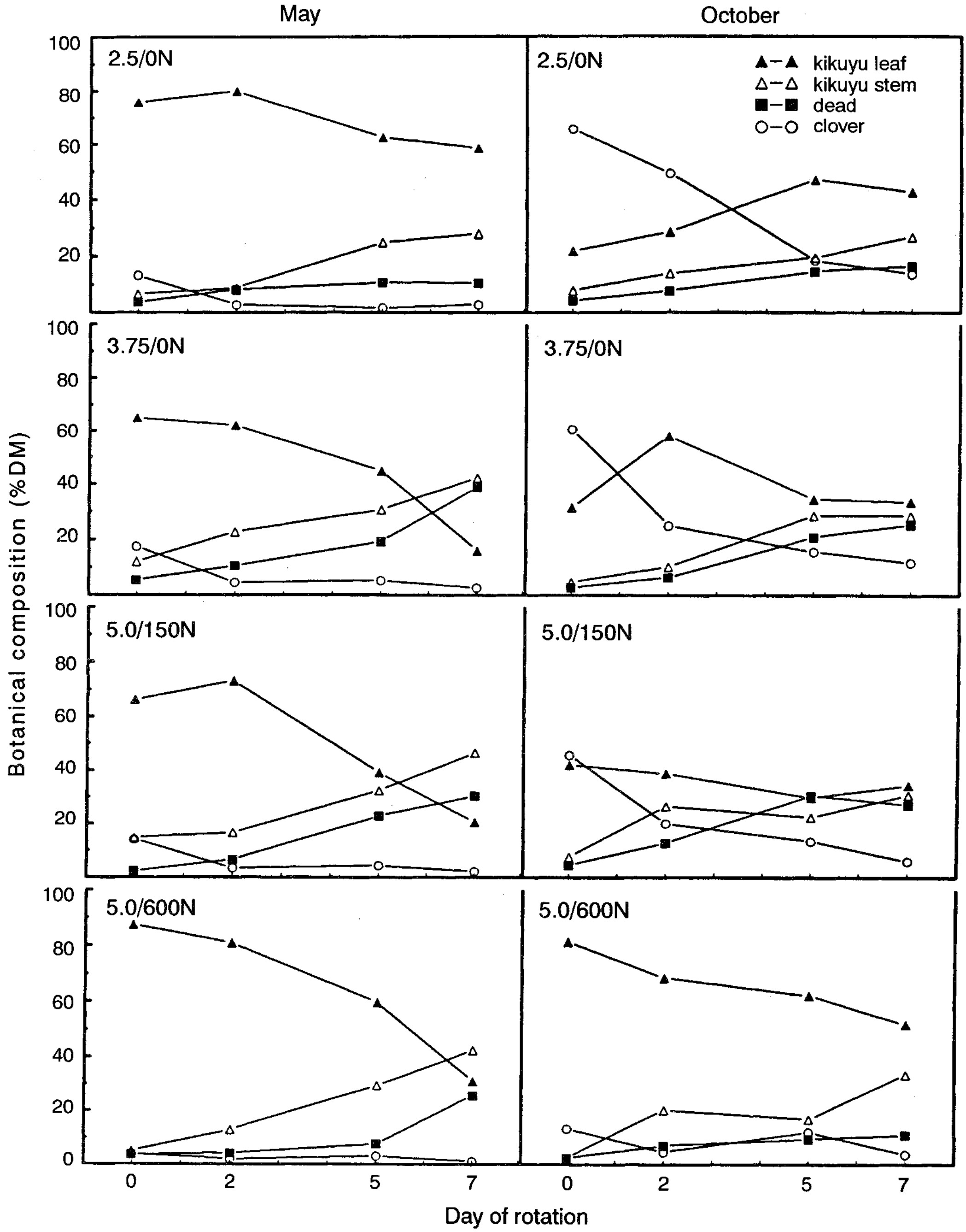

Figure 3. Changes in the botanical composition of the diet of cows grazing kikuyu–clover pastures in autumn (May) and spring (October).

Table 2. Botanical composition of the diet meaned across days in May and October for perennial kikuyu-clover pastures.

		Treatments					
Stocking rate (cows/ha)		2.5	3.75	5.0	5.0	s.e.	LSD
N fertiliser (kg/ha N)		0	0	150	600	mean	(P=0.05)
				(% DM)			
Clover	May	5.2	7.6	6.1	2.6	1.2	ns
	Oct	36.9	28.3	21.3	8.4	3.5	15.9
Kikuyu leaf	May	69.2	46.9	49.8	64.8	3.6	16.1
	Oct	35.1	39.5	36.4	65.9	1.4	6.5
Kikuyu stem	May	17.1	26.9	27.6	22.4	2.4	ns
	Oct	17.1	18.2	21.9	18.2	2.7	ns
Dead	May	8.4	18.6	15.6	10.3	3.0	ns
	Oct	10.9	14.0	18.9	7.4	1.8	ns

Table 3. Chemical composition (% DM) of the diet in May and October for perennial kikuyu-clover pastures meaned across 7 grazing days.

		Treatments					
Stocking rate (cows/ha)		2.5	3.75	5.0	5.0	s.e.	LSD
N fertiliser (kg/ha N)		0	0	150	600	mean	(P=0.05)
				(% DM)			
Crude protein	May	14.7	15.1	16.6	19.2	0.58	2.63
	Oct	19.0	19.1	17.1	20.5	0.60	ns
Calcium	May	0.36	0.35	0.40	0.32	0.02	ns
	Oct	0.71	0.63	0.59	0.43	0.02	0.08
Magnesium	May	0.18	0.17	0.17	0.14	0.01	ns
	Oct	0.21	0.22	0.21	0.20	0.02	ns

Dietary calcium % selected from pasture was higher (P<0.01) in October than in May with means of 0.59% and 0.36%, respectively. There was a significant decrease (P<0.01) in dietary Ca across the grazing week from 0.45% to 0.31% in May and from 0.81% to 0.42% in October. In October, dietary Ca was lowest for cows on 5/600N (P<0.01) and highest at 2.5/0N (Table 3). Dietary magnesium % (DMg) selected from pasture was also higher in October than in May (means 0.21% and 0.17%). There was no difference between treatments within seasons but there was a decrease with day of grazing in both seasons, and this was represented by the following equations:

$$\text{May DMg \%} = 0.184\ (\pm 0.006) - 0.0051\ (\pm\ 0.0014)\ D\ (P<0.01)$$

$$\text{Oct DMg \%} = 0.242\ (\pm 0.014) - 0.0095\ (\pm\ 0.0032)\ D\ (P = 0.012)$$

where D = day of grazing cycle.

Pasture and diet relationships

The rate of selection of kikuyu leaf in relation to leaf on offer differed significantly (P<0.01) between May and October. In May, kikuyu leaf % in the diet increased by 0.058 ±0.008% (P<0.01) for each additional kg of kikuyu leaf on offer, whereas in October, this increase was 0.042 ±0.009% per kg (P<0.01) (Figure 4). Day of the grazing cycle and treatment influenced the base level of kikuyu leaf in the diet, but not the rate of selection with increasing yield of leaf on offer (R^2 = 0.74). In both May and October, dietary kikuyu leaf increased by 1.86% (P<0.01; ±0.45) for each additional percentage unit of kikuyu leaf in the pasture (R^2 = 0.83).

Clover per cent in the diet (DCLOV %) was related to clover yield on offer in the pasture (PCLOVY), but with significantly different (P<0.05) intercepts for each month and different (P<0.01) coefficients for each day (R^2 = 0.86; P<0.01). Equations were:

$$\text{May DCLOV \%} = -0.30\ (\pm 1.36) + \beta\ (\pm 0.004)\ \text{PCLOVY}$$

$$\text{Oct DCLOV \%} = 4.63\ (\pm 2.36) + \beta\ (\pm 0.004)\ \text{PCLOVY}$$

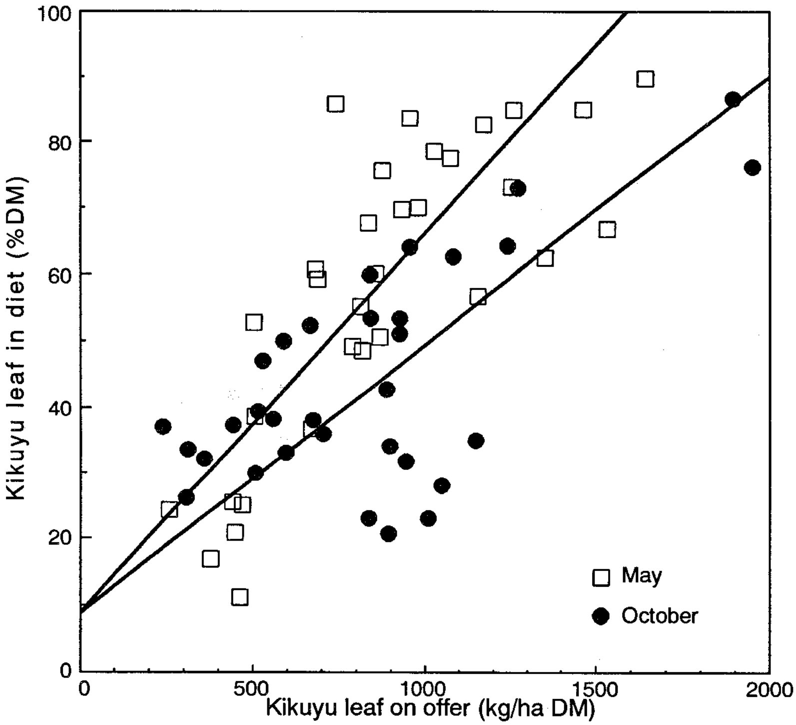

Figure 4. Relationship between kikuyu leaf % in the diet and pasture kikuyu leaf on offer averaged across days of the cycle for autumn (May) and spring (October).

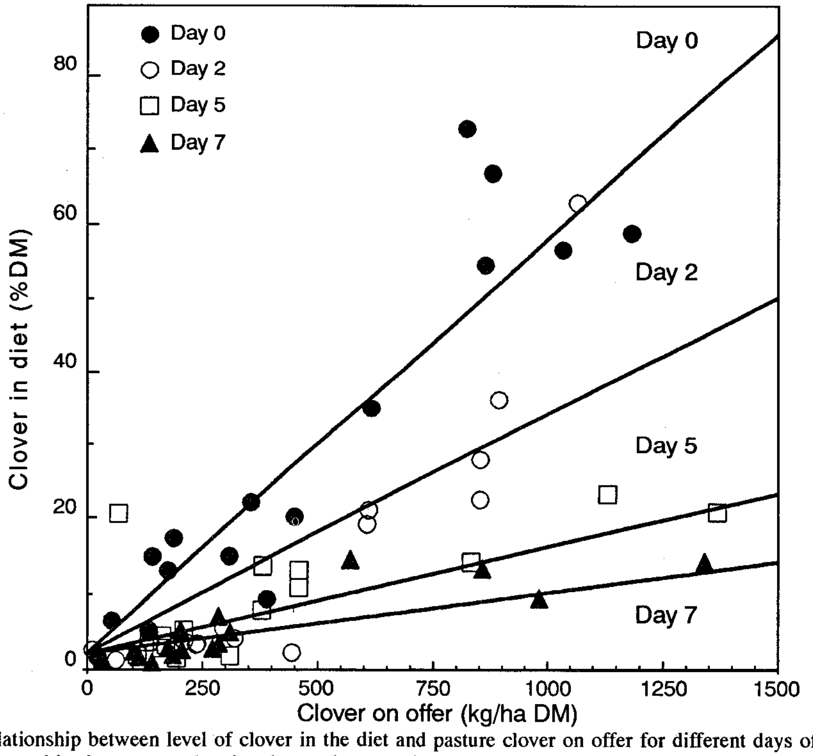

Figure 5. Relationship between level of clover in the diet and pasture clover on offer for different days of the grazing rotation using combined autumn and spring data and a mean intercept.

Coefficients (β) were 0.056, 0.032, 0.014 and 0.008 for Days 0, 2, 5 and 7, respectively, in both May and October. Graphic representation of this relationship for each day used an average intercept of 2.165 for clarity due to the small absolute differences (Figure 5).

A similar relationship was observed between clover percent in the diet and clover percent in the pasture (R^2 = 0.81). DCLOV% increased by 2.37 (±0.32)% and 1.08 (±0.36)% for each 1% increase in pasture clover on offer for Days 0 and 2, respectively. These coefficients were the same for both May and October and common across treatments. For Days 5 and 7, the coefficients were positive but not significantly different from zero (P>0.05).

Factors affecting milk yield

When all diet and pasture parameters were combined across seasons, the factor most strongly correlated with average daily milk yield (MY; kg/d) was the clover % in the diet (DCLOV%) on the first day of the grazing cycle. The best model to demonstrate this relationship used a common slope and different intercepts for each month:

$$MY = 11.77\ (\pm 0.65) + 3.94\ (\pm 1.18)\ MONTH + 0.069\ (\pm 0.025)\ DCLOV\ \%$$
$$(R^2 = 0.84;\ P<0.001)$$

where MONTH = 0 for May and 1 for October.

Average daily milk yield in October was strongly correlated with both % dead material in the pasture (r = 0.93) and yield of dead material on offer (r = 0.85) on Day 1, whereas clover on offer was less strongly correlated (r = 0.69).

The relationships between diet, pasture and milk yield differed between May and October. In May, pasture green dry matter (GDM) on offer at the start of the 7-day grazing cycle was the factor most closely related (r = 0.63) to milk yield.

Discussion

Milk yield

This study has shown that the factor most related to average daily milk yield across both seasons was clover % in the diet on the first day of the grazing cycle. This was also the factor found to be best related to whole lactation milk yield in the 3-year study (Davison *et al.* 1997b). Clover was the highest quality dietary component on offer in terms of digestibility, protein and mineral composition and would also have allowed a higher overall intake and therefore milk yield (Stobbs 1976; Minson 1990).

This study has also shown that, where lactating cows are rotationally grazed on kikuyu-clover pastures, the order of selection in spring will be for clover, kikuyu leaf and kikuyu stem, with dead material the least preferred. In late autumn, when clover comprised less than 20% of the diet, kikuyu leaf comprised 65–90% of the diet at the start of the rotation. Only once easily accessible leaf was eaten did the proportion of kikuyu stem and dead material increase in the diet. In contrast to the marked selection for clover early in the grazing period in this study, Cowan *et al.* (1986), with a *Panicum maximum* cv. Gatton and *Neonotonia wightii* cv. Tinaroo sward in the same environment, observed little variation in the legume component of the diet over a 7-day grazing period. A similar pattern of selection of leaf, stem and dead material was observed for *Panicum maximum* cv. Gatton swards that received 200–400 kg/ha N (Cowan *et al.* 1986) as for the 5/600 N treatment in our study which was predominantly kikuyu.

Clover selection

There was a linear relationship between clover on offer and clover % in the diet, but rate of selection of clover decreased from the start to the end of the grazing cycle (Figure 5), despite clover on offer remaining approximately constant (Figure 1). This suggested there was another dimension to selection other than clover on offer. Possibly, once the tops of clover plants were eaten early in the week, clover was less accessible amongst the predominantly kikuyu sward. The importance of sward structure has long been recognised as a factor affecting selection and intake (Stobbs 1973; Hodgson 1990).

In May, pastures contained less clover on both a yield and % basis, so clover had less influence on diet quality and milk yield than in October. The lower overall milk yields in May could be explained by stage of lactation and the diet selected from pasture as cows had calved for an average of only 4 weeks. Intakes would have been low, but increasing rapidly over this period (Webster 1987), so it is understandable that milk yield was highly related to green pasture on offer (Chacon *et al.* 1978; Meijs 1981; Hodgson 1990).

In May, clover and kikuyu leaf on offer averaged 73% of that on offer in October and diet quality in terms of crude protein, calcium and magnesium selected from pasture was also lower than in spring.

In October, cows were in mid-lactation, but milk yields were higher than in May. The proportion of clover in the diet was the major factor related to treatment milk yields in October. This was most likely mediated through its effect on dietary crude protein and digestibility and a higher pasture intake (Minson 1990).

Chemical composition of the diet

The decline in dietary crude protein, calcium and magnesium from Day 0 to Day 7 demonstrates the difficulty with grazing in set rotation patterns. Most farms in northern Australia require a reasonably even milk output each month to maintain milk quotas (Lowe and Hamilton 1985). Dietary crude protein % decreased by approximately 1.4% per day so that, in May, cows would have fallen below 16% dietary crude protein on Day 5 (NRC 1989). Calcium selected from pasture was below recommended levels of 0.51% (NRC 1989) in May, even on Day 0. This dietary deficiency was compensated for by the supplements of dicalcium phosphate and molasses which supplied 55 g/d Ca out of a total requirement of 87 g/d Ca (NRC 1989). Magnesium selected from pasture was also low in May at 0.17%, compared with 0.20% recommended by NRC (1989). The magnesium present in molasses (0.4% DM) would have compensated for this deficiency.

To reduce fluctuation in diet quality and pasture on offer and to obtain a more even milk flow than was recorded in this study, a shorter grazing rotation would have been of benefit. Agronomic and pasture management practices need to be directed to increasing the amount of clover on offer as they will yield the biggest dividends in milk yield in these pasture mixtures.

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