Herbage production from perennial ryegrass and tall fescue pastures under irrigation in the Canterbury and Waikato regions of New Zealand

E.M.K. MINNEÉ[1], T.L. KNIGHT[2], B.L. SUTHERLAND[2], J.B. VLAMING[2], L.R. FLETCHER[2] and D.A. CLARK[1]
[1]*DairyNZ, PB 3221, Hamilton*
[2]*AgResearch Lincoln, Lincoln Research Centre, Private Bag 4749, Christchurch 8140*
elena.minnee@dairynz.co.nz

Abstract

The major limitation to perennial ryegrass-based systems is low soil moisture which reduces perennial ryegrass growth. Irrigation can maintain adequate soil moisture levels for pasture growth, however, the associated cost requires high levels of forage water use efficiency. The field plot experiments reported here evaluate dry matter production (DM) of two varieties of tall fescue (*Lolium arundinacea*), a Continental (CTF) and a Mediterranean type (MTF), and a tetraploid perennial ryegrass (*Lolium perenne*) (PR) under irrigation in the Canterbury and Waikato regions of New Zealand. In Year 1, perennial ryegrass produced more dry matter than tall fescue. However, in the Waikato, in summer, CTF was more water use efficient and productive than ryegrass pastures. In Years 2 and 3 of the Canterbury experiment, there was no significant difference in yield between ryegrass and CTF, but the MTF pastures had failed by the third year.

Keywords: chicory, clover, dry matter yield, lucerne, seasonal yield

Introduction

On New Zealand dairy farms the amount of high quality pasture harvested by dairy cows has a major effect on profitability. Thom (2000) estimated the potential annual production of dairy pastures in the Canterbury and Waikato at 23 and 24 t DM/ha, respectively, yet these yields are rarely achieved in practice. Climatic factors (temperature and rainfall) have the greatest affect on pasture production and persistence (Rawnsley *et al.* 2007). While New Zealand receives ample radiant energy for high DM yields (Clark *et al.* 2001), soil moisture can be a major limitation (Thom 2000). The expansion of dairy farming into dry areas of New Zealand has led to an increase in the area of irrigated pastures, but water is a limited resource. Therefore alternative species to ryegrass that are more efficient at utilising water and better adapted to higher temperatures are being investigated. Tall fescue is more heat tolerant (Reed 1996) and drought tolerant (Garwood *et al.* 1979) than perennial ryegrass. McCallum *et al*. (1992) and Thomson *et al*. (1988) showed that tall fescue produced higher annual DM yields than ryegrass without irrigation; and under cutting, Martin (2008) showed that irrigated tall fescue had higher water use efficiency and produced more DM than ryegrass. However, the slow establishment and management difficulties of tall fescue (Easton *et al.* 1994) have limited its use on dairy farms (Milne *et al.* 1997). The recent development of cultivars bred for improved establishment (Fraser & Lyons 1994) with the inclusion of a non-toxic novel endophyte, MaxP®, which protects against a wide range of pasture pests, has renewed interest in this forage.

It is hypothesised that annual DM yields of tall fescue with Max P® endophyte will be greater than perennial ryegrass when grazed by dairy cows in the Canterbury and Waikato regions of New Zealand. This hypothesis was tested over 3 years in Canterbury. Trends over the establishment year in the Waikato provide supporting data. The Waikato experiment is still in progress.

Materials and Methods

Experiment 1 (Canterbury)

This experiment was conducted on a Canterbury Grasslands commercial dairy farm near Hororata (43.6°S, 171.8° E). Climatic data were recorded at the Darfield Meteorological station (43.5°S, 172.2° E). Soil type at the site was a Lismore stony silt loam. Treatment pastures were either tetraploid perennial ryegrass (cv. 'Banquet II' with Endo 5, sown at 22 kg/ha) (PR), Continental tall fescue (cv. 'Advance' with MaxP®; 25 kg/ha) (CTF) or Mediterranean tall fescue (cv. 'Resolute II' with MaxP®; 25 kg/ha) (MTF) sown either in monoculture or in mixtures with red (*Trifolium pratense*) (cv. 'Colenso'; 5 kg/ha) or white clover (*Trifolium repens*) (cv. 'Kopu II'; 3 kg/ha). Additional treatments were CTF in a mixed sward with lucerne (*Medicago sativa*) (cv. 'Torlesse D3'; 8 kg/ha) and the MTF with lucerne (cv. 'WL35D7'; 8 kg/ha). Plots (n = 32, each measuring 1.5 x 5 m) were arranged in a randomised complete block design with four replicates. The study area was sprayed with glyphosate (6 L/ha, glyphosate a.i. 360 g/L) herbicide then cultivated (ploughed, heavy-rolled, rota-crumbled, harrowed and rolled again) before sowing with a precision cone-seeder drill in late February 2007. Maintenance fertiliser, Cropmaster 15 (15.1% N, 10% P, 10% K, 7.7% S), was applied annually at a rate of 450 kg/ha from late winter to early spring. Monoculture plots received an additional 300 kg/ha of urea (46% N) in three applications during the growing season. Water was applied via a centre pivot irrigation system delivering 12 mm every 2.5 days over the 7 month soil moisture deficit period except for 5 and 8 weeks over the summers of 2009 and 2010, respectively, when there were low water levels in the Rakaia River.

Herbage mass was determined using an electronic pasture probe before and after each grazing. The probe was calibrated with pasture cuts at the beginning of the experiment. Plots were grazed by dairy cows as determined by the farm manager.

Experiment 2 (Waikato)

The Waikato experiment is underway at Scott Farm, DairyNZ, near Hamilton (37°47'S, 175°19'E, 40 m a.s.l.). Monthly rainfall and temperatures were recorded at the Ruakura Meteorological station (37.8°S, 175.3° E). The soil type is a Matangi silt loam (Typic Orthic Gley) (Hewitt 1998). Soil samples (January 2007) from the study area showed Olsen P levels of 28 µl/ml and pH of 5.9. Treatment plots (n = 60, each 2.5 x 5 m) were arranged in a randomised complete block design with five replicates, with a factorial combination of three grasses and four species mixtures. The three grass species sown and sowing rates were: tetraploid perennial ryegrass (cv. 'Banquet II' with Endo 5; 22 kg/ha) (PR), Continental tall fescue (cv. 'Advance' with MaxP®; 32 kg /ha) (CTF) and Mediterranean tall fescue (cv. 'Resolute II' with MaxP®; 32 kg/ha) (MTF). The four species mixtures are: grass sown in a monoculture; grass in mixed sward with either red clover (cv. 'Colenso'; 4 kg/ha), white clover (cv. 'Kopu II'; 4 kg/ha) or chicory (*Cichorium intybus*) (cv. 'Choice'; 1.5 kg/ha). Before planting, existing perennial ryegrass-white clover pastures were sprayed with Roundup® Transorb (4 L/ha, glyphosate 540 g a.i./L) plus Pulse® surfactant (200 ml/100 L water) in February 2007. In early March 2007 the study area was ploughed, limed (2.5 t/ha) and Superten 7 K fertiliser was applied (500 kg/ha; 7.7% P, 7.5% K, 8.9% S, 19% Ca) and incorporated into the soil by power-harrowing and rolling to prepare a fine seedbed. Trial plots were sown late March 2007 using an Oyjord drill. An insecticide (Suscon Green: 15 kg/ha; a.i. 100g/kg chlorpyrifos) was applied at sowing to control grass grub, and urea was applied 6 weeks after sowing (65 kg/ha; 46% N). Soil moisture content (SMC) was monitored weekly from October 2007 to May 2008 using a capacitance meter. When SMC fell below 35 % (mid-point between field capacity and permanent wilting point) water was applied using pop-up sprinkler irrigators at a rate of 6 mm/hr until estimated field capacity was reached.

Forage DM yield was assessed before each grazing by cutting (to 5 cm stubble) a 2.5 m^2 strip within each plot using a rotary mower. The fresh weight of the cut herbage was recorded in the field and a representative subsample was taken for determination of DM content after drying in a forced-air oven at 95°C for 36 h. Grazing interval was determined by weekly visual estimates of herbage mass, and plots were grazed by dairy cows when the highest yielding plot had reached 2 800 kg DM/ha, leaving a residual stubble of 4 and 5 cm for ryegrass and tall fescue, respectively. Ryegrass and tall fescue plots were grazed independently. Granulated fertiliser (Yara Mila Complex) was applied at 250 kg/ha (12.4% N, 4% P, 15% K, 8% S, 1.7% Mg, 3% Ca) after each grazing. Water use efficiency was calculated by dividing DM yield by the amount of water received (rainfall plus irrigation).

Statistical analyses

Data from both studies were analysed as a factorial design with a split plot layout using Analysis of Variance (GenStat 12.1). For Experiment 2, replicates and grazing area within each replicate were included as blocking factors in the analysis where each replicate had been divided into two grazing areas, one for ryegrass and another for tall fescue. Pasture type was included as a treatment effect in the model.

Results

Experiment 1

Mean maximum daily temperatures in summer over the experimental period were 22.4°C, with temperatures exceeding 25°C on 7, 27 and 13 days in Years 1, 2 and 3, respectively.

The average yield across sward mixtures for the entire year and for each season (excluding winter as plots were not grazed during this period) is shown in Table 1. The highest annual DM productions were achieved on the ryegrass pastures in Year 1 averaging 15.9 t DM/ha, while the CTF and MTF pastures produced on average 25 % less. In Year 2, total annual DM production was similar across all pasture types, which was also the case for CTF and PR in Year 3, but not for MTF, it was significantly lower. Annual yield generally declined with time, especially for MTF pasture where Year 3 yields were only 50% of those in Year 1. Total yield over the 3 year experiment was highest on the PR pastures at 34 t DM/ha, compared with 29 and 25 t for CTF and MTF, respectively.

Table 1 Herbage yield (t DM/ha) in Canterbury (Experiment 1) comparing annual and seasonal yields. Data describe the average yield across all species mixes for each grass type: continental tall fescue (CTF), Mediterranean tall fescue (MTF) and perennial ryegrass (PR).

	Total	Spring	Summer	Autumn
Year 1				
CTF	11.9	4.3	5.2	2.4
MTF	11.4	4.0	4.6	2.8
PR	15.9	6.7	6.6	2.6
SED (CTF vs. MTF)	0.5	0.2	0.2	0.2
SED (TF vs. PR)	0.6	0.2	0.2	0.2
Year 2				
CTF	7.7	2.9	3.3	1.5
MTF	7.3	2.9	3.0	1.4
PR	8.2	2.6	3.6	2.0
SED (CTF vs. MTF)	0.5	0.2	0.2	0.2
SED (TF vs. PR)	0.6	0.2	0.2	0.2
Year 3				
CTF	9.5	3.6	3.9	2.0
MTF	5.7	3.4	2.3	
PR	10.2	4.0	4.2	2.0
SED (CTF vs. MTF)	0.5	0.2	0.2	
SED (TF vs. PR)	0.6	0.2	0.2	0.2

Table 2 Herbage yield (t DM/ha) in Waikato (Experiment 2) comparing total (27 March 2007-31 May 2008) and seasonal yield (Establishment: 27 Mar-31 May 07; Winter: 1 Jun- 31 Aug 07; Spring: 1 Sep-30 Nov 07; Summer: 1 Dec 07- 28 Feb 08; Autumn: 1 Mar-31 May 08). Data describe average yield across all species mixes for each grass type: continental tall fescue (CTF), Mediterranean tall fescue (MTF) and perennial ryegrass (PR).

	Total	Establishment 07	Witnter 07	Spring 07	Summer 07/08	Autumn 08
CTF	15.6	0.3	1.1	4.2	6.4	3.6
MTF	14.2	0.4	1.1	4.0	5.6	3.1
PR	17.1	0.7	1.6	5.1	5.8	3.9
SED (TF vs. PR)	0.48	0.06	0.11	0.17	0.27	0.18
SED (CTF vs. MTF)	0.37	0.03	0.07	0.17	0.16	0.13

Experiment 2

Highest mean maximum temperatures (26.7°C) were recorded in January 2008, higher than the 10-year average of 23.9°C. In summer (December to February) levels of radiant energy was 2 008 MJ/m^2, compared with the average level received in the previous 2 years of 1 727 MJ/m^2. Temperatures were similar to the 10-year average in other seasons.

Tall fescue plots were grazed on 11 occasions, one fewer than ryegrass. Highest total DM yields were achieved on the PR monoculture (18.8 t DM/ha). Yields from monocultures of CTF and MTF were 16.0 and 14.1 t DM/ha (SED = 0.69). Sown grass had the greatest effect on total DM yield. Across all treatments, pasture monocultures or those sown with chicory (Ch) had higher DM yields (16.3 and 15.8 t DM/ha, respectively) than those sown with red or white clover (15.3 and 15.3 t DM/ha, respectively; SED = 0.40). The average yields across sward mixtures for the entire trial period and for each season are shown in Table 2. Total yield from pastures containing PR were highest (range, 16.0-18.8 t DM/ha). In summer, pastures containing CTF produced the most DM (range, 5.6-7.0 t DM/ha); this was greater than the summer yield from MTF and PR which were similar. The establishment yield of CTF pastures was lower than both MTF and PR

(Table 2), but there was no difference in yield between fescue pastures in winter or spring.

Water use efficiency in summer was greatest on the CTF pastures at 23.5 kg DM/mm applied, compared with 21.4 and 19.3 kg DM/mm on the MTF and PR pastures, respectively.

Discussion

Tetraploid perennial ryegrass had a greater annual yield than tall fescue in Year 1 (establishment year) at both sites, contrary to the original hypothesis. This is possibly due to the rapid establishment of perennial ryegrass resulting in less time to first grazing of PR pastures and up to a 90 % increase in DM production during the early establishment phase (March to May) compared with fescue pastures at the Waikato site. Higher production from PR than tall fescue has also been reported by Neal *et al.* (2009) and this was attributed to superior seedling vigour (Kemp *et al.* 2004). The implications of slow early growth after seedling emergence of CTF pastures must be considered when incorporating them in to the dairy system. However, current recommendations are that tall fescue is sown in spring on irrigated Canterbury farms, as opposed to the autumn establishment investigated here. Warming soil temperatures under a spring sowing may enhance tall fescue establishment and may have increased Year 1 yield. Further investigation of this possibility is required.

The finding of similar yields of PR and CTF pastures after the establishment year (Canterbury only) is supported by Rollo *et al.* (1998) for Canterbury, Hawkes Bay and Taranaki. CTF production in Canterbury was more consistent than PR across the 3 years of this study (a 48 % decline in PR production was observed), a trend also noted by Neal *et al.* (2009). Neal *et al.* (2009) reported that it is the year to year consistency of pasture yield that is most important to dairy farmers, as it allows stable farm production and profitability. Total yield over the 3 years of the Canterbury experiment was greatest from the PR pastures, also contrary to the original hypothesis and in contrast to the findings of Thomson *et al.* (1988) and McCallum *et al.* (1992) who showed a 40% production gain from CTF over PR averaged over 3 years. However, they compared newly established CTF pastures with 30 year old PR pastures.

In the establishment year in Waikato, CTF had greater production and water use efficiency than PR during the summer when air temperatures and radiation levels were above average, supporting earlier findings (Brock *et al.* 1982; Lowe & Bowlder 1984). This probably resulted from a higher temperature tolerance (Razmjoo *et al.* 1993) of tall fescue and a more extensive root system that extracts more water from the soil compared with PR (Garwood *et al.* 1979; Martin *et al.* 2008). One limitation of a PR-based system is the summer decline in production as PR growth suffers at temperatures above 18°C (Blaikie & Martin 1987) and ceases above 31°C (Thorogood 2003). This ryegrass response can in turn limit milk production. Therefore, including a species like CTF that is more tolerant of warmer temperatures, means the post-peak decline in milk yield can be reduced and lactation extended (Exton *et al.* 1996), lowering the need for supplementary feed.

Greater summer CTF yield compared with PR was not observed at the Canterbury site. Lowe & Bowlder (1984) in a study conducted under irrigation in sub-tropical Queensland, attributed the higher annual yield from CTF to increased production in summer and autumn. As the Canterbury pastures were not irrigated for substantial periods during the summers of 2009 and 2010, potential production from these pastures cannot be fully ascertained. The results of this study, and Lowe & Bowlder (1984), suggest that CTF exhibits superior production under adequate water supply, when high temperatures limit PR growth, making it suitable for increasing DM production in regions with high summer temperatures, such as Northland.

Production from the MTF pastures was similar to CTF in Canterbury in the first 2 years but by Year 3, MTF only accounted for a small proportion of the sward (data not shown). A similar effect was observed at the Waikato site where summer production from MTF pastures was low because of summer dormancy. The main growth period of MTF is from autumn to late spring (Lamp *et al.* 2001), but there was no significant production advantage observed during this period in these experiments, therefore, MTF pastures do not mitigate the problem of low summer feed supply in Canterbury or Waikato.

Conclusions

- Tetraploid perennial ryegrass was more productive in Year 1 at both Canterbury and Waikato sites.
- Continental tall fescue demonstrated more consistent dry matter production over the 3 year experiment in Canterbury than did the tetraploid perennial ryegrass.
- In the Waikato, continental tall fescue had greater water use efficiency in summer and produced higher DM yields in summer than tetraploid perennial ryegrass.
- Continental tall fescue is a viable option for dairy farmers in areas where high temperatures limit the production of tetraploid perennial ryegrass.
- Mediterranean tall fescue is not suitable for dairy pastures in the Canterbury or Waikato regions of New Zealand.

ACKNOWLEDGEMENTS

This study is part of a larger Pastoral 21 Feed research programme, which includes development and extension research in other regions of New Zealand. The authors wish to thank D. Woodfield (Science Leader of Pastoral 21); PGG Wrightson Seeds for supplying seed and NZ Agriseeds Ltd for assistance with sowing; technical staff at AgResearch and DairyNZ for assistance with measurements; E. Thom for agronomic advice; and B. Dow and C. van Koten for statistical analysis.

REFERENCES

Blaikie, S.J.; Martin, F.M. 1987. Limits to the productivity or irrigated pastures in south-east Australia. pp. 119-122. *In*: Temperate pastures: their production, use and management. Australian Wool Corporation/CSIRO, Melbourne.

Brock, J.L.; Anderson, L.B.; Lancashire, J.A. 1982. 'Grasslands Roa' tall fescue: seedling growth and establishment. *New Zealand Journal of Experimental Agriculture 10*: 285-289.

Clark, D.A.; Matthew, C.; Crush, J.R. 2001. More feed for New Zealand dairy systems. *Proceedings of the New Zealand Grassland Association 63*: 283-288.

Easton, H.S.; Lee, C.K.; Fitzgerald, R.D. 1994. Tall fescue in Australia and New Zealand. *New Zealand Journal of Agricultural Research 37*: 405-417.

Exton, P.R.; Dawson, J.E.; Thomson, N.A.; Moloney, S. 1996. More summer milk - progress to date. *Proceedings of the Ruakura Farmers' Conference 48*: 34-41.

Fraser, T.J.; Lyons, T.B. 1994. Grasslands Advance tall fescue establishment and animal performance. *Proceedings of the New Zealand Grassland Association 56*: 117-119.

Garwood, E.A.; Tyson, K.C.; Sinclair, J. 1979. Use of water by six grass species: I. Dry-matter yields and response to irrigation. *Journal of Agricultural Science 93*: 13-24.

Hewitt, A.E. 1998. New Zealand soil classification. 2nd ed. *Landcare Research Science Series 1*.

Kemp, P.D.; Matthew, C.; Lucas, R.J. 2004. Pasture species and cultivars. pp. 89-90. *In*: New Zealand pasture and crop science. Eds. White, J.; Hodgson, J. Oxford University Press, Melbourne.

Lamp, C.A.; Forbes, S.J.; Cade, J.W. 2001. Grasses of temperate Australia - a field guide. C.H. Jerram & Associates Science Publishers.

Lowe, K.F.; Bowlder, T.M. 1984. Performance of temperate and tropical grasses and legumes under two irrigation frequencies in south-eastern Queensland. *Tropical Grasslands 18*: 46-55.

Martin, R.J.; Knight, T.L.; Gillespie, R.N.; Riddle, M.U.; Fraser, T.J. 2008. Growth and water use of perennial ryegrass and tall fescue under different irrigation treatments. *Proceedings of the XXI International Grasslands Congress 1*: 835.

McCallum, D.A.; Thomson, N.A.; Thom, E.R. 1992. The place of tall fescue in intensive dairying. *Proceedings of the Ruakura Farmers' Conference. 44*: 93-97.

Milne, G.D.; Shaw, R.; Powell, R.; Pirie, B.; Pirie, J. 1997. Tall fescue use on dairy farms. *Proceedings of the New Zealand Grassland Association 59*: 163-167.

Neal, J.S.; Fulkerson, W.J.; Lawrie, R.; Barchia, I.M. 2009. Difference in yield and persistence among perennial forages used by the dairy industry under optimum and deficit irrigation. *Crop and Pasture Science 60*: 1071-1087.

Rawnsley, R.P.; Donaghy, D.J.; Stevens, D.R. 2007. What is limiting production and consumption of perennial ryegrass in temperate dairy regions of Australia and New Zealand? pp. 256-274. *In*: Proceedings of the Australasian Dairy Science Symposium. Melbourne. Ed. Chapman, D.F.; Clark, D.A.; Macmillan, K.L.; Nation, D.P. National Dairy Alliance.

Razmjoo, K.; Kaneko, S.; Imada, T. 1993. Varietal differences of some cool-season turfgrass species in relation to heat and flood stress. *International Turfgrass Society Research Journal 7*: 636-642.

Reed, K.F.M. 1996. Improving the adaptation of perennial ryegrass, tall fescue, phalaris, and cocksfoot for Australia. *New Zealand Journal of Agricultural Research 39*: 457-464.

Rollo, M.D.; Sheath, G.W.; Slay, M.W.A.; Knight, T.L.; Judd, T.G.; Thomson, N.A. 1998. Tall fescue and chicory for increased summer forage production. *Proceedings of the New Zealand Grassland Association 60*: 249-253.

Thom, E.R. 2000. How much pasture can we really grow? *Proceedings of the South Island Dairying Event*: 72-79.

Thomson, N.A.; Lagan, J.F.; McCallum, D.A.; Prestidge, R. 1988. An evaluation of Grasslands Roa tall fescue and Graslands Maru phalaris for dairying. *Proceedings of the New Zealand Grassland Association 49*: 187-191.

Thorogood, D. 2003. Perennial ryegrass (*Lolium perenne* L.). pp. 75-105. *In*: Turfgrass biology genetics and breeding. Eds. Casler, M.D.; Duncan, R.R. John Wiley & Sons, New Jersey.