# The performance of irrigated mixtures of tall fescue, ryegrass and white clover in subtropical Australia. 2. The effects on yield and botanical composition of managing for quality

K.F. LOWE, T.M. BOWDLER, J.A. WHITE, S.A. LOWE AND M.N. CALLOW
*Department of Primary Industries and Fisheries, Mutdapilly Research Station, Peak Crossing, Queensland, Australia*

## Abstract

The effects on yield, botanical composition and persistence, of using a variable defoliation schedule as a means of optimising the quality of the tall fescue component of simple and complex temperate pasture mixtures in a subtropical environment was studied in a small plot cutting experiment at Gatton Research Station in south-east Queensland. A management schedule of 2-, 3- and 4-weekly defoliations in summer, autumn and spring and winter, respectively, was imposed on 5 temperate pasture mixtures: 2 simple mixtures including tall fescue (*Festuca arundinacea*) and white clover (*Trifolium repens*); 2 mixtures including perennial ryegrass (*Lolium perenne*), tall fescue and white clover; and a complex mixture, which included perennial ryegrass, tall fescue, white, red (*T. pratense*) and Persian (*T. resupinatum*) clovers and chicory (*Cichorium intybus*).

Yield from the variable cutting schedule was 9% less than with a standard 4-weekly defoliation. This loss resulted from reductions in both the clover component (13%) and cumulative grass yield (6%). There was no interaction between cutting schedule and sowing mixture, with simple and complex sowing mixtures reacting in a similar manner to both cutting schedules. The experiment also demonstrated that, in complex mixtures, the cutting schedules used failed to give balanced production from all sown components. This was especially true of the grass and white clover components of the complex mixture, as chicory and Persian clover components dominated the mixtures, particularly in the first year.

Quality measurements (made only in the final summer) suggested that variable management had achieved a quality improvement with increases in yields of digestible crude protein (19%) and digestible dry matter (9%) of the total forage produced in early summer. The improvements in the yields of digestible crude protein and digestible dry matter of the tall fescue component in late summer were even greater (28 and 19%, respectively). While advantages at other times of the year were expected to be smaller, the data suggested that the small loss in total yield was likely to be offset by increases in digestibility of available forage for grazing stock, especially in the critical summer period.

Correspondence: Kevin F. Lowe, Department of Primary Industries and Fisheries, Mutdapilly Research Station, MS 825, Peak Crossing, Qld 4306, Australia.
E-mail: kevin.lowe@dpi.qld.gov.au

## Introduction

Alternative temperate perennial grasses, especially tall fescue (*Festuca arundinacea*), are more persistent during the hotter months and produce more yield in subtropical areas of Australia than perennial ryegrass (*Lolium perenne*) cultivars, which are more seasonally variable and heat-sensitive (Lowe and Bowdler 1984; 1995). Callow *et al*. (2003) established that there were differences in the adaptation of tall fescue cultivars to a subtropical environment, with Dovey, Quantum, Jessup, AU Triumph and Cajan being most productive. However, these were also generally those with lowest forage quality. In a grazing experiment in a subtropical environment, milk production from AU Triumph tall fescue was less efficient (less milk produced per unit of forage on offer) than from Yatsyn 1 perennial ryegrass, although production improved when pastures were managed to limit a build-up of mature forage (Lowe *et al*. 1999a; 1999b).

In an investigation into the effects of aging on tall fescue foliage in this environment, Callow *et al*. (2003) established that quality could be improved, irrespective of cultivar, if tall fescue was grazed every 2–3 weeks during spring and summer and every 3–4 weeks in autumn and winter. However, the effect of this management strategy on growth and persistence was not established. This second paper in a series to study tall fescue-ryegrass mixtures, investigated the effects of this variable defoliation treatment, compared with a standard, 4-weekly defoliation, on the yield, botanical composition and persistence of the best pasture mixture options from the previous experiments (Lowe *et al*. 2009).

## Materials and methods

### *Site*

A field study was conducted from 1999 to 2002 at Gatton Research Station in south-east Queensland (27°34′S, 152°20′E; elevation 95 m). The soil type, described in Lowe *et al*. (2009), was a deep, fertile alluvium. During April 2000 and 2001, 300 kg/ha of superphosphate (88 g/kg P; 110 g/kg S) was applied to treat a possible sulphur deficiency in long-term swards (Dickson and Asher 1974). Urea (460 g/kg N) was applied at 120 kg/ha in early spring to improve grass recovery after winter (Anon 1995). Plots were irrigated fortnightly using hand-shift overhead sprinklers to ensure yields were not limited by soil moisture stress (Anon 1995).

### *Treatments and design*

Forty 10 $m^2$ plots were sown by hand in April 1999 with seed of one of 5 temperate pasture mixtures (see below). The cultivars were chosen because they contributed specific characteristics to the various mixtures: the tall fescue cultivars, Dovey and Quantum, had the most vigorous seedlings and were the only commercially available cultivars of those recommended by Callow *et al*. (2003); and the perennial ryegrass cultivars, Bronsyn (diploid) and Quartet (tetraploid), had performed well in screening experiments (Lowe *et al*. 1999c). In the simple mixtures, all ryegrasses were sown at 10 kg/ha and white clover (*Trifolium repens* cv. Haifa) at 5 kg/ha. There were 3 tall fescue sowing rates: 5 (complex mixtures), 15 (ryegrass-tall fescue mixtures) and 25 (tall fescue mixtures) kg/ha. The complex mixture contained temperate species, which, when combined, could provide a longer growing period than that expected from simple mixtures.

The treatments (sowing rate in brackets) were:

(1) Dovey tall fescue (15), Bronsyn perennial ryegrass (10) and Haifa white clover (5) (DBH)
(2) Dovey (25) and Haifa (5) (DH)
(3) Dovey (5), Impact perennial ryegrass (10), Aran white (1), Sustain white (1), Renegade red (*T. pratense*) (6) and Maral Persian (*T. resupinatum*) (1) clovers and Puna chicory (*Cichorium intybus*) (1) (Complex mixture)
(4) Quantum tall fescue (15), Quartet hybrid ryegrass [*L. hybridum* (syn. *L.* x *boucheanum*)] (10) and Haifa (5) (QmQtH)
(5) Quantum (25) and Haifa (5) (QmH).

There were 2 cutting frequencies:

(1) fixed (4-weekly)
(2) variable [2-weekly (summer), 3-weekly (autumn and spring) and 4-weekly (winter)].

Plots were laid out in a randomised block design with 4 replicates. Harvesting commenced in June 1999 and sampling continued for 3 years.

### *Measurements*

*Yield and botanical composition.* Yield and botanical composition were measured by cutting a 5.9 $m^2$ quadrat from the central section of each plot as described in Lowe *et al*. (2009). Subsamples were taken for determining dry matter and botanical composition. Sorting of all samples during the first 12 months revealed that botanical composition did not change significantly within seasons so, in subsequent years, only the sample from the harvest at the end of each seasonal period was sorted. These data were applied to the preceding harvests in the same season. Samples were dried in a forced-draught oven at 80°C for 24 h. After each sampling, the residual material on each plot was removed using a forage harvester. Seasonal yields were calculated by summing the DM yields measured within the following periods: autumn — March 1 to May 31, winter — June 1 to August 31, spring — September 1 to November 30 and summer — December 1 to February 28/29. A harvest was included in a seasonal yield if more than half the growth period occurred in that season.

Plant density of all components was assessed monthly from October 1999 to September 2000 using a fixed 1 × 0.25 m quadrat, divided into a 100-square grid. Subsequently, plant density was recorded at the end of summer 2001 and on completion of the study. Plant occurrence of components was determined for all plots in late summer 2002 using the same fixed quadrat by estimating the percentage of the 100 squares containing grass basal tillers or growing points of clover or chicory.

*Forage quality.* Differences in forage quality as a result of the management strategies utilised here were established by Callow *et al*. (2003). As the aim of the experiment was to determine the effect of management on growth and persistence, there was no plan for detailed quality sampling to confirm Callow's findings over the duration of the experiment. However, to establish that an improvement in quality had been achieved, 'point in time' checks on all treatments were conducted in early and late summer 2001–02, when quality differences were expected to be greatest (Callow *et al*. 2003).

As the variable treatment was defoliated twice over a 4-week period in summer and the fixed treatment only once, the two 2-weekly samples of the variable treatment were combined (in direct proportion to their respective yields) for quality analyses over the same time-frame. As no ryegrass remained in any of the swards, the DH and DBH and QmH and QmQtH treatments were also combined, providing 3 treatments (Dovey, Quantum and complex mixture) by 4 replicates for quality analyses.

In early January 2002, bulk forage samples (unsorted) were submitted for analysis using Near Infrared Reflectance Spectroscopy (NIR006), while in late February 2002 material was sorted into tall fescue, white clover, chicory and weeds but only the tall fescue component was submitted for analysis. Calibrations were previously derived according to procedures outlined by Smith and Flinn (1991): crude protein (CP)%, acid detergent fibre (ADF)%, neutral detergent fibre (NDF)%, digestible protein (DCP)% and digestible dry matter (IVDDM)%. The reference methods used for NIR calibration were the Flinn and Saul (1983) method for CP and NDF and a pepsin-cellulase technique (Clarke *et al*. 1982) for IVDMD. Analytical values were first adjusted using a linear regression based on similar samples of known *in vivo* DMD and checked by analysing a small number of samples using reference methods and comparing NIR and reference values (Callow *et al*. 2003).

### *Statistical analyses*

Cumulative yields were analysed for each season, each year and the duration of the study. Data for yields, plant density and plant occurrence were subjected to 3-way analyses of variance using the statistical package 'Genstat' (Payne *et al*. 2007). Repeated measurements analysis of variance was performed on the seasonal yield and plant density data. Component and total yield data were normally distributed and did not require transformation. Weed data were log-transformed using (yield+0.0001). Detailed first-year plant density data needed square root transformation but annual plant density and % occurrence data analyses were not improved by the transformation and are presented untransformed.

### *Climate*

Rainfall, evaporation and temperature recorded at Gatton during the experimental period have been presented previously (Lowe *et al*. 2009). Generally, the summers became hotter over the 3 years of the experiment while the winters became colder. More frosts were recorded in the 2001 winter than in the preceding winters. Evaporation rates increased in the same manner as maximum temperature. Spring rainfall was average or above average in all 3 years, while summer rainfall was always below average.

## Results

As there were no significant interactions between pasture mixture and cutting frequency, only the main effects data have been presented.

### *Annual and total yields*

*Cutting schedule.* Over the 3 years, total yield with the variable cutting schedule was 9% less ($P<0.05$) than with a fixed, 4-weekly cutting schedule (Table 1). This reduction was made up of a 13% reduction in clover yield and a 6% reduction in grass yield. All pasture components except perennial ryegrass and chicory produced higher yields (P<0.05) under the fixed schedule; ryegrass yield was higher (P<0.05) under variable cutting.

Total and tall fescue yields were higher (P<0.05) under the fixed cutting schedule in all 3 years (Figure 1A), while combined white and Persian clover yields were higher (P<0.05) under the fixed cutting schedule in the first year only. Ryegrass yield was unaffected by cutting schedule in the first year but was higher under the variable schedule in the second year.

*Pasture mixtures.* Total yield in the DBH mixture was less (P<0.05) than in most other mixtures (Table 1). Total grass yield in the complex mixture was less than 40% of that for the other mixtures (P<0.05), and total clover yield was lower (P<0.05) in the complex mixture, even with the contribution of the Persian and red clover components.

Bronsyn was the highest-yielding ryegrass (P<0.05), producing over 1 t/ha more over 3 years than Quartet, while Impact ryegrass produced low yields in the complex mixture (Table 1). Both tall fescue cultivars in the single-grass mixtures (DH and QmH) produced about 50% more than the tall fescue component in the 2-grass mixtures (DBH and QmQtH). While Dovey tall fescue produced more (P<0.05) than Quantum in the 1-grass mixtures, there were no cultivar differences in the 2-grass mixtures. On the other hand, the yield of Dovey in the complex mixture was much lower (P<0.05) than in the 1- or 2-grass treatments. Chicory yield was outstanding in the complex mixture. Haifa white clover yielded more (P<0.05) in association with Quantum than with Dovey in both the 1- and 2-grass mixtures, and yielded more than the combination of white clovers in the complex mixture (P<0.05). Weed yields were unaffected (P>0.05) by sowing combination.

While the complex mixture yielded more than the other mixtures in the first year, it yielded less in the second and third years (Figure 1B). This was the result of the contribution made by chicory and Persian clover in the first year. All other components were lower-yielding (P<0.05) in the complex mixtures in all 3 years. Tall fescue yields were higher (P<0.05) in the 1-grass mixtures than in the 2-grass mixtures in the first and second years.

### *Seasonal yields*

*Stand age.* In all seasons, total yields were lower in Years 2 and 3 than in the first year (P<0.05), with the greatest effect in winter (Figure 2A). However, components responded differently in different seasons. Ryegrass yields were very low after the first winter-spring period, while yields of tall fescue tended to increase with time. White clover responded differently between seasons, with significant (P<0.05) decreases with age of stand in summer and autumn but increases in winter and spring.

*Cutting schedule.* Fixed cutting generally produced higher (P<0.05) total and white clover

**Table 1.** Cumulative yields of ryegrass, tall fescue, clovers, chicory and weeds in various pasture mixtures at two cutting frequencies over 3 years (1999–2002).

| Treatment | Cumulative yields | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Ryegrass | Fescue | White clover | Red clover | Persian clover | Chicory | Weeds | Total grass | Total clovers | Overall total |
| | (t/ha) | | | | | | | | | |
| *Effect of pasture mixture* | | | | | | | | | | |
| Dovey, Bronsyn, Haifa (DBH) | 8.89 | 15.07 | 15.29 | — | — | — | 0.19 | 23.95 | 15.29 | 39.44 |
| Dovey, Haifa (DH) | 0 | 24.25 | 16.12 | — | — | — | 0.32 | 24.29 | 16.28 | 40.89 |
| Complex mixture | 2.00 | 7.31 | 3.01 | 2.80 | 6.98 | 19.48 | 0.29 | 9.30 | 12.79 | 41.60 |
| Quantum, Quartet, Haifa (QmQtH) | 7.81 | 15.63 | 17.77 | — | — | — | 0.15 | 23.44 | 17.77 | 41.36 |
| Quantum, Haifa (QmH) | 0 | 22.92 | 18.02 | — | — | — | 0.21 | 22.92 | 18.02 | 41.14 |
| LSD (P=0.05) | 0.59 | 1.06 | 1.57 | — | — | — | NS | 1.02 | 1.57 | 1.69 |
| *Effect of cutting schedule*[1] | | | | | | | | | | |
| Fixed | 3.55 | 17.92 | 14.63 | 0.70 | 1.79 | 3.76 | 0.15 | 21.47 | 17.12 | 42.77 |
| Variable | 3.95 | 16.14 | 13.45 | 0.49 | 1.00 | 4.03 | 0.21 | 20.09 | 14.94 | 39.00 |
| LSD (P=0.05) | 0.37 | 0.67 | 0.99 | 0.23 | 0.40 | 0.41 | NS | 0.68 | 0.99 | 1.07 |

[1] Fixed = cut 4-weekly; Variable = cut 2-weekly in summer, 3-weekly in autumn and spring and 4-weekly in winter.

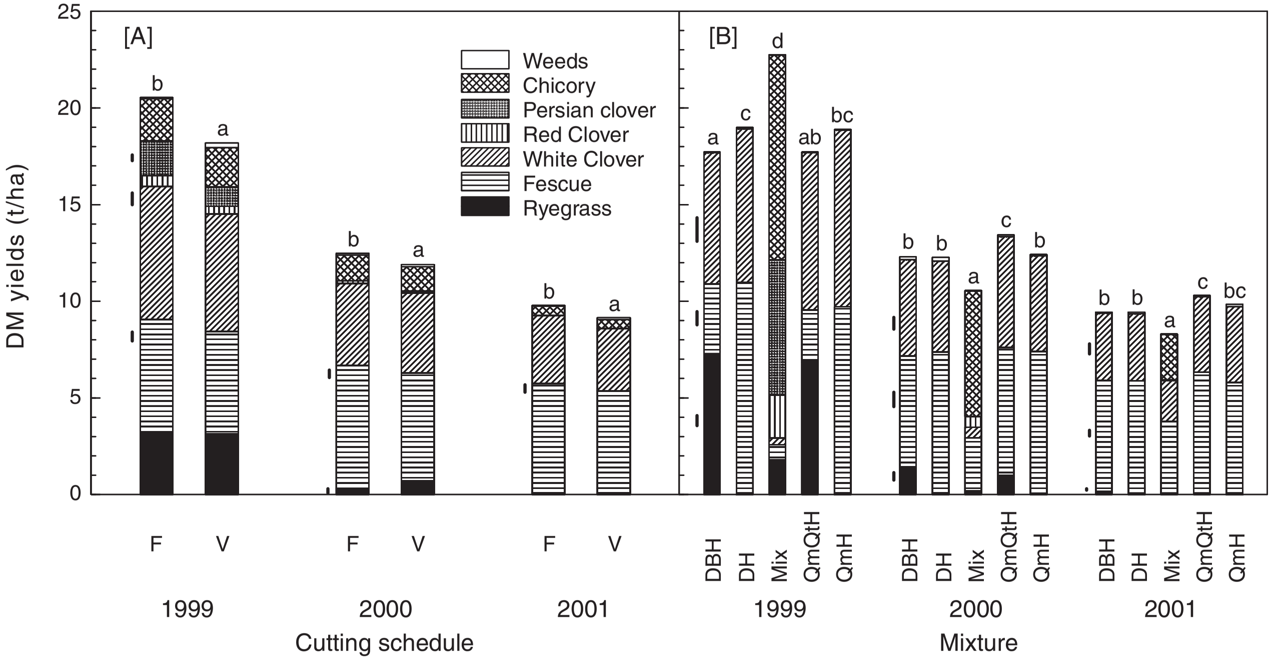


**Figure 1**. Effects of: [A] cutting schedule (F — fixed cutting schedule; V — variable cutting schedule) and [B] mixture (DBH — Dovey, Bronsyn, white clover; DH — Dovey, white clover; Mix — complex mixture; QmQtH — Quantum, Quartet, white clover; QmH — Quantum, white clover) on the annual DM yield and component yields of tall fescue-based mixtures at Gatton over 3 years.
Vertical bars alongside each component indicate significance at P=0.05. Column totals, within years, headed by different letters are significantly different at P=0.05.

yields in all seasons and higher tall fescue yields in spring and summer than a variable cutting regime (Figure 2B). Persian clover produced more (P<0.05) under fixed cutting in winter and spring, but made little contribution in the other seasons. Chicory was unaffected by cutting schedule in any season.

*Pasture mixture.* Total yields were affected by sowing mixture only during winter and spring (Figure 2C). During winter, the order was: complex mixture < 1-grass mixtures < 2-grass mixtures — (P<0.05). However in spring, the reverse occurred with the complex mixture producing the highest yields and the 1-grass mixtures outyielding the 2-grass mixtures.

Ryegrass, tall fescue and white clover yields were always lower (P<0.05) in the complex mixture in all seasons (Figure 2C). While Bronsyn outyielded (P<0.05) Quartet in spring, yields of tall fescue were similar in all seasons (P>0.05). Chicory contributed most to the complex mixture during spring and summer, while Persian clover yielded best in spring.

### *Plant density*

*Cutting schedule.* Tall fescue density was generally highest (P<0.05) under the variable cutting schedule in the second 6 months (November 1999–April 2000) (Figure 3A), but there was no difference (P>0.05) by the end of the experiment (Table 2). There was a significant rise in tall fescue density from October to mid-summer of the first year, a fall (P<0.05) to March and a further significant rise until the second spring (Figure 3A). By the end of the third summer, density had dropped from a peak of about 160 plants/$m^2$ to about 10 plants/$m^2$. While ryegrass density tended to be higher under the variable cutting schedule during the first year (Figure 3B), the differences rarely reached significant levels. Ryegrass density declined (P<0.05) to February–March but increased again to September (Figure 3B) in the establishment year but there was little ryegrass by the end of the third summer (Table 2). White clover density was also generally higher (P<0.05) under the variable cutting schedule in the first year (Figure 3C) but the effect disappeared in subsequent years (Table 2). White clover density increased (P<0.05) until January, fell to March and then rose until September of the first year (Figure 3C). There was a continued rise until the end of the second summer (Table 2), with plant numbers falling to very low levels (about 10 plants/$m^2$) by the end of the third summer.

**Table 2.** Plant density of ryegrass, tall fescue and clovers in various pasture mixtures at the end of each summer from 2000 to 2002 under two cutting frequencies.

| Treatment | February 2000 | | | February 2001 | | | February 2002 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ryegrass | Fescue | White clover | Ryegrass | Fescue | White clover | Ryegrass | Fescue | White clover |
| | | | | | (Plants/$m^2$) | | | | |
| *Effect of pasture mixture* | | | | | | | | | |
| Dovey, Bronsyn, Haifa (DBH) | 4.2 (73)[1] | 8.5 (74) | 16.0 (259) | 4.8 (122) | 9.7 (94) | 18.6 (346) | 0.9 (2) | 3.1 (10) | 3.0 (9) |
| Dovey, Haifa (DH) | — | 12.8 (164) | 16.1 (263) | — | 14.4 (209) | 18.6 (348) | — | 3.3 (11) | 2.6 (7) |
| Complex mixture | 1.7 (8) | 4.2 (21) | 3.2 (14) | 4.7 (109) | 7.2 (56) | 8.1 (69) | 0.4 (1) | 3.3 (11) | 3.2 (11) |
| Quantum, Quartet, Haifa (QmQtH) | 4.0 (57) | 9.1 (84) | 15.9 (257) | 4.8 (123) | 10.1 (104) | 17.3 (305) | 0.8 (2) | 3.1 (10) | 2.9 (9) |
| Quantum, Haifa (QmH) | — | 12.4 (158) | 16.3 (265) | — | 14.7 (217) | 18.4 (341) | — | 3.6 (13) | 3.0 (10) |
| LSD[2] (P=0.05) | | | | 0.6 | 1.1 | 1.1 | | | |
| *Effect of defoliation frequency*[3] | | | | | | | | | |
| Fixed | 3.3 (28) | 9.1 (95) | 12.1 (182) | 4.7 (69) | 10.6 (125) | 16.0 (280) | 0.5 (1) | 3.2 (10) | 3.0 (10) |
| Variable | 3.3 (27) | 9.7 (105) | 13.0 (242) | 4.8 (73) | 11.8 (146) | 16.4 (283) | 0.9 (2) | 3.3 (11) | 2.9 (9) |
| LSD[2] (P=0.05) | | | | 0.2 | 0.4 | 0.4 | | | |

[1] Means are square root transformations (back transformed values in brackets).
[2] LSD values are provided for testing within and between years for each species.
[3] Fixed = cut 4-weekly; Variable = cut 2-weekly in summer, 3-weekly in autumn and spring and 4-weekly in winter.

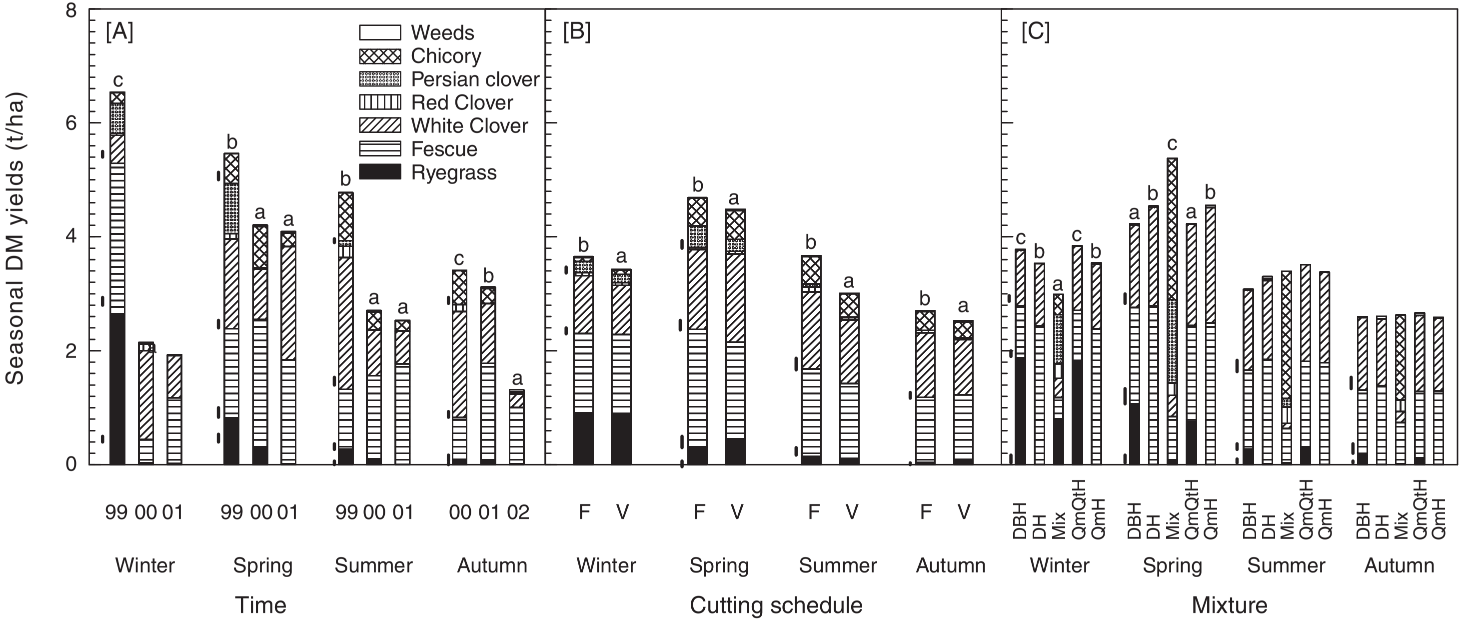


**Figure 2.** Effects of: [A] year (99 — 1999, 00 — 2000, 01 — 2001, 02 — 2002), [B] cutting schedule (F — fixed cutting schedule; V — variable cutting schedule) and [C] mixture (DBH — Dovey, Bronsyn, white clover; DH — Dovey, white clover; Mix — complex mixture; QmQtH — Quantum, Quartet, white clover; QmH — Quantum, white clover) on the seasonal DM yields of swards and component species sown at Gatton in 1999.
Vertical bars alongside each component indicate significance at P=0.05. Column totals, within seasons, headed by different letters are significantly different at P=0.05.

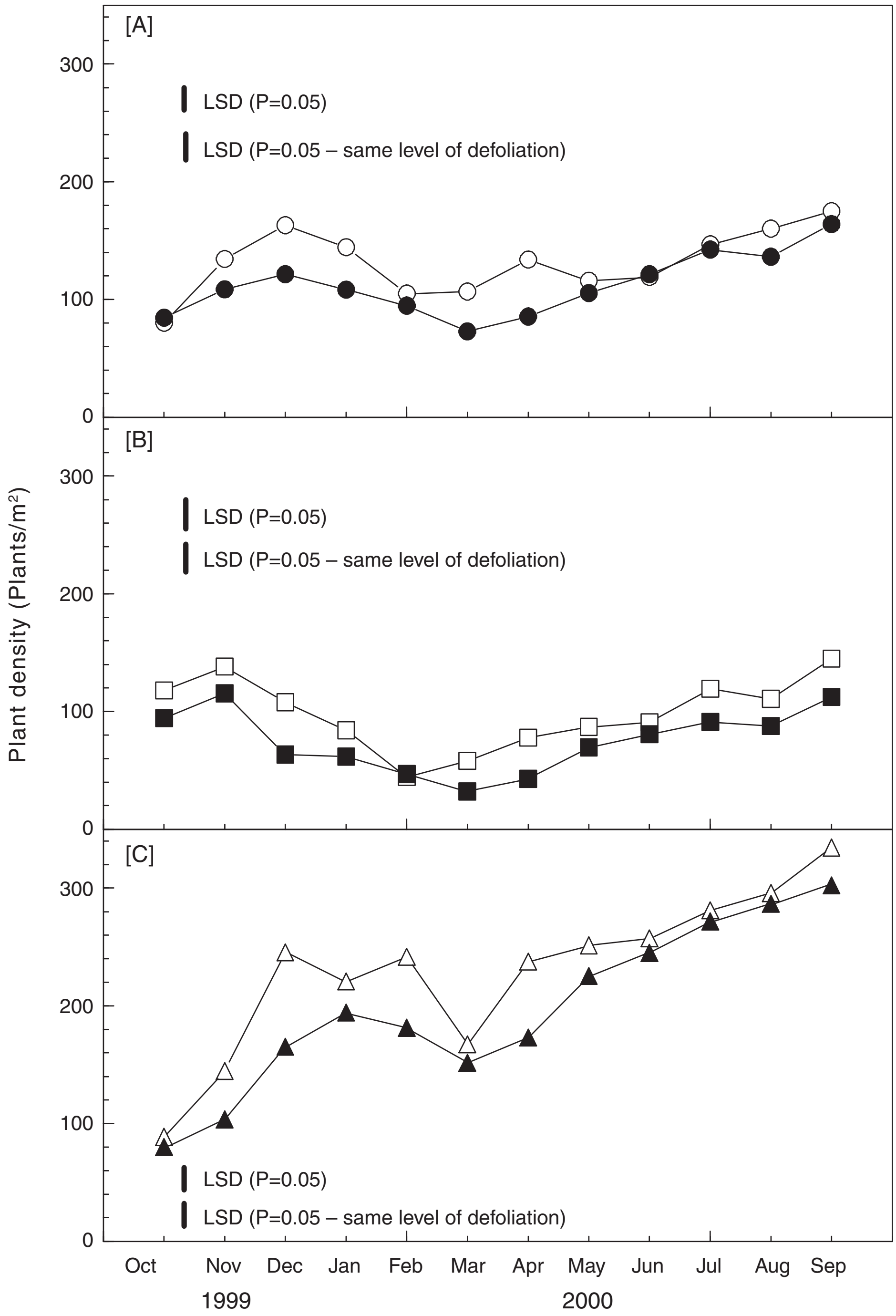


**Figure 3**. The effects of cutting schedule (open markers — fixed frequency; solid markers — variable frequency) on the plant density of [A] tall fescue, [B] perennial ryegrass, [C] white clover in tall fescue-based pastures (averaged over 5 pasture mixtures) from spring 1999 to spring 2000.

Persian and red clovers and chicory failed to respond to cutting schedule and were always present at lower densities than the other components. Red clover density increased in the second winter and spring periods but there was no effect of cutting schedule (data not presented).

*Pasture mixtures.* Tall fescue density was highest in the 1-grass mixtures and lowest in the complex mixture (Figure 4A). Ryegrass density in the 2-grass mixtures was similar (P>0.05) but higher (P<0.05) than that in the complex mixture until the first winter (Figure 4B). White clover density was similar (P>0.05) in all except the complex mixture (Figure 4C). In the complex mixture, Persian clover did not regenerate after the first summer (data not presented), while red clover increased in numbers (P<0.05) in the second spring but had disappeared by the end of the experiment. Chicory maintained a density of around 25–30 plants/m$^2$ until the end of the second year (Figure 4E). Component density in all mixtures was generally similar (P>0.05) at the end of the experiment (Table 2).

### *Percent occurrence*

While the density data (Table 2) suggest that there were very few plants of any species remaining at the end of the experiment, plant size was substantial and plots retained a substantial level of ground cover (Table 3). In general, tall fescue was most prolific, followed by white clover, with very little ryegrass. Only tall fescue persistence was influenced by defoliation schedule, with a higher % occurrence under the variable defoliation frequency (42% *vs* 55 %).

**Table 3.** Percent occurrence of pasture components in various pasture mixtures in February 2002.

| Pasture mixture | Ryegrass | Fescue | White clover | Chicory |
|---|---|---|---|---|
| | | (%) | | |
| Dovey, Bronsyn, Haifa (DBH) | 0.6 | 43.6 | 27.5 | 0 |
| Dovey, Haifa (DH) | 0 | 51.7 | 29.4 | 0 |
| Complex mixture | 2.5 | 37.1 | 19.3 | 9.6 |
| Quantum, Quartet, Haifa (QmQtH) | 0 | 49.5 | 40.5 | 0 |
| Quantum, Haifa (QmH) | 0 | 61.0 | 41.1 | 0 |
| LSD (P=0.05) | NS | 11.6 | 15.3 | na |

### *Quality*

Defoliating on a 2-weekly basis significantly (P<0.05) increased quality of mid-summer forage in the third year in all measured attributes, compared with the standard 4-weekly defoliation (Table 4). This amounted to an 11–15% improvement in ADF, NDF, CP and DCP concentrations, and a 3% increase in DDM. Pasture mixture affected (P<0.05) only crude protein and digestible crude protein concentrations with foliage from the complex mixture generally of lower quality than that of the simple mixtures. The trends for tall fescue forage in late summer were similar (Table 5).

Yields of CP, DCP and DDM in both January and February were higher (P<0.05) under the variable defoliation treatment than under the fixed cutting schedule (Tables 4 and 5). The complex mixture yielded 30–50% less for all quality attributes than the simple mixtures (data not presented). Variable cutting increased digestible crude protein and digestible dry matter yields of the whole pasture by 19% and 9%, respectively, in early summer compared with the fixed schedule. Corresponding figures in late summer for the tall fescue component were 28% and 19%, respectively. While there was a significant interaction between pasture mixture and defoliation system in early summer, these effects were small compared with the main effects.

## Discussion

Employing a seasonally variable defoliation schedule, as recommended by Callow *et al*. (2003) to improve the quality of the tall fescue component of perennial ryegrass-tall fescue mixtures at critical times of the year, reduced the yield of all pasture components except ryegrass over the 3-year life of this experiment, compared with the currently recommended fixed frequency of 4 weeks. While total yield was reduced by around 9%, the depression in clover yields was much greater (about 13%). We are unaware of reports from other environments of experiments which employed differential seasonal defoliation management specifically to improve forage quality. However, Milne *et al*. (1989) cited farmer experience from New Zealand to demonstrate improved tall fescue utilisation in summer by the use of increased defoliation frequency. Varying

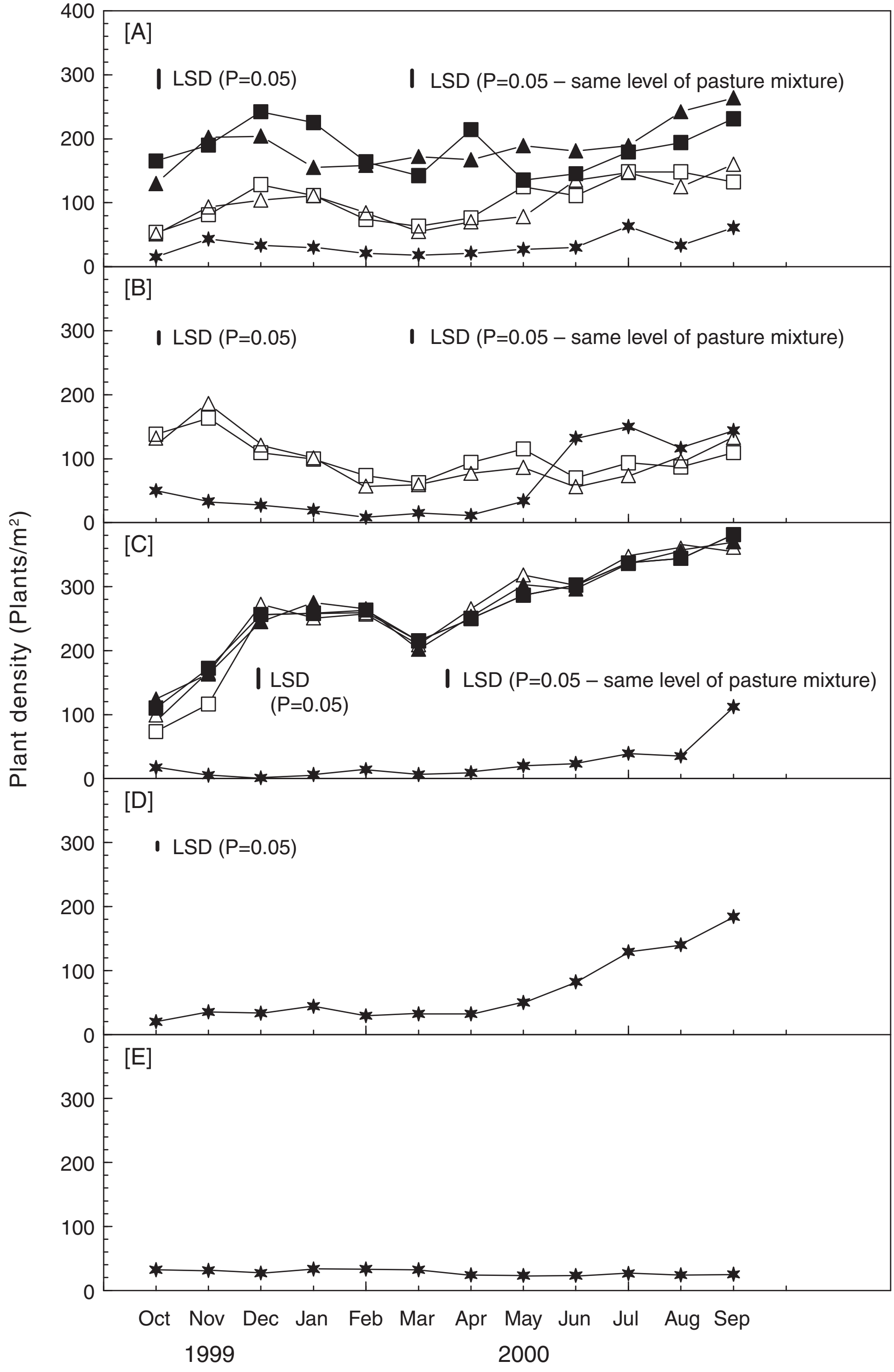


**Figure 4**. The effects of pasture mixture (DH — closed squares, DBH — open squares, QmH — closed triangles, QmQtH — open triangles, Complex mixture — stars) on the plant density of [A] tall fescue, [B] perennial ryegrass, [C] white clover, [D] red clover and [E] chicory in tall fescue-based pastures (averaged over cutting schedule effects) from spring 1999 to spring 2000.

defoliation frequency has been used to increase production of perennial ryegrass (Chestnutt *et al*. 1977) and to modify competitive advantage (Rhodes and Ngah 1983; Bell 1985). There is also ample evidence of depression in yields of clover (Rhodes and Ngah 1983), perennial ryegrass (Chestnutt *et al*. 1977) and tall fescue (Bell 1985) as cutting frequency increases. In Northern Ireland, introducing a single, 2-weekly defoliation into a regular 3-weekly defoliation frequency reduced total yield in a pure ryegrass sward by around 5% (Binnie *et al*. 1997).

Callow *et al*. (2003) provided no estimate of the likely penalty in yield by using a variable defoliation schedule and this current experiment has provided some evidence of the magnitude of the loss. While Callow's data showed improvement in quality by reducing defoliation frequencies in spring, summer and autumn, the major improvement came in summer. The spot checks on quality we took in this study support his findings as variable cutting improved the yield of digestible dry matter and digestible crude protein of the total forage by 9% and 19%, respectively, in January and of the tall fescue component by 19% and 28%, respectively, in late February. Similarly, in a temperate environment, Binnie *et al*. (1997) suggested that longer defoliation intervals for ryegrass in summer would increase production, but this would be at the expense of quality. As the digestibility of tall fescue deteriorates rapidly as forage matures (Gillet 1975), especially in summer in subtropical regions (Callow *et al*. 2003), the yield loss we recorded with more frequent cutting should be offset to some extent by the higher digestibility of the available material. Our recommendation of a combination of longer growth intervals in spring and shorter intervals in summer is similar to that of Binnie *et al*. (1997) from research in a temperate environment.

**Table 4.** Concentration and yield of protein, digestible protein and digestible dry matter of total herbage produced in the 4 weeks preceding the mid-summer harvest in the 2001–02 summer in response to defoliation schedule. Variable cutting frequency data are the mean of two 2-week growth periods.

| Treatment[1] | Acid detergent fibre | Neutral detergent fibre | Crude protein | Digestible crude protein | Digestible dry matter |
|---|---|---|---|---|---|
| *Quality (g/kg)* | | | | | |
| Fixed | 275 | 433 | 179 | 126 | 690 |
| Variable | 241 | 390 | 206 | 144 | 720 |
| LSD (P=0.05) | 11 | 31 | 8 | 6 | 11 |
| *Yield (kg/ha)* | | | | | |
| Fixed | — | — | 272.6 | 190.7 | 1039 |
| Variable | — | — | 323.9 | 226.7 | 1133 |
| LSD (P=0.05) | — | — | 20.7 | 14.8 | 67.2 |

[1] Fixed = cut 4-weekly; Variable = cut 2-weekly in summer, 3-weekly in autumn and spring and 4-weekly in winter.

**Table 5.** Concentration and yield of protein, digestible protein and digestible dry matter of tall fescue herbage produced in the 4 weeks preceding the late-summer harvest in the 2001–02 summer in response to defoliation schedule. Variable cutting frequency data are the mean of two 2-week growth periods.

| Treatment[1] | Acid detergent fibre | Neutral detergent fibre | Crude protein | Digestible crude protein | Digestible dry matter |
|---|---|---|---|---|---|
| *Quality (g/kg)* | | | | | |
| Fixed | 327 | 600 | 187 | 131 | 652 |
| Variable | 313 | 592 | 206 | 144 | 663 |
| LSD (P=0.05) | 7 | NS | 5 | 4 | 6 |
| *Yield (kg/ha)* | | | | | |
| Fixed | — | — | 57.2 | 40.1 | 196.0 |
| Variable | — | — | 73.2 | 51.3 | 233.9 |
| LSD (P=0.05) | — | — | 10.5 | 7.4 | 34.2 |

[1] Fixed = cut 2-weekly; Variable = cut 2-weekly in summer, 3-weekly in autumn and spring and 4-weekly in winter.

Variable defoliation frequency generally resulted in higher plant density of all components except chicory and in better persistence of the tall fescue component. Ishida (1978) also demonstrated an increase in density and a decrease in yield of both tall fescue and perennial ryegrass under more frequent defoliation.

Bell (1985) and Sato *et al*. (1989) showed that the competitive advantage of perennial ryegrass over tall fescue was reduced under less frequent defoliation. Our data support this finding as tall fescue yield was higher and ryegrass yield was lower under the fixed (and less frequent) cutting schedule.

We also demonstrated that a variable cutting schedule can affect the seasonality of production. Cutting schedule had the greatest effect on winter and spring yields, with the fixed schedule generally producing higher yields. As the defoliation frequency was the same for both treatments during winter, this appeared to be a carry-over effect from the previous summer and autumn periods. In Northern Ireland, Chestnutt *et al*. (1977) suggested that short cutting intervals reduced yield more early in the growing season (*i.e*., spring and early summer) than in autumn. In New Zealand, defoliation frequency had no effect on the yields of either tall fescue or perennial ryegrass if the summer and autumn periods were wet (*i.e*., equivalent to irrigation in our environment) but very frequent defoliations increased yields of both in dry summer and autumn periods (Kerrisk and Thomson 1990). We found that the effect of cutting schedule on seasonal yield was not consistent between years, possibly related to a change in the competitive ability of other components (Rhodes and Ngah 1983; Sugiyama and Nakashima 1991). For example, the tall fescue response was regulated by the reduced competition provided by the perennial ryegrass component as swards aged (Bell 1985).

This experiment confirmed the results of previous experiments (Lowe *et al*. 2009), which suggested that tall fescue performance was reduced as the number of grasses combined in a mixture increased. Further, the performance of all plant components in the complex mixture was affected by the aggressive production of Persian clover during the first winter and chicory during the first spring and summer. This dramatically changed the botanical composition of this pasture without increasing the overall performance. It also reduced the performance of perennial ryegrass, tall fescue and white clover, which are the most valuable long-term components. Our experiments suggest that care needs to be taken when formulating complex mixtures containing tall fescue so that all components are allowed to establish adequately, a factor also emphasised by McCallum *et al*. (1992) for the temperate New Zealand environment.

Combinations of different cultivars of perennial ryegrass and tall fescue had little effect on overall yields and this agrees with data from temperate regions (Rhodes and Ngah 1983; Sugiyama and Nakashima 1991; McCallum *et al*. 1992; Sanderson *et al*. 2005). However, in other work, the contribution of each species, and especially the seasonality of that contribution, was affected by the cultivar sown (Keane 1982). This result agrees with our previous finding (Lowe *et al*. 2009), and that from temperate areas (Pederson and Brink 1991; Sanderson *et al*. 2005), that it is more difficult to achieve a satisfactory contribution from all sown components when sowing complex mixtures containing species and cultivars of different growth habit and competitive ability (Rhodes and Ngah 1983).

## Conclusions

The results of both papers in this series suggest that combinations of tall fescue and ryegrass can be established successfully under subtropical conditions where higher autumn temperatures allow tall fescue to establish more vigorously than under cooler environments. The success of a delayed sowing of the ryegrass component suggests that this may be an option if low autumn temperatures are expected. The choice of components to sow with tall fescue is important to the success of these mixtures, with aggressive species such as chicory and Persian clover being particularly detrimental to other sown components. Managing to achieve the best quality from the tall fescue component results in a small yield penalty, which should be offset by improved quality. Under subtropical conditions, tall fescue can dominate these mixtures and severe renovation may be required to re-introduce pasture components.

## Acknowledgements

The authors thank Mr Dave Schofield and the staff at the Gatton Research Station for the day-to-day management of the experiments, Mrs Sandra Nolan for the botanical composition assessments and Dairy Australia (formerly Dairy Research and Development Corporation) for co-funding the research.

## References

Anon (1995) Temperate pastures. In: Lake, M. (ed.) *Dairy technical handbook*. 2nd Edn. *Information Series QI 94053. Queensland Department of Primary Industries, Brisbane*.

Bell, C.C. (1985) Effect of defoliation frequency on simulated swards of ryegrass, tall fescue and a 50/50 mixture of the two species. *New Zealand Journal of Agricultural Research*, **28**, 307–312.

Binnie, R.C., Kilpatrick, D.J. and Chestnutt, D.M.B. (1997) The effect of altering the length of regrowth interval in early, mid and late season on the productivity of grass swards. *Journal of Agricultural Science, Cambridge*, **128**, 303–309.

Callow, M.N., Lowe, K.F., Bowdler, T.M., Lowe, S.A. and Gobius, N.R. (2003) Dry matter yield, forage quality and persistence of tall fescue (*Festuca arundinacea*) cultivars compared with perennial ryegrass (Lolium perenne) in a subtropical environment. *Australian Journal of Experimental Agriculture*, **43**, 1093–1099.

Chestnutt, D.M.B., Murdoch, J.C., Harrington, F.J. and Binnie, R.C. (1977) The effect of cutting frequency and applied nitrogen on production and digestibility of perennial ryegrass. *Journal of the British Grassland Society*, **32**, 177–183.

Clarke, K.F., Flinn, P.C. and McGowan, A.A. (1982) Low-cost pepsin-cellulase assays for prediction of digestibility of herbage. *Grass and Forage Science*, **37**, 147–150.

Dickson, T. and Asher, C.J. (1974) The role of sulphur in maintaining lucerne yields in the Lockyer Valley. *Australian Journal of Experimental Agriculture and Animal Husbandry*, **14**, 515–519.

Flinn, P. and Saul, G.R. (1983) Measurement of hay quality and its effect on intake and liveweight gain of weaner sheep. In: Robards, G.E. and Packham, R.G. (eds) *Feed Information and Animal Production*. pp. 259–263. (Commonwealth Agricultural Bureaux: Farnham Royal, UK).

Gillet, M. (1975) Selection for ease of utilization in *Festuca arundinacea* and cocksfoot. *Fourrages*, 11–17.

Ishida, R. (1978) Vegetational structure of sown grassland. 6. Changes in population density and distribution of stubbles in swards of some grass species. *Journal of Japanese Society of Grassland Science*, **24**, 154–161.

Keane, G.P. (1982) The annual yield, and its distribution, of some grass cultivars and mixtures. *Irish Journal of Agricultural Research*, **21**, 159–169.

Kerrisk, J.J. and Thomson, N.A. (1990) Effects of intensity and frequency of defoliation on growth of ryegrass, tall fescue and phalaris. *Proceedings of the New Zealand Grassland Association*, **51**, 135–138.

Lowe, K.F. and Bowdler, T.M. (1984) The performance of temperate and tropical grasses under two irrigation frequencies. *Tropical Grasslands*, **18**, 46–55.

Lowe, K.F. and Bowdler, T.M. (1995) Growth, persistence, and rust sensitivity of irrigated, temperate perennial grasses in the Queensland subtropics. *Australian Journal of Experimental Agriculture*, **35**, 571–578.

Lowe, K.F., Bowdler, T.M., Casey, N.D. and Moss, R.J. (1999a) Performance of temperate perennial pastures in the Australian subtropics 1. Yield, persistence and pasture quality. *Australian Journal of Experimental Agriculture*, **39**, 663–676.

Lowe, K.F., Bowdler, T.M., Casey, N.D. and Moss, R.J. (1999b) Performance of temperate perennial pastures in the Australian subtropics 2. Milk production. *Australian Journal of Experimental Agriculture*, **39**, 677–683.

Lowe, K.F., Bowdler, T.M., Lowe, S.A., Gobius, N. and Fulkerson, W.J. (1999c) *Evaluation of temperate species in the subtropics* — 1998. (Queensland Department of Primary Industries: Ipswich, Australia).

Lowe, K.F., Callow, M.N., Bowdler, T.M., Lowe, S.A., White, J.A. and Gobius, N. (2009) The performance of irrigated mixtures of tall fescue, ryegrass and white clover in subtropical Australia. 1. The effects of sowing mixture combinations, nitrogen, and oversowing on establishment, productivity, botanical composition and persistence. *Tropical Grasslands*, **43**, 4–23.

McCallum, D.A., Thomson, N.A. and 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. and Pirir, J. (1989) Tall fescue use on dairy farms. *Proceedings of the New Zealand Grassland Association*, **59**, 163–167.

Payne, R.W., Harding, S.A., Murray, D.A., Soutar, D.M., Baird, D.B., Welham, S.J., Kane, A.F., Gilmour, A.R., Thompson, R., Webster, R. and Wilson, G.T. (2007). *The Guide to GenStat Release 10, Part 2: Statistics*. (VSN International: Hemel Hempstead).

Pederson, G.A. and Brink, G.E. (1991) Productivity and quality of annual and perennial clover-tall fescue mixtures. *Agronomy Journal*, **83**, 694–699.

Rhodes, I. and Ngah, A.W. (1983) Yielding ability and competitive ability of forage legumes under contrasting defoliating regimes. In: Jones, D.G. and Davies, D.R. (eds) *Temperate legumes: physiology, genetics and nodulation*. pp. 77–88.

Sanderson, M.A., Soder, K.J., Muller, L.D., Klement, K.D., Skinner, R.H. and Goslee, S.C. (2005) Forage mixture productivity and botanical composition in pastures grazed by dairy cattle. *Agronomy Journal*, **97**, 1465–1471.

Sato, K., Yasmada, T., Hirota, H. and Ito, M. (1989) Transition of competitive superiority from a primary pasture canopy to the succeeding canopies. 5. Advancement of interspecific competition in a clonal sward of perennial ryegrass (*Lolium perenne* L.) — tall fescue (*Festuca arundinacea* L.) under infrequent defoliation. *Journal of Japanese Society of Grassland Science*, **34**, 264–270.

Smith, K. and Flinn, P. (1991) Monitoring the performance of a broad-based calibration for measuring the nutritive value of two independent populations of pasture using near infrared reflectance (NIR) spectroscopy. *Australian Journal of Experimental Agriculture*, **31**, 205–210.

Sugiyama, S. and Nakashima, H. (1991) Effects of cultivars of tall fescue (*Festuca arundinacea* Schreb.) on the botanical composition of mixed swards. *Grass and Forage Science*, **46**, 365–373.

*(Received for publication April 15, 2008; accepted July 2, 2008)*