Effects of nitrogen and irrigation on productivity of different ryegrass ecotypes when grazed by dairy cows

I. BAHMANI[1], E.R. THOM[1] and C. MATTHEW[2]
[1]*Dairying Research Corporation, PB 3123, Hamilton*
[2]*Department of Plant Science, Massey University, PB 11-222, Palmerston North*

Abstract

The responses of two perennial ryegrass cultivars, Ellett and Grasslands Ruanui, to nitrogen fertiliser and irrigation, applied before and after flowering, were studied in a field experiment at the Dairying Research Corporation, Ruakura. The former was included as representative of the Mangere perennial ryegrass ecotype, and the latter as representative of older material. Data on herbage accumulation, tiller density and tiller weight were collected, before and after grazing by dairy cows, from September 1996. Nitrogen increased summer herbage accumulation and tiller density by 41% and 37%, respectively. Irrigation increased ryegrass yield by 21% in summer but effects on tiller density and weight were small and inconsistent. No significant effects of nitrogen fertiliser or irrigation treatments on herbage accumulation, tiller density, or tiller weight were observed in spring. Ellett swards produced 5390 kg DM/ha over the trial period, compared with 4450 kg DM/ha for Grasslands Ruanui, although this difference was not statistically significant. However, Ellett had a larger mean tiller weight and a lower tiller density than Ruanui. The contrasting tiller size/density characteristics of the two cultivars are quantified and discussed.

Keywords: dairy cow grazing, Ellett ryegrass, Grasslands Ruanui ryegrass, herbage accumulation, irrigation, *Lolium perenne*, nitrogen fertiliser, tiller size/density compensation

Introduction

Ryegrass ecotypes that have developed over long periods in particular environments are often used by plant breeders as source parent material for new cultivars. Up until 1975, an ecotype from Hawke's Bay (named Grasslands Ruanui in 1964) was the most widely used. Since 1975, the Mangere ecotype from South Auckland has been extensively used. Cultivars such as Ellett, Yatsyn 1, Grasslands Nui, Vedette and Dobson have been derived from this ecotype, and are representative of the "modern" perennial ryegrass.

Ellett and Grasslands Nui were the first of the modern perennial ryegrasses to be commercialised. Plants of these cultivars were more erect with larger leaves than Ruanui (Corkill 1981; Easton 1983) and showed a higher yield potential (Armstrong 1977). Other features of the new selections were better tolerance of summer drought and crown rust, and superior responses to autumn rains and nitrogen (N) fertiliser (Easton 1983).

Matthew *et al.* (1993) suggested that the Mangere ecotype, represented by Ellett ryegrass, had a different perennation strategy from Ruanui, with Ellett more dependent on survival of daughter tillers produced at the base of tillers that had flowered and Ruanui more dependent on surviving vegetative tillers. However, this tentative suggestion was based on data collected in different years. Few other data describing agronomic or ecological comparisons between Ellett and Ruanui ryegrasses have been published. Another aspect of persistence in ryegrass swards is summer tiller population density, which Harris *et al.* (1996) showed was stimulated by N fertiliser. Averaging data for January 1994 and 1995, for example, N-treated areas had 9950 tillers/m^2 compared with 4750 in untreated areas. Irrigation has also increased ryegrass growth during dry periods (Holmes & Wilson 1987).

This paper reports data from the first year of a 2-year study, specifically designed to provide further information on the growth strategies adopted by Ellett and Ruanui ryegrass cultivars. Here we report responses to N fertiliser and irrigation before and after flowering, and the relationships between tiller size, tiller density and herbage accumulation for these two cultivars.

Materials and methods

Site and treatments

The trial was located at the Dairying Research Corporation, Hamilton, New Zealand (37° 47' south, 175° 19' east, altitude 40 m a.s.l). The region is warm temperate with an average air temperature of 13°C and an annual rainfall of 1250 mm. The soil was a poorly drained Te Kowhai clay loam (Singleton 1991).

The trial design was a 2^3 factorial split-plot with the main (6 m × 12 m) plots of endophyte-free perennial ryegrass cultivars Ellett and Ruanui randomly arranged in four blocks. The ryegrass cultivars were direct-drilled

(10 kg /ha) on 24 April 1996, following spraying with glyphosate at 1.44 kg a.i./ha (equivalent to 4l/ha of Roundup[R] G2) plus Pulse penetrant. Nitrogen fertiliser (30 kg N/ha) was applied as urea to half the plot area (sub-plot) following grazings, with a total of 210 kg N/ha applied from September 1996 to April 1997. Isazophos insecticide (Miral 5G at 2 kg a.i./ha) was applied after grazing every 2 months from September 1996 to March 1997 to control Argentine stem weevil. In addition, sub-subplots (three 1 m^2 plots within each subplot) were irrigated from November 1996 to March 1997 using a metal frame to prevent run-off and reduce subsurface water movement. Frames were inserted 2–3 cm into the soil on the plot margins and were removed after the applied water had disappeared. Irrigation took place when the soil moisture measured by a Time Domain Reflectometer dropped below a soil moisture content of 44% or half way between field capacity (60% soil moisture) and wilting point (28% soil moisture) (Thom 1984). In spring and summer 22 litres or 23 mm and 259 litres or 264 mm of irrigation water, respectively, were applied. Dairy cows, stocked at 3.5 cows/ha, grazed the trial for the first time on 24 September 1996, and at intervals of 29 days (spring 1996) and 33 days during summer 1997.

Sward measurements

Herbage accumulation

Pre- and post-grazing herbage mass on each subplot and subsubplot were estimated by taking 40 readings in the former and 5 readings in the latter with a calibrated pasture probe (L'Huillier & Thomson 1988).

Ryegrass tiller density and weight

Two fixed frames (200 mm × 50 mm) were positioned at random across drill rows within each subplot and another in two of the three subsubplots. The number of perennial ryegrass tillers in each fixed frame was counted 1–2 days before and after each grazing. Before each grazing, ryegrass clumps, sufficient to provide a sample of 100 tillers, were located at random positions on drill lines in each subplot and subsubplot, and were cut to ground level. Cut tillers were oven dried at 80°C and weighed.

Data analysis

Tiller density and tiller size data were analysed separately and then the distance from an arbitrarily positioned -3/2 size/density line on a log-log plot calculated as described by Matthew *et al.* (1996). All data were evaluated by analysis of variance, using Genstat version 5. The SAS repeated measures procedure was used to compare spring and summer data. No data transformations were necessary. The distance from the size/density line was assumed to compare the physiological behaviour of each cultivar and to be an index of yield responses to different treatments. The relationship between distance from the size/density line and herbage accumulation was tested by linear regression.

Results

Climate

Weather data from the Ruakura climatological station, 2 km from the trial site, showed total rainfall during October, November 1996 and January, February 1997 was 9% higher than the 10-year average (1185 mm). Autumn and winter 1996 were both wetter than normal as rainfalls in April and September 1996 were 54% and 40%, respectively, higher than average. However, late spring and summer 1996/97 were drier than normal, with rainfall in January and February 1997 being 43% and 75%, respectively, lower than average. Air maximum and grass minimum temperatures were close to the 10-year average for each month except for April 1996, when the grass minimum temperature averaged 5°C above normal (9.2 vs 4.1°C).

Herbage accumulation

Ryegrass herbage accumulation was higher during spring than summer (mean 3110 and 1870 kg DM/ha, respectively) (P<0.001) for all treatments (Table 1).

Table 1 Effects of N fertiliser and irrigation on herbage accumulation (kg DM/ha) of Ellett and Ruanui ryegrasses in spring and summer 1996/97.

Treatments	Spring	Summer	Total
Cultivars			
Ellett	3350	2040	5390
Ruanui	2870	1700	4450
SED[a]	315	129	398
Significance	NS	NS	NS
Nitrogen			
+N	3320	2190	5510
-N	2890	1550	4450
SED	185	158	235
Significance	NS	**	**
Irrigation			
+I	2920	2080	5000
-I	3300	1660	4960
SED	210	139	298
Significance	NS	**	NS

** P<0.01 ; NS not significant
[a]Standard error of difference between pairs of means.
+N : N fertiliser, -N : no N fertiliser
+I : irrigation, -I : no irrigation.

Table 2 Effects of N fertiliser and irrigation on the pre-grazing tiller density in fixed frames (tillers/m^2) over spring and summer 1996/97.

Treatments	Spring	Summer	Average
Cultivars			
Ellett	5120	5895	5510
Ruanui	8170	9350	8750
SED[a]	370	1164	717
Significance	**	(†)	*
Nitrogen			
+N	7260	8810	8040
-N	6040	6430	6220
SED	628	888	686
Significance	NS	*	*
Irrigation			
+I	7150	8150	7650
-I	6140	7100	6610
SED	614	687	591
Significance	NS	NS	NS

(†) P=0.059 ; * P<0.05 ; ** P<0.01 ; NS not significant
[a]Standard error of difference between pairs of means.
+N : N fertiliser, -N : no N fertiliser
+I : irrigation, -I : no irrigation.

Table 3 Effect of season on tiller weight (g/100 tillers) of Ellett and Ruanui ryegrass over spring and summer 1996/97.

Treatment	Spring	Summer	Average
Cultivars			
Ellett	8.82	5.96	7.39
Ruanui	5.49	4.19	4.84
SED[a]	0.470	0.577	0.388
Significance	**	(†)	**
Nitrogen			
+N	7.30	5.10	6.20
-N	7.00	5.06	6.03
SED	0.716	0.198	0.409
Significance	NS	NS	NS
Irrigation			
+I	6.83	4.94	5.88
-I	7.48	5.22	6.35
SED	0.356	0.248	0.211
Significance	(†)	NS	*

(†) P=0.055 ; ** P<0.01
[a]Standard error of difference between pairs of means.
+N : N fertiliser, –N : no N fertiliser
+I : irrigation, –I : no irrigation.

Spring responses to both N and irrigation, were not significant, but summer ryegrass herbage accumulation was increased by 41% (P<0.01) with N, and by 26% (P<0.01) with irrigation. The irrigation response was greatest during January–February when ryegrass yield was increased by 84% (1110 vs 600 kg DM/ha, P<0.001). There were no significant interactions between N and irrigation treatments. Total yield of Ellett was 21% greater than Ruanui, but this difference was not statistically significant.

Pre-grazing tiller density and weight

Pre-grazing ryegrass tiller density was consistently higher on N and irrigated plots (Table 2), but differences were significant (P<0.05) only for N effects in summer. Tiller density was higher (P<0.01) in summer than in spring for both cultivars (Table 2), but tiller weight for Ellett and Ruanui decreased by 32% and 24%, respectively (P<0.001), between spring and summer (Table 3). N and irrigation in spring and summer did not significantly affect tiller weights. Ruanui had a higher tiller density than Ellett during spring and summer, but again there was size/density compensation. Ruanui always had a lower tiller weight (P<0.01) than Ellett (Table 3).

Assuming that a -3/2 power relationship between tiller weight and tiller density represents a constant sward leaf area status (Matthew *et al.* 1996), a log-log plot of treatment mean summer tiller weight versus summer tiller density (Figure 1) allows visual evaluation of the equivalence of different tiller density values, after correction for difference in mean tiller size. This plot shows the tiller density responses within cultivars to N and irrigation, and the lower tiller density and larger tiller size of Ellett compared with Ruanui. Distance from the -3/2 reference line should theoretically correlate with sward productivity (herbage accumulation). This correlation (Figure 2) was statistically significant (R^2 = 0.79, P=0.02) for treatment mean data when parallel lines with different intercepts for Ellett and Ruanui cultivars were fitted, but was not significant when fitted to individual plot data for both cultivars.

Post-grazing tiller density

Post-grazing tiller densities were compared with pre-grazing tiller densities, to estimate tiller losses during grazings. The average percentage removal of tillers during summer grazings was higher for Ellett than Ruanui (11 and 7%, P<0.05) but no significant difference between cultivars was observed in spring. The greatest differences in tiller removal between Ellett and Ruanui were observed under N fertiliser and unirrigated treatments (mean, 17 vs 5%, P<0.05). N and irrigation did not influence tiller removal in spring.

Figure 1 Nitrogen, irrigation and cultivar effects on tiller weight and density in summer.

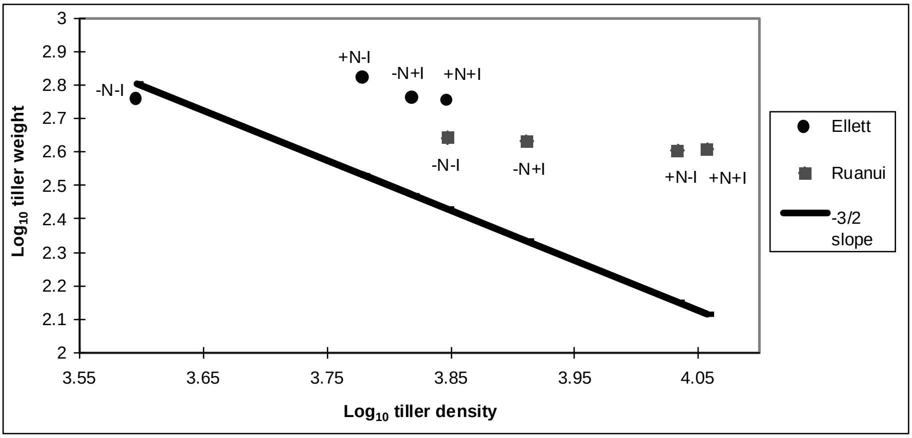
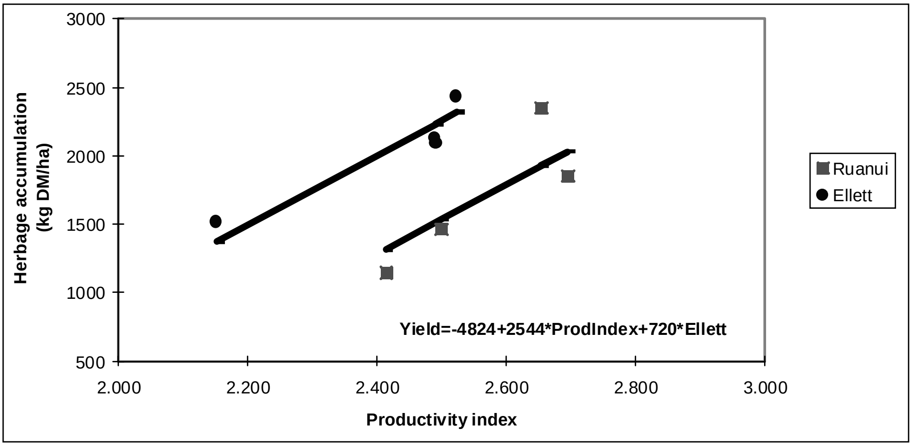


Figure 2 Correlation between herbage accumulation in summer and productivity index.



Discussion

Seasonal pattern of perennial ryegrass growth

Tiller density increased from spring to summer (Table 2), but tiller size decreased (Table 3). These changes reflect a transition from reproductive growth in spring to vegetative growth in summer. During flowering in late spring, a large portion of total plant dry weight is contributed by reproductive tillers and seed-heads, with a small proportion of smaller vegetative tillers, but by mid-summer, after death of reproductive tillers, the tiller population is dominated by vegetative tillers (Korte 1986). Hernandez-Garay *et al.* (1997) also showed an increase of perennial ryegrass tiller weight during the reproductive period, in swards rotationally grazed by sheep. The tiller density increase during the transition from reproductive growth to vegetative growth can be linked to high tillering rates in December. Similar periods of intense tillering by perennial ryegrass have been observed in grazed swards (Chapman *et al.* 1983; Korte *et al.* 1984; L'Huillier 1987; Da Silva *et al.* 1993, 1994) and cut swards (Korte 1986).

However, the optimal management at the time of this transition from a lower density of large reproductive tillers to a higher tiller density of smaller vegetative tillers remains a matter of debate. It is clear that it is possible to target a higher herbage mass (Hernandez-Garay *et al.* 1997) in which case the potential tiller density increase moving into summer is partially blocked by larger tiller size (Figure 2). Alternatively it is possible to target a lower herbage mass and a consequent larger increase in tiller density. This latter strategy is recommended by Brock & Hay (1993).

Previously there has been no theoretical basis to compare these different strategies. The approach suggested by Matthew *et al.* (1996) is directed at answering this question, but cannot yet be regarded as proven. However, we tested the productivity index derived by Matthew *et al.* (1996). Adjustment of spring and summer tiller densities for tiller weight as illustrated for summer in Figure 1, confirmed that greatest productivity was expected in spring, swards being 0.05 log units closer to a -3/2 reference line in summer. Hence this productivity index does correctly predict the higher productivity of the spring swards compared with summer swards. However, this study does not provide data appropriate for validating the optimum herbage mass, since different herbage masses were not a feature of the trial.

Size/density compensation

This experiment clearly shows an inherent difference in tiller size between Ellett and Ruanui (Table 3). However, owing to size/density compensation (Table 2), yield differences were not statistically significant. An unexpected finding was that Ruanui, when compared with Ellett, was less productive than predicted on the basis of weight-corrected tiller density, as indicated by the significant intercept difference in Figure 2. Possible reasons for this higher-than-predicted herbage accumulation of Ellett include lower % pseudostem or root:shoot ratio, or higher photosynthetic activity in Ellett. Further research will be needed to clarify this point.

N fertiliser and irrigation effects

N fertiliser generated the greatest response during summer (December–January). This is consistent with earlier findings that grass plants are relatively unresponsive to nitrogen during reproductive growth, but may show some response in early summer when nitrogen can partly offset moisture stress (Whitehead 1970; Field & Ball 1978). Similarly, the irrigation response in summer was expected. For example, Thomson (1996) found that 235 mm irrigation water in summer–autumn increased average pasture production by 57% compared with no irrigation (4590 vs 2920 kg DM/ha) under intensive cow grazing. Figure 1 suggests that Ruanui was more responsive to N and less sensitive than Ellett to stress when water and N were withheld, but this was not confirmed by significant interaction terms in ANOVA. Dry conditions in summer have an important impact on ryegrass growth. Plant response to water and N stress, stimulated by different physiological mechanisms, were associated with a decrease in plant shoot/root ratio (Thornley 1977). Lack of moisture inhibits the macro- and microbiological activity in soil, necessary to decompose the vegetative or animal organic matter such as dung left by dairy cows after each grazing.

No significant effects of N fertiliser or irrigation were observed on tiller weight whereas the tiller density response to N was strong and resulted in a similar response in herbage accumulation, but was non-significant for irrigation. From these results it appears that the two components of yield, tiller density and size were not influenced by the same factors. According to Chapman & Lemaire (1993), tiller density is a sward structural character that is influenced by environmental factors and sward botanical composition, whereas tiller weight is a genotypic character that is influenced by frequency and intensity of defoliation. In addition, effects of environmental factors, particularly N, on herbage accumulation were shown more via tiller density than tiller weight.

Tiller loss during grazing

Ellett ryegrass (derived from the Mangere ecotype) lost more tillers by pulling during summer grazing than did Ruanui. Thom *et al.* (1996) has also shown a low tolerance of pulling for some ryegrass cultivars originating from the Mangere ecotype. The morphological and genotypic differences in tiller size between the two cultivars may explain differences in pulling, Ellett having larger leaves (Easton 1983) and more upright tillers than Ruanui, which are more easily accessible to dairy cows and may therefore be easier to pull. Thom *et al.* (1996) also showed the leaf shear strength affects pulling.

The highest pulling levels were observed when N fertiliser was applied without irrigation, confirming research (Tallowin 1985; Thom *et al.* 1996) that ryegrass pulling increased when soil moisture levels were low, as was the case in the 1996/97 summer of this trial. Others have also correlated increased ryegrass pulling with N fertiliser use (Tallowin *et al.* 1986; Fulkerson *et al.* 1993).

Conclusion

Nitrogen fertiliser and irrigation increased ryegrass herbage accumulation in summer. Two cultivars, Ellett, representative of “modern” perennial ryegrass, and the older cultivar Ruanui had different sward structures. Ellett had greater pulling losses, and a higher tiller weight and a lower tiller density than Ruanui. Based on weight-corrected tiller density, Ruanui should have been the more productive, but the opposite was the case. Elucidation of reasons for the relatively good performance of Ellett ryegrass could lead to identification of selection criteria for use in plant breeding.

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