Are diverse species mixtures better pastures for dairy farming?

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Abstract

Pressure on New Zealand's largely pasture-based dairy industry has grown with a drive to increase production, expansion into new regions and demand for farmers to mitigate environmental impacts e.g., leaching of excess urinary nitrogen. A 3-year trial in the Waikato investigating the use of mixed pasture (e.g. perennial ryegrass, white clover, prairie grass, lucerne, chicory and plantain) showed similar annual dry matter (DM) production to standard pasture (perennial ryegrass and white clover) with greater yields of mixed pasture during summer (December, January, February) when lucerne and chicory grew better than perennial ryegrass in the warm, dry conditions. However, this yield advantage did not persist during the winter (June, July, August). Milk yields from cows grazing the mixed and standard pasture were similar. The mixed pasture retained a high level of species diversity and, while a single "magic bullet" is an unlikely solution to the challenges facing dairy farmers, increased species diversity could reduce risks and increase pasture stability.

Keywords: pasture species diversity, dry matter yield, milk, nitrogen

Introduction

New Zealand's dairy industry has traditionally been based on perennial ryegrass/white clover pastures which are often, incorrectly, viewed as monocultures. For many years the success of a farm system was determined by the amount of dry matter (DM) available to support milk production. Today, many factors impact on the success of a farm system, and it is likely that profitability in the future will require further diversification of the industry's forage base to meet the challenges of drought, pests (e.g., black beetle, clover root weevil), and introduction of environmental regulations controlling use of water and nitrogen fertilisers.

Such diversification is already occurring at the farm level. For example, inclusion of maize silage as a supplementary feed crop has become common over the last 15 years. Expansion of dairying in the South Island has seen increasing use of brassica crops (e.g. kale, swedes and turnips) to fill the winter (June, July, August) feed gap so that around 105 000 ha of brassica crops are grown (Dumbleton *et al*. 2012), while herbs (e.g. chicory and plantain) are now grown on many dairy farms to provide additional summer (December, January, February) feed (Lee *et al*. 2012; Li & Kemp 2005; Waugh *et al*. 1998). Although chicory can be undersown or broadcast into existing ryegrass swards (Lancashire & Brock 1983), most supplementary forages on dairy farms are grown as monocultures and are re-sown annually. While such management routines have been shown to have advantages (Lee *et al*. 2012; Li & Kemp 2005; Waugh *et al*. 1998), costs associated with crop establishment can be high.

The inclusion of grazeable mixed species pastures in the farm system provides a more even distribution of DM and feed quality throughout the grazing season and more stability than reliance on perennial ryegrass/white clover pastures (Gerrish 2001). Success of a farm system is dependent on DM yield, persistence of the pasture mixtures and milk production from cows grazing the mixtures – all measures in the trial described here over three consecutive dairy seasons: 1 June 2010–31 May 2011 (Year 1); 1 June 2011–31 May 2012 (Year 2); 1 June 2012 – 31 May 2013 (Year 3).

Methods

Trial design

"Standard" and "Mixed" pastures were established in 0.5 ha paddocks on a 3 ha site (Matangi silt loam; Stiles & Singleton 1997) at DairyNZ's Scott Farm, Hamilton, New Zealand (37°47′ S, 175°19′ E) in autumn 2010. Both the Standard and Mixed pastures were based on perennial ryegrass (*Lolium perenne* cv. 'One50-AR1'), and contained white clover (*Trifolium repens* cv. 'Kopu II'). The Mixed pasture also contained prairie grass (*Bromus willdenowii* cv. 'Atom'), chicory (*Cichorium intybus* cv. 'Choice'), plantain (*Plantago lanceolata* cv. 'Tonic') and lucerne (*Medicago sativa* cv. 'Torlesse'). Paddocks of each pasture type were randomly arranged in a block design with three replicates.

Site preparation began in late February 2010 with double spraying of existing paddocks with glyphosate 510 (4.25 L/ha, or 2.2 kg a.i./ha) and application of 9 mm liquid effluent (63 kg N/ha, 9 kg P/ha and 26 kg K/ha) across all paddocks. Soil testing (15 cm depth) pre-sowing showed an average pH 5.8, Olsen P 37, K 5 MAF Quick Test units, and Sulphate-S 15 ppm. In late March 2010 paddocks were ploughed before application of 2 t/ha lime and 635 kg/ha maintenance fertiliser (550 kg/ha "Superten", 50 kg/ha NaCl and 35 kg/ha "CalMag" i.e. 50P: 58S: 18Mg: 122Ca: 20Na) before power-harrowing of the site. Sowing (roll-drill-roll) occurred on 26 March 2010 (seed number per hectare (Table 1) was equivalent on both treatments). Seedlings of all species had emerged across both treatments by 6 April 2010. All paddocks were harvested (either grazed by cows or cut for silage) at the same time, although this meant that not all species were at their optimum grazing stage. This was believed to be the best strategy given the scale of the trial and its objectives. Throughout the trial, paddocks received the same level of fertiliser. Nitrogen (N) fertiliser (urea) was applied strategically post-grazing, targeting 200 kg N/ha/year. The target was reduced to 100 kg N/ha/year in Year 3 to comply with growing environmental awareness within the dairy industry. Maintenance fertiliser (P = 35 kg/ha/year; K = 117 kg/ha/year; S = 50 kg/ha/year (mean for 3 years)) was applied in autumn of each year.

No herbicide was applied to paddocks during the trial.

Dry matter yield and pasture composition

Available herbage DM yield in each treatment paddock was estimated from cuts to grazing height (approximately 4–5 cm) before every grazing or silage cut. A Jenquip HT-Kuma plot harvester was used to cut three 0.75 × 5 m strips (3.75 m^2) in each paddock. From January 2013, a Haldrup plot harvester with cut width of 1.5 m (7.5 m^2 cuts) was used.

Herbage from harvester cuts was weighed fresh in the field and subsamples were collected for measurement of DM% (dried at 95°C for 48 h in a forced-draught oven), weighing and calculation of yield (kg DM/ha). Botanical composition (% of total DM) was determined by separating well mixed herbage samples into perennial ryegrass, prairie grass, white clover, lucerne, chicory, plantain, other species and dead matter of all species, before drying at 95°C for 48 h and weighing. Pasture quality samples were collected seasonally, in winter and coinciding with the spring, summer and autumn milk measurement periods. Samples were freeze-dried, ground, then bulked by treatment and analysed by Hill Laboratories for the wet chemistry equivalent analyses to Near-Infrared Spectroscopy and for soluble sugars and starch.

Table 1. Nominal sowing rates of Standard and Mixed pasture (kg/ha).

Species	Mixed	Standard
Perennial ryegrass	10	18
White clover	2	5
Prairie grass	15	-
Chicory	2	-
Plantain	1.5	-
Lucerne	8	-
Total	38.5	23

Note: The white clover component was sown at 75% heavier than the nominal rate to account for weight of the seed coating.

Milk production

Once during spring, summer and autumn each year the normal grazing routine was modified to allow measurement of milk yield (kg/cow/day) and concentrations of fat (%) and protein (%) of cows grazing each of the treatment paddocks. For at least 2 weeks before each milk measurement period the 30 multiparous Holstein-Friesian dairy cows to be used were grazed together on Standard ryegrass/white clover pasture. Current milk yield and milk composition measurements together with cow liveweight and body condition score were used to allocate cows into balanced herds of five cows per paddock (15 per treatment). Treatment paddocks were split using temporary fencing so that the daily break size in each paddock provided cows with a daily allowance of approximately 20 kg DM/cow/day. Cows began grazing their allocated paddocks on a Thursday morning and after 5 days of grazing, milk measurements were conducted over consecutive days. Daily (pm + am) milk yield (kg/cow/day) was measured automatically and subsamples collected from each cow for analyses of milkfat and protein concentration by infrared spectrophotometry (SCC; Fossomatic™, Foss Electric, Hillerod, Denmark).

Statistical Analyses

Pasture production

DM data from individual cuts within a season and year were combined for each treatment replicate to obtain season and annual totals. Totals were analysed separately for each year and season. A mixed model approach to repeated measures analysis of variance (Proc Mixed, SAS 9.3) was used. ANOVA was followed by Tukey's t-test for pairwise comparisons. Significance was declared if $P<0.05$. Results are presented as P-values (for the effects included in the model), least-squares means, and standard error of the difference (SED) for diversity.

Milk production

Where data from more than two milkings in the covariance period were available, they were averaged. Data from individual cows were averaged for each replicate and the replicates were treated as experimental units. Firstly, data were analysed separately for each year and season. A mixed model approach to repeated

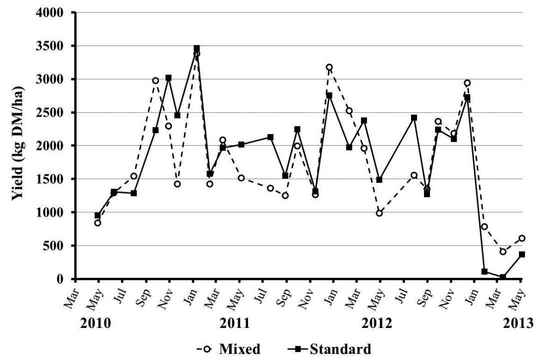

Figure 1 Available dry matter yield (kg DM/ha) in Mixed and Standard pasture at each harvest.

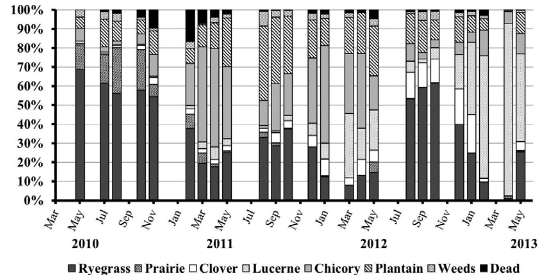

Figure 2 Botanical composition (% of total DM) of the Mixed pasture at each harvest.

measures analysis of variance (Proc Mixed, SAS 9.3) was used. ANOVA was followed by Tukey's t-test for pairwise comparisons. Significance was declared if P<0.05. Results are presented as P-values (for the effects included in the model), least-squares means, and standard error of the difference (SED) for diversity. Secondly, data were analysed separately for each season (but across all years) to examine whether any diversity effects were consistent across years. A mixed model approach to repeated measures analysis of variance (Proc Mixed, SAS 9.3) was used. Significance was declared if P<0.05.

Results and Discussion

Pasture production

Annual available DM yields, averaged over the 3-year trial, were similar across the Mixed and Standard pasture (Standard =15.3 vs Mixed=14.7 t DM/ha/year) (Table 2). However, there were seasonal differences in DM production in summer and autumn once the Mixed pasture was established (Figure 1). The Mixed treatment yielded 12% more over summer and autumn in Year 2 and 47% more than the Standard pasture in Year 3 during the summer-autumn drought when DM yields were considerably lower on both treatments compared with previous years (Figure 1). However, the yield advantage of the Mixed treatment was lost during winter, especially in both Years 2 and 3 when the Mixed pasture yielded 36% less than the Standard pasture (Figure 1).

In contrast, a 3-year trial conducted by Daly *et al*. (1996) under dryland conditions in Mid-Canterbury and Marlborough showed even greater annual DM production (10–41%) of multi-species pasture containing a range of grasses (excluding perennial ryegrass but including prairie grass), legumes (including lucerne and white clover) and herbs (including chicory and plantain), compared with perennial ryegrass/ white clover. The multi-species pasture had higher dry matter yields than the ryegrass pasture during summer, spring and winter but no difference in autumn, thus demonstrating a different seasonal growth pattern to the reported Waikato trial. Differences between the reported results and those of Daly *et al*. (1996) are probably due to differences in climatic effects and species selected.

Botanical composition

Currently, more than 3 years since sowing, the Mixed pasture retains a high level of species diversity and all species sown are still present. There were large increases in the chicory and lucerne contents of the Mixed pasture over summer compared with other times of the year (Figure 2). In Years 1 and 2, for example, chicory comprised up to 50% of total DM while the lucerne content, although low over summer in Year 1, reached 30% in Year 2 and 85% in Year 3. These trends were expected and were most probably the main factors contributing to the higher DM production over summer in the Mixed pasture. Chicory, a summer grower (Waugh *et al*. 1998), has become popular as a summer supplement on dairy farms in recent years.

Table 2 Establishment autumn and annual available dry matter yields (t DM/ha) of Mixed and Standard pasture.

Treatment	Establishment autumn	*Year 1 (2010/11)*	*Year 2 (2011/12)*	*Year 3 (2012/13)*	Mean annual yield
Mixed	0.84	17.9	14.5	11.6	14.7
Standard	0.95	19.3	15.8	10.9	15.3
SED	0.142	1.41	1.08	1.08	-
P value	NS	NS	NS	NS	-

NS = not significant

Lucerne is a perennial legume with a deep taproot and good heat tolerance, which allows it to keep producing high quality forage during droughts (McGuckin 1983), although use of lucerne on New Zealand dairy farms is still limited compared with chicory. Visual observation of the pastures in summer of Year 3 suggested that shading by lucerne provided protection for shorter species such as the chicory and ryegrass during the extreme drought conditions.

Even though plantain is accepted as a summer growing forage species, its greater tolerance of variations in growing temperature (Skinner & Gustine 2002) meant that plantain content in the Mixed pasture was more seasonally stable than either chicory or lucerne (Figure 2).

Chicory and lucerne dominated the Mixed pasture during summer and autumn in Years 2 and 3, whilst ryegrass content decreased to less than 10% of DM in the Mixed pasture. However, in each following spring the ryegrass content recovered and represented up to 60% of the Mixed pasture.

Clover contents in summer and autumn were much lower in the Mixed (2 to 20%) compared to the Standard pasture (11 to 46%). This was probably due to increased competition from the other summer active species in the Mixed pasture (chicory, lucerne, plantain). Due to increased species diversity and associated competition, the weed and dead content in the Mixed pasture (averages of 4% and 3%) were lower than in the Standard pasture (averages of 7% and 8%). Lower weed content has previously been linked to greater species diversity in pasture (Tracy & Sanderson 2004).

Milk production

The increased level of plant species diversity in the Mixed pasture usually had no significant effect on milk yields throughout the trial (Table 3). The only exception was in autumn Year 1 when milk yield from cows grazed on the Mixed pasture was significantly higher than the Standard (Table 3). This was probably due to the high chicory content in the Mixed pasture in autumn Year 1 (47% of total DM) and resulting lower DM content compared to the Standard pasture (Standard = 16.5 vs Mixed = 10.8%). The concentrations of fat and protein in the milk from cows on both treatments were usually similar as was milksolids production (data not presented) except in spring Year 1 when milksolids yields were lower on the Mixed pasture (Standard = 1.48 vs Mixed = 1.29 kg MS/cow/day, $P<0.05$). This may have been due to the lower crude protein levels in the Mixed pasture at this time (Standard = 18.4 vs Mixed = 13.9%). In the USA, Soder *et al*. (2006) reported similar results for cows grazing a mixed pasture containing nine different species (cocksfoot, perennial ryegrass, tall fescue, Kentucky bluegrass, white clover, red clover, lucerne, birdsfoot trefoil and chicory) compared with those grazing cocksfoot and white clover. During all 3 years, analyses of pasture quality showed the average metabolisable energy contents of both the Standard and Mixed pasture were usually similar (Standard = 11.7 vs Mixed = 11.8 MJ ME/kg DM) while the crude protein (% CP) content was slightly lower in the Mixed pasture (Standard = 19.9 vs Mixed = 19.3%). Predictions using the Cornell Net Carbohydrate and Protein System model (CNCPS v6.1.39) (Fox *et al.* 2004) indicated that energy and protein intake of cows on both pasture treatments at each measurement were, on average, above requirements for their level of milk production, helping to explain why there was little difference in milk yield.

Potential use of Mixed pastures on dairy farms

Results from this trial showed that Mixed pasture can produce as much DM per year as Standard pasture containing perennial ryegrass and white clover, and that cows grazing Mixed pasture can produce at least as much milk as cows grazing Standard pasture. Indoor trials (Woodward *et al.* 2012) showed lactating dairy cows fed Mixed pasture partitioned more of their feed nitrogen intake into milk (Standard = 15% vs Mixed = 23%) and less was wasted in the urine (Standard = 43% vs Mixed = 29%), which meant the urinary nitrogen output was halved in the cows fed Mixed pasture (Standard = 200 vs Mixed = 100 g N/cow/day). Mixed pasture could, therefore, be used on dairy farms to help improve nitrogen use efficiency of cows and reduce nitrate leaching and nitrous oxide emissions.

Table 3. Milk production (kg/cow/day) from cows grazing Mixed and Standard pasture. There was no milk measurement in Autumn Year 3 since all cows on the Scott Farm had been dried off by time of milk measurement.

	Year 1 (2010-11)			Year 2 (2011-12)			Year 3 (2012-13)	
	Spring	Summer	Autumn	Spring	Summer	Autumn	Spring	Summer
Mixed	18.6	11.6	9.6	18.6	15.4	12.0	23.0	18.2
Standard	19.7	11.6	8.1	18.6	15.0	12.2	22.4	18.4
SED	0.66	0.78	0.35	0.50	0.47	0.31	0.44	0.33
P value	NS	NS	*	NS	NS	NS	NS	NS

*P<0.05, NS = not significant.

Continuation of botanical composition measurements on the Scott Farm trial over the next few years will provide further information about persistence of the different species in the Mixed pasture and will indicate what happens to the pastures if the chicory and lucerne disappear i.e., does the ryegrass fill in the gaps, do the pastures become thin with large patches of bare ground, or does the weed population increase? This is considered important by dairy farmers who prefer not to re-sow large areas of the farm every few years. Any dairy farmers using Mixed pasture on their farms must decide what proportion of their farm can be sown as Mixed pasture and the most appropriate forage species to include in the mix. This trial suggests mixed species pastures could have a place on New Zealand dairy farms especially as more emphasis is placed on reducing leaching of nitrogen in farm systems.

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