Birdsfoot trefoil – an alternative legume for New Zealand dairy pastures

S.L. HARRIS, D.A. CLARK and P.J. LABOYRIE
Dairying Research Corporation, Private Bag 3123, Hamilton

Abstract

Two grazing trials conducted with Friesian cows in mid lactation showed milk yields were higher on birdsfoot trefoil (*Lotus corniculatus*)-dominant pasture (19.8 and 16.7 l/cow/day) than on white clover-dominant (17.8 and 15.4 l/cow/day) or ryegrass-dominant (13.0 and 11.7 l/cow/day) pastures. Increased milk production on the *Lotus* and clover was attributed to the higher nutritive value of the legume-based pasture compared with the ryegrass, and to higher dry matter intakes. Cows grazing *Lotus* also had improved feed conversion efficiency compared with those grazing either ryegrass or clover, indicating that the presence of condensed tannins in the *Lotus* may have contributed to the improved efficiency. Milk protein concentration was consistently higher on the *Lotus* (3.36 and 3.35%) than on the ryegrass (3.15 and 3.21%) or clover (3.30 and 3.21%) in both experiments, while milk fat levels were lower in Experiment 1. While *Lotus* increased milk yield and milk protein concentration, its potential as a forage legume for dairy cows also depends on annual herbage production and the determination of how best to utilise it in a farm system.

Keywords: birdsfoot trefoil, dairy cows, dry matter intake, *Lotus corniculatus*, milk composition, milk yield, perennial ryegrass, white clover

Introduction

Previous experiments (Harris *et al.* 1997, 1998) have shown increased summer-autumn milk yield in response to increased white clover (*Trifolium repens*) content in the diet of dairy cows grazing perennial ryegrass–white clover pastures. However, the numerous environmental and management factors that can decrease clover content in mixed dairy pastures (Caradus *et al.* 1996; Harris 1998) make it difficult to reach, let alone maintain, clover levels at the optimum for milk production (50–70% of total dry matter (DM)). This, combined with clover root weevil (*Sitona lepidus)* damage to clover in the upper North Island, provided the impetus to investigate the potential of an alternative legume species, birdsfoot trefoil (*Lotus corniculatus*), as a forage for dairy cows.

Lotus corniculatus (referred to as "*Lotus*" in this paper) is a perennial legume with a well-developed crown, ascending stems, five leaflets per leaf, yellow flowers and a tap-root (Scott & Charlton 1983). Unlike Grasslands Maku lotus (*Lotus pedunculatus*) it is non-rhizomatous. The growth habit of *Lotus* ranges from erect to prostrate, although the cultivar used in our research (cv. Grasslands Goldie) has an erect growth habit. Introduced to New Zealand in the early 1900s, *Lotus* has been used mainly as a forage legume for sheep in drier hill and high country regions. It has been shown to increase liveweight gain and wool growth in weaned lambs (Wang *et al.* 1994), liveweight gain in beef cattle (Alison & Hoveland 1989) and dairy heifers (Marten *et al.* 1987), and milk yield in lactating sheep (Wang *et al.* 1996). Despite extensive use as a forage legume in North and South America and Europe (Seaney & Henson 1970), there are no reports of the effect of *Lotus* on the milk production of dairy cows.

Suitable forages for dairy cows must provide adequate DM and increase milk yield above that produced by cows grazing pure perennial ryegrass without compromising milk composition, particularly fat and protein concentrations. The objective of this research was to compare the effects of *Lotus* on milk yield and composition of Friesian dairy cows in mid lactation with those on white clover and perennial ryegrass.

Method

Two 10-day experiments were conducted when cows were in mid lactation: Experiment 1 in December 1997 (mean: 107 days in milk) and Experiment 2 in January–February 1998 (mean: 162 days in milk). For the week before each experiment (uniformity period), all cows grazed the same ryegrass–white clover pasture and measurements collected during this period were used for covariate analysis of data.

In both experiments cows were split into balanced groups according to age, current production, days in milk and liveweight. They rotationally grazed (new area every 24 hours) pastures which were predominantly either perennial ryegrass (cv. Yatsyn), white clover (cv. Grasslands Kopu) or *L. corniculatus* (cv. Grasslands Goldie). The actual white clover and *Lotus* contents are given in Tables 1 and 2 for Experiments 1 and 2, respectively. Groups of 10 cows were used, except in

Experiment 1 when group number was reduced to 6, as insufficient *Lotus* pasture was available. A constant pasture allowance of 60 kg DM/cow/day was offered to all groups of cows by adjusting the daily grazing area. A pre-grazing herbage cover of 3000 to 3600 kg DM/ha existed on all treatments in both experiments as estimated by calibrated visual assessment.

Daily milk yield and composition (p.m. + a.m. sample) was measured over the final 5 days of each experiment. Milk samples were analysed for fat, protein and lactose concentration using an infra-red milk analyser (Milkoscan 133B).

Herbage DM intake (DMI) was estimated using the alkane technique (Dove & Mayes 1991). Controlled release alkane capsules containing synthetic C32 and C36 alkanes were administered to cows 2 days before the start of each experiment. Individual faecal samples, collected twice daily over the final 5 days of the experiment, were bulked, and analysed for alkane content, together with herbage samples representative of grazed pasture. DMI was calculated for each cow.

Pasture samples (random ground level cuts) for determination of botanical composition were collected from each treatment over the final 5 days of each experiment and bulked before analysis. In Experiment 1 these pasture samples were analysed for chemical composition using NIRS. In Experiment 2, pasture samples used for estimation of chemical composition were cut to grazing height and analysed in duplicate using NIRS and wet chemistry techniques, as a check for NIRS calibration. The wet chemistry analyses of crude protein, acid detergent fibre (ADF), neutral detergent fibre (NDF), ash, ether extract (lipids) and *in vitro* organic matter digestibility (OMD) confirmed the NIRS analyses presented here. During both experiments samples of pure white clover and pure *Lotus* were separated from pasture samples and freeze dried. These samples were analysed for extractable (free) and bound condensed tannin (CT) concentration using the butanol-HCl colorimetric procedure (Terrill *et al.* 1992).

Milk yield and composition data were analysed for variance using covariate data collected during the uniformity period using SAS 6.12. Adjusted means and SEDs are presented. DMI and conversion efficiency data were also analysed for variance using SAS 6.12 while pasture composition data were analysed for variance using Genstat 5.3.

Results

Pasture botanical composition and chemical composition

Neither the white clover nor the *Lotus* pastures were pure swards but clover and *Lotus* comprised 70–75% of the total DM on their respective treatments (Tables 1 and 2). In both experiments the *Lotus* pasture also contained low levels of white clover. The balance of herbage on all treatments was predominantly perennial ryegrass (*Lolium perenne*), with small amounts of *Poa annua* and weeds.

Crude protein, OMD and metabolisable energy (ME) levels were all higher (P<0.001) for the *Lotus* and white clover than for the ryegrass while the DM%, and levels of ADF and NDF were all lower (P<0.001) (Tables 1 and 2). There was no significant difference in levels of crude protein ADF, NDF, OMD and ME between *Lotus* and clover pasture in Experiment 2 (Table 2). In Experiment 1, however, OMD and ME were higher (P<0.001) for the *Lotus* than the clover while ADF and NDF were lower (P<0.001) (Table 1).

The CT concentration of the *Lotus* was slightly lower in Experiment 2 (Table 2) than Experiment 1 (Table I). Low levels of CT were also present in the clover, particularly in Experiment 1 when the clover was in heavy flower.

Table 1 Botanical and chemical composition (analysed by NIRS) of herbage on offer during Experiment 1 (December 1997).

Treatment	Ryegrass	Clover	*Lotus*	SED
White clover (% total DM)	0	70	10	N.A.
Lotus (% total DM)	0	0	73	N.A.
Dry matter (%)	21.0	13.5	12.7	1.9
Crude protein (g/100g DM)	11.3	23.2	23.7	1.2
ADF[a] (g/100g DM)	31.5	23.9	19.0	1.3
NDF[b] (g/100g DM)	53.2	36.8	25.0	2.4
OMD[c] (g/100g DM)	69.0	75.8	80.2	1.1
ME[d] (MJ/kg DM)	10.8	11.9	12.7	0.2
Total condensed tannin (% total DM)	0	0.36	2.49	N.A.

[a] Acid detergent fibre
[b] Neutral detergent fibre
[c] *In vitro* organic matter digestibility
[d] Metabolisable energy

Table 2 Botanical and chemical composition (analysed by NIRS) of herbage on offer during Experiment 2 (January–February 1998).

Treatment	Ryegrass	Clover	*Lotus*	SED
White clover (% total DM)	0	74	3	N.A.
Lotus (% total DM)	0	0	75	N.A.
Dry matter (%)	26.3	18.4	17.9	1.5
Crude protein (g/100g DM)	11.9	20.9	22.4	1.4
ADF[a] (g/100g DM)	32.8	25.2	23.8	1.2
NDF[b] (g/100g DM)	55.9	38.4	32.4	3.5
OMD[c] (g/100g DM)	66.1	75.4	77.8	1.7
ME[d] (MJ/kg DM)	10.0	11.5	11.8	0.3
Total condensed tannin (% total DM)	0	0.14	2.16	N.A.

[a] Acid detergent fibre
[b] Neutral detergent fibre
[c] *In vitro* organic matter digestibility
[d] Metabolisable energy

Milk yield and composition

In Experiments 1 and 2 cows grazing clover pasture produced 40% (Table 3) and 32% (Table 4) ($P<0.001$) more milk, respectively, than cows grazing pure ryegrass. Cows grazing *Lotus* produced more milk than those grazing either ryegrass ($P<0.001$) or clover (Experiment 1: $P<0.01$; Experiment 2: $P<0.05$), although the differences were smaller in Experiment 2.

Table 3 Daily milk yield, milk composition, herbage intake and conversion efficiency of cows grazing either ryegrass, white clover or *Lotus* during Experiment 1 (December 1997).

Treatment	Ryegrass	Clover	*Lotus*	SED[a]	SED[b]
Yield (l/cow/day)	13.0	17.8	19.8	0.6	0.6
Milk fat (%)	4.29	4.41	4.07	0.11	0.13
Milk protein (%)	3.15	3.30	3.36	0.02	0.02
Milk lactose (%)	4.76	4.78	4.69	0.06	0.07
Milksolids (kg/cow/day)	0.96	1.37	1.48	0.05	0.06
DMI (kg DM/cow/day)	13.5	15.4	14.6	0.8	0.9
Conversion efficiency (MJ ME/l milk/day)	10.65	10.02	8.75	0.35	0.46

[a] SED for comparison between ryegrass and clover treatments
[b] SED for comparison of *Lotus* with either ryegrass or clover treatments

Table 4 Daily milk yield, milk composition, herbage intake and conversion efficiency of cows grazing either ryegrass, white clover or *Lotus* during Experiment 2 (January–February 1998).

Treatment	Ryegrass	Clover	*Lotus*	SED
Yield (l/cow/day)	11.7	15.4	16.7	0.5
Milk fat (%)	4.44	4.37	4.29	0.11
Milk protein (%)	3.21	3.21	3.35	0.02
Milk lactose (%)	4.70	4.77	4.77	0.03
Milksolids (kg/cow/day)	0.90	1.15	1.28	0.04
DMI (kg DM/cow/day)	11.3	14.6	13.0	0.5
Conversion efficiency (MJ ME/l milk/day)	8.91	9.09	7.04	0.35

In Experiment 1, cows grazing *Lotus* had lower milk fat concentrations ($P<0.05$) than cows grazing clover (Table 3) but in Experiment 2 *Lotus* had no effect on milk fat% (Table 4). Clover had no effect on milk fat% in either experiment (Tables 3 and 4) compared with ryegrass. Milk protein% was higher ($P<0.001$) on both the *Lotus* and clover treatments than on ryegrass in Experiment 1 (Table 3), but there was no difference between the *Lotus* and clover groups. In Experiment 2, however, clover content had no effect on milk protein%, but cows grazing *Lotus* had higher ($P<0.001$) milk protein concentrations than cows grazing either ryegrass or clover pasture (Table 4). Grazing *Lotus* or clover had no effect on lactose% compared with grazing ryegrass in either experiment (Tables 3 and 4). Milksolids (MS) production showed a similar trend to milk yield in response to clover and *Lotus*. Cows grazing *Lotus* produced more MS than those grazing ryegrass (Experiment 1: $P<0.001$; Experiment 2: $P<0.001$) (Tables 3 and 4), but the difference in MS yield between *Lotus* and clover was only significant ($P<0.01$) in Experiment 2.

Herbage intake (DMI) and conversion efficiency

DMI of cows grazing *Lotus* was not significantly different from cows grazing either ryegrass or clover in Experiment 1 (Table 3). In Experiment 2, however, DMI on the *Lotus* was greater ($P<0.001$) than on ryegrass (Table 4). In both experiments cows grazing clover had higher DMI (Experiment 1: $P<0.05$; Experiment 2: $P<0.001$) than those grazing ryegrass (Tables 3 and 4) and in Experiment 2, DMI on the clover was also higher ($P<0.01$) than for the cows grazing *Lotus*.

Conversion efficiencies were calculated according to the formula of Holmes *et al.* (1984) using the estimates of pasture ME level and DMI, measurements of fat corrected milk yield, and taking into account maintenance energy requirements. In both experiments cows grazing *Lotus* were more efficient (Experiment 1: $P<0.01$; Experiment 2: $P<0.001$) than those grazing either ryegrass or clover (Tables 3 and 4). Clover, however, had no significant effect on conversion efficiency compared with ryegrass in either experiment.

Discussion

Cows grazing *Lotus* had higher milk yields than those grazing ryegrass owing to a combination of improved pasture quality, in particular higher crude protein and ME levels, and higher DMI. The impact of pasture quality and DMI on milk yield was similar to that shown for white clover in these experiments and in previous research (Harris *et al.* 1997; 1998). The increase in milk production on *Lotus* compared with white clover was probably owing to improved conversion efficiency. Since the cows grazing clover showed no change in conversion efficiency compared with those grazing ryegrass, it is possible that the improved efficiency of cows was associated with the presence of condensed tannins (CT) in *Lotus* rather than pasture quality. Wang *et al.* (1996) showed CT had a specific role in increasing the milk yield of lactating ewes grazing *L. corniculatus*.

CT are widespread in the plant kingdom and are found in a restricted number of legumes including Maku lotus, sainfoin (*Onobrychis viciifolia*), Sericea lespedeza (*Lespedeza cuneata*) and in the flowers of white clover. CT bind to plant protein complexes in the pH range 3.5–7.0 and therefore reduce microbial degradation of protein to ammonia in the rumen (mean rumen pH of pasture fed cows pH 5.8–6.3; E.S. Kolver pers. comm.). CT-protein complexes dissociate below pH 3.5, increasing non-ammonia nitrogen flux to the abomasum and small intestine, and increasing the absorption of essential amino acids from the small intestine (Waghorn *et al.* 1987).

Aside from contributing to increased milk yield, CT are beneficial to ruminants in other ways. For example, CT prevent the formation of stable foams that cause bloat (Kendall 1966). The action of CT in *Lotus* may also explain the increase in milk protein concentration. Wang *et al.* (1996), however, showed no difference in milk protein concentration between ewes grazing *Lotus* and those grazing *Lotus* supplemented with PEG to block the action of the CT, therefore indicating CT had no effect on milk protein. Interestingly, Experiment 1 also showed a positive effect of white clover on milk protein concentration, while Experiment 2 and previous experiments (Harris *et al.* 1997; 1998) have demonstrated no effect. This may have been because the clover was in full flower and therefore contained enough CT to have a measurable effect. Alternatively, the changes in milk protein% may have been associated with the higher pasture protein levels in the clover and *Lotus* compared with the ryegrass, along with the increased ME intakes, promoting increased availability and absorption of protein. However, the lack of change in milk protein concentration of cows grazing clover in Experiment 2, when pasture protein and ME levels were similar to the *Lotus* but the clover contained much lower CT levels than in Experiment 1, would suggest the effect on milk protein in both experiments was owing to the action of CT.

High levels of CT can, however, be detrimental to animal performance. High CT concentrations, for example, may reduce the availability of protein N for microbial use, so that microbial growth is sufficiently reduced to lower the rate of plant fibre degradation in the rumen (Waghorn *et al.* 1990). In addition, observations that livestock find *L. corniculatus* and *L. pedunculatus* herbage less acceptable than other common legumes, but readily consume it once accustomed to it, have been attributed to CT (Scott & Charlton 1983). Similarly, Barry & Duncan (1984) reported that Maku lotus containing high concentrations of CT (60–110g/kg DM) reduced DMI when fed to sheep. In our experiment, however, cows, which before the trial had never grazed *Lotus*, readily consumed it and DMIs were higher than for cows grazing pure ryegrass. DMI was lower, however, on *Lotus* than for cows grazing clover pasture which was of a comparable OMD, and this may have been associated with the presence of CT. Wang *et al.* (1996), however, showed no effect of CT on the DMI of ewes grazing *Lotus*. The level of CT in the *Lotus* cultivar (Goldie) used in both our experiments, and therefore the concentration of CT ingested by the cows grazing a sward that was not pure *Lotus*, was considerably lower than the 4% of plant DM reported by Waghorn *et al.* (1990) as having a detrimental effect on DMI. *L. corniculatus* cultivars also have lower levels of free CT, which are linked to the detrimental effects of CT, as a proportion of total CT concentration than Maku lotus (Barry & Manley 1986).

The decrease in milk fat concentration measured in Experiments 1 and 2 in response to feeding *Lotus* was similar to the effect measured by Wang *et al.* (1996) in sheep fed *Lotus*. They suggested the effect on milk fat concentration was owing to simple dilution caused by the action of CT increasing the secretion rates of lactose and protein and increasing milk volume. Overall, the effects of feeding *Lotus* on milk protein and milk fat concentrations comply with goals for milk composition set by the New Zealand Dairy Board.

Summary

L. corniculatus clearly shows promise as a legume forage for dairy cows because of its positive effects on milk yield and milk protein levels. Although *Lotus* is tolerant of dry summers and appears well adapted to rotational grazing, reported difficulties with establishment, low competitive ability and poor winter growth (Chapman *et al.* 1990; Scott & Charlton 1983) may limit its use as a substitute for white clover in ryegrass-based pastures. Alternatively, *Lotus* could be used as a green-feed crop largely during summer-autumn, although the economic viability of this in a farm system is yet to be tested.

ACKNOWLEDGEMENTS

We thank the DRC laboratory, farm and technical staff who assisted with this trial, to Dr Warren McNabb (AgResearch Grasslands) who carried out the analysis of the condensed tannin content of the herbage, and to Rhonda Hooper for statistical analysis.

REFERENCES

Alison, M.W.; Hoveland, C.S. 1989. Root and herbage growth response of birdsfoot trefoil entries to subsoil activity. *Agronomy journal 81:* 677–680.

Barry, T.N.; Duncan, S.J. 1984. The role of condensed tannins in the nutritional value of Lotus pedunculatus for sheep. 1. Voluntary intake. *British journal of nutrition 51:* 485–491.

Barry, T.N.; Manley, T.R. 1986. Interrelationships between the concentrations of total condensed tannin, free condensed tannin and lignin in *Lotus* sp. And their possible consequences in ruminant nutrition. *Journal of the science of food and agriculture 37:* 248–254.

Caradus, J.R.; Harris, S.L.; Johnson, R.J. 1996. Increased clover content for increased milk production. *Proceedings of the Ruakura Farmers' Conference 48:* 42–49.

Chapman, H.M.; Lowther, W.L.; Trainor, K.D. 1990. Some factors limiting thr success of *Lotus corniculatus* in hill and high country. *Proceedings of the New Zealand Grassland Association 51:* 147–150.

Dove, H.; Mayes, R.W. 1991. The use of plant wax alkanes as marker substances in studies of the nutrition of herbivores: a review. *Australian journal of agricultural research 42*: 913–952.

Harris, S.L. 1998. White clover – how much and how to get it. *Proceedings of the Ruakura Farmers' Conference 50:* 73–79.

Harris, S.L.; Auldist, M.J.; Clark, D.A.; Jansen, E.B.L. 1998. Effects of white clover content in the diet on herbage intake, milk production and milk composition of New Zealand dairy cows housed indoors. *Journal of dairy research 65:* 389–400.

Harris, S.L.; Clark, D.A.; Auldist, M.J.; Waugh, C.D.; Laboyrie, P.G. 1997. Optimum white clover content for dairy pastures. *Proceedings of the New Zealand Grassland Association 59:* 29–33.

Kendall, W.A. 1966. Factors affecting foams with forage legumes. *Crop science 6:* 487–489.

Marten, G.C.; Ehle, F.R.; Ristau, E.A. 1987. Performance and photosensitization of cattle related to forage quality of four legumes. *Crop science 34:* 1074–1079.

Scott, D.; Charlton, J.F.L. 1983. Birds foot trefoil (*Lotus corniculatus*) as a potential dryland herbage legume in New Zealand. *Proceedings of the New Zealand Grassland Association 44:* 98–105.

Seaney, R.R.; Henson, P.R. 1970. Birdsfoot trefoil. *Advances in agronomy 22:* 119–157.

Terrill, T.H.; Rowan, A.M.; Douglas, G.B.; Barry, T.N. 1992. Determination of extractable and bound condensed tannin concentrations in forage plants, protein concentrate meals and cereal grains. *Journal of the science of food and agriculture 58:* 321–329.

Waghorn, G.C.; Jones, W.T.; Shelton, I.D.; McNabb W.C. 1990. Condensed tannins and the nutritive value of herbage. *Proceedings of the New Zealand Grassland Association 51:* 171–176.

Waghorn, G.C.; Ulyatt, M.J.; John, A.; Fisher, M.T. 1987. The effect of condensed tannins on the site of digestion of amino acids and other nutrients in sheep fed on *Lotus corniculatus* L. *British journal of nutrition 57:* 115–126.

Wang, Y.; Douglas, G.B.; Waghorn, G.C.; Barry, T.N.; Foote, A.G. 1996. Effect of condensed tannin in *Lotus corniculatus* upon lactation performance in ewes. *Journal of agricultural science, Cambridge 126:* 353–362.

Wang, Y.; Waghorn, G.C.; Douglas, G.B.; Barry, T.N.; Wilson, G.F. 1994. The effects of condensed tannin in *Lotus corniculatus* upon nutrient metabolism and upon body and wool growth in grazing sheep. *Proceedings of the New Zealand Society of Animal Production 54:* 219–222.

■