An evaluation of lucerne for persistence under grazing in New Zealand

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Abstract
The on-farm use of lucerne (*Medicago sativa)* for grazing and conserved feed has increased in New Zealand over recent years, with new cultivars coming onto the market, including more winter-active ones. The extent to which the winter active types contribute to annual feed production, and the relationship to critical traits like persistence, has not been systematically tested. Two concurrent trials over a 4-year period were used to evaluate a range of lucerne cultivars and elite experimental populations ranging in dormancy from 2 (highly dormant) to 10 (non-dormant) under contrasting grazing regimes near Lincoln, New Zealand. More winter-active cultivars in the higher fall dormancy (FD) classes had similar growth to lower FD classes in all seasons except autumn, where they exhibited 18% greater yield than the lowest FD entry. However, these higher FD populations do not persist as well under heavy grazing, with a reduction in ground cover of up to 90% after four years, compared with only a 25% loss in lower FD classes. There was a negative correlation between FD and persistence measured as plant survival over 4 years (R^2=0.73). However, one high FD entry showed increased survival under grazing, suggesting there is scope for selection of types with improved cool season growth and grazing tolerance. The concurrent lucerne trial subjected to a low-frequency grazing/cutting regime showed faster recovery from defoliation than the adjacent hard grazed regime, suggesting stored underground reserves were more available for regrowth. We concluded that lucerne cultivars with FD ratings in the 3 to 5 range are most suitable for yield and persistence under grazing in these conditions. There is also scope for breeding to improve plant survival and dry matter yield within FD class.

Keywords: Lucerne (*Medicago sativa*), grazing tolerance, persistence, fall dormancy

Introduction
Lucerne (*Medicago sativa*) is the most widely used forage crop in the world, and has been promoted as a dryland forage pasture legume in New Zealand since the beginning of the previous century. It is a high-yielding, highly nutritive forage crop with excellent drought-tolerant characteristics (Brown *et al*. 2005), and more recently improved tolerance to grazing (Sewell *et al.* 2011). The area sown to lucerne in New Zealand peaked in 1975 (Douglas 1986; Moot *et al*. 2003) prior to a sharp decline due to pest and disease susceptibility. This susceptibility has been addressed through breeding and management; however there is still reluctance by some to use lucerne in farming systems due to perceived inflexibility in grazing management, particularly in spring (Moot 2012). Given the use of grazing ruminants to harvest forage in New Zealand, grazing tolerance measured in terms of dry matter yield and plant survival is a priority for farmers who finish lambs on lucerne. It has been known for some time that this trait is under a measure of genetic control, and that some commercially available cultivars in the United Sates offer improved persistence under heavy grazing regimes (Bouton & Gates 2003). The trait has also been tied to morphological characteristics including prostrateness, crown structure and creeping-rootedness (Smith *et al*. 2000; Humphries *et al*. 2001; Lodge 1991; Piano *et al*. 1996).

Lucerne cultivars are classified by their winter activity, a trait which determines the above-ground growth rate of the plant during late autumn and winter. This is referred to as fall dormancy (FD), with commercially available cultivars ranging from FD2 (winter dormant) to FD10 (winter active). The FD class is assigned based on plant height measurements in autumn, after allowing regrowth following uniform defoliation (Teuber *et al*. 1998). Plant heights are measured 20–30 days after defoliation and compared with reference cultivars to assign an FD class. A widely grown cultivar in New Zealand has been ‘Wairau’ (Moot *et al.* 2003), which is FD3. Generally the more winter-dormant material has been considered the most suitable for South Island farming systems, although more winter-active cultivars are starting to come onto the market (Specialty Seeds, 2013).

The winter activity traits underlying FD are tied to resource allocation for the above-ground growth of the plant; the plant shifts its focus in response to decreasing photoperiod to direct more of its photosynthate to the roots, therefore decreasing its above-ground growth (Moot *et al*. 2003). These reserves allow the plant to overwinter and provide energy for spring growth (Teixeira *et al*. 2007). Continuous hard grazing, particularly in autumn, adversely affects the production and, possibly, persistence of a lucerne stand (Lodge 1991). It is partly due to this relationship that grazing tolerance has been defined by some researchers as the rate of plant recovery from removal of plant tissue by animals (Humphries & Auricht 2001).

The objective of the current study was to assess a range of lucerne cultivars and elite experimental populations, across a wide range of FD classes under severe grazing stress, compare their performance and persistence with a concurrent trial that was under less severe defoliation stress, and identify germplasm that may offer improved growth and persistence under grazing.

Methods and Materials

Two adjacent field trials with contrasting high and low frequency grazing regimes were established in a Wakanui silt loam soil (Cox 1978) at the AgResearch Lincoln Farm in Canterbury (43°37′48.9″S 172°28′16.7″E). Each trial contained 13 lucerne cultivars from New Zealand, Australia or USA, as well as six elite experimental populations (Table 1). Seeds were coated with a peat-based rhizobium inoculant (Group AL) before sowing in November 2009. Each trial was arranged as a randomised block design in 4 × 1.35 m plots, sown using a small plot drill at a rate of 10 kg of seed per hectare (uncoated seed). The high frequency grazing trial contained three replicates, while the low frequency grazing trial had four. Both trials were irrigated once a month during the first summer to aid uniform establishment, after which no further irrigation was applied. Neither trial received any fertiliser input. For weed control, both trials were subjected to a final defoliation in June each year and immediately sprayed with a mixture of paraquat (600 g a.i./ha as Gramoxone®) and atrazine (900 g a.i./ha as Atranex WG®).

Grazing regimes

The high frequency grazing trial was first grazed 4 months after sowing, and subjected to only two more light grazing events until the trial was almost a year old. The trial was then set-stocked with ewes in early October at a rate equivalent to 23–35 stock units per hectare through spring until late January, when the management changed to rotational grazing. The trial was grazed every 2 to 3 weeks in late summer-autumn. Annually in October and January, and then again in April of the final year, stock were removed from the trial to allow regrowth for DM yield cuts.

The low grazing frequency trial was not grazed for the first 6 months after sowing, after which it was mown/cut when 10% flowering was reached (averaged across all cultivars), although often the trial was allowed to grow for up to 2 weeks after this point before defoliation. In the second and subsequent years it was also occasionally rotationally grazed, using the same 10% flowering requirement. In the third year of the trial, DM yield cuts were taken to calculate seasonal and annual yield data.

Measurements & Analysis

Dry matter (DM) yield estimates were made by sampling foliage with 0.25 m^2 of each plot for six of the cultivars (ranging in FD rating from 2 to 9) from within each trial and recording the total fresh weight. DM cuts were made after each trial had regrown from a simultaneous uniform defoliation. A subsample was oven-dried and reweighed to calculate the DM percentage, from which an estimate of DM yields in kg/ha was calculated.

Ground cover percentage was assessed visually, by estimating the percentage of the plot area that was covered with lucerne growth. It was assumed that each plot began with 100% ground coverage at the beginning of the trial.

Table 1 List of lucerne cultivars and elite experimental populations sown in the high grazing frequency and low grazing frequency trials. Lines marked with a * were sampled for dry matter yield.

Entry Name	Fall Dormancy Rating	Origin
Cultivars		
Alfamaster 10*	10	USA
SARDI 10	10	Australia
Pegasis*	9	Australia
Supersonic	9	Australia
Beacon	9	USA
SuperSequel	9	Australia
Aquarius*	8	Australia
SuperSiriver	8	Australia
Fiesta	8	USA
Genesis*	7	Australia
Icon	6	Australia
Kaituna*	5	New Zealand
Torlesse*	4	New Zealand
Elite Experimental Populations		
Exp-A	10	USA
Exp-B	9	USA
Exp-C	9	USA
Exp-D	9	USA
AgR Winter Active*	4	New Zealand
AgR Palatable*	2	New Zealand

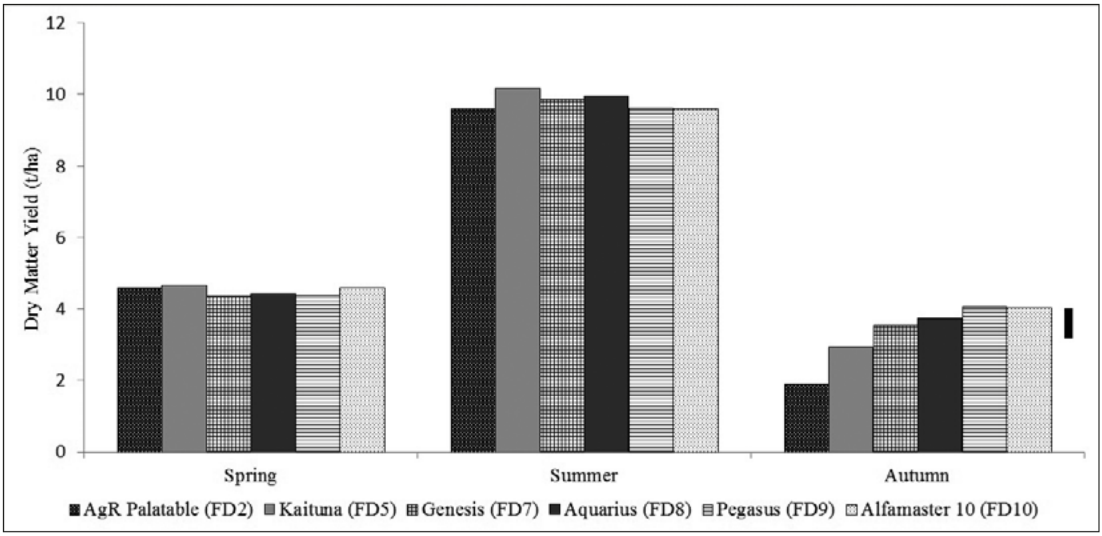

Figure 1 Seasonal growth patterns of lucerne cultivars and elite experimental populations across a range of fall dormancy (FD) ratings summarised from dry matter yields estimated in the low frequency grazing regime. The bar at the right of the graph represents the LSD (5%) for differences among cultivars within the autumn data set (P<0.01). Cultivars in the spring (P<0.3) and summer (P<0.5) data sets were not significantly different.

In late autumn each year, average stand height was calculated by measuring the height of five typical plants per plot and calculating their mean height. These height data were used to estimate the FD rating of elite experimental populations for which a rating did not exist.

Statistical analysis of variance was carried out using the GenStat 16th Edition SP1 software, with significance declared at P<0.05.

Results

In the third year of the low frequency grazing trial, the lucerne cultivars produced an average of 17.5 tonnes DM/ha on the unirrigated Wakanui soil, with 25%, 57% and 18% of the annual yield in spring (September-November), summer (December-February) and autumn-winter (remainder of the growing season) respectively. The DM yield from a range of cultivars of different FD classes was not significantly different within the spring (P<0.3) and summer (P<0.5) months of the year (Figure 1). In late autumn and winter (when defoliation of any kind is not advised apart from a final "clean-up" graze), higher FD lucerne cultivars showed a higher DM yield (P<0.01). However, although the higher FD classes yielded significantly higher dry matter in the colder months, this season only contributed 18% of the total annual DM production. The total annual DM yield data shows that the most winter-dormant material produced 11% less than the most winter-active.

In the first year, autumn DM production in the two trials did not differ significantly (Figure 2a), while after 4 years there was a drop-off (P<0.002) in the ability of the hard-grazed plots to produce above-ground growth (Figure 2b). The yield decline was greater (P<0.05) in the high FD cultivars compared with the low FD material except for 'AgR Palatable' which also produced a lower yield probably through the earlier onset of fall dormancy.

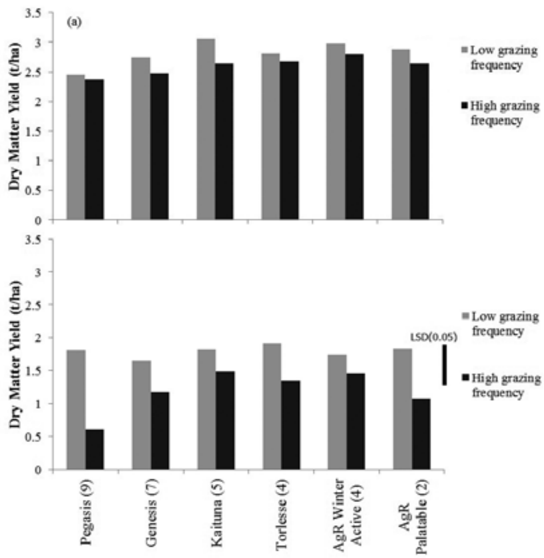

Figure 2 Comparison of autumn DM yield in high and low grazing frequency plots after (a) 0.5 year and (b) 4.5 years. Fall dormancy ratings are shown beside each cultivar in brackets. LSD $_{\text{cultivar x grazing (0.05)}}$ = 0.560 (shown as a bar to the right of the graph).

In the high frequency grazing trial, there was a strong

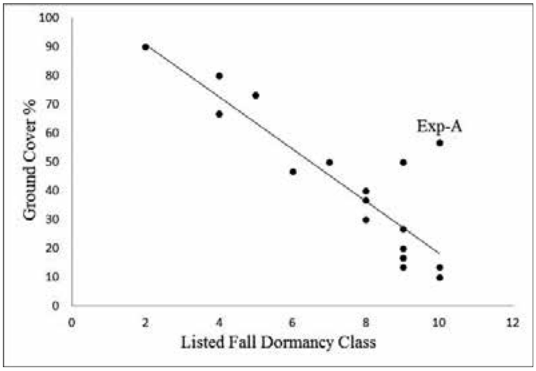

Figure 3 Relationship between fall dormancy class and percentage ground cover in a range of lucerne cultivars and elite experimental populations after 4 years of high frequency grazing by sheep at the Lincoln trial site (R^2 = 0.73).

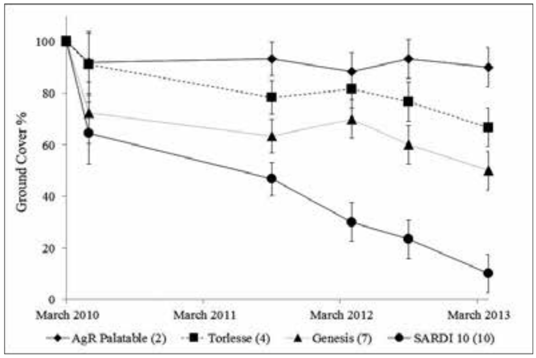

Figure 4 Trends in percentage ground cover over time of four lucerne cultivars with different fall dormancy ratings under high frequency grazing management at the Lincoln trial site. Coverage was assumed to be 100% at the start of the trial. Fall dormancy classes are shown in brackets. Standard error bars are shown.

negative correlation between fall dormancy (FD) class and percentage ground cover under grazing (Figure 3). The more dormant cultivars had the highest percentage ground cover in the plots while the converse occurred for the more winter-active cultivars. An anomalous result was the outlying data point represented by the experimental line known as Exp-A, an elite experimental population from the USA, which had been assigned a FD class of 10. While it is a possibility that this may have been a mis-classification by the breeder, further data would be required to support or refute this. When the data point for Exp-A was omitted from the analysis, the correlation increased from R^2=0.73 to R^2=0.88.

The decline in percentage ground cover in the high grazing frequency trial was generally linear after an initial separation between the high and low FD classes (Figure 4). Differences in percentage ground cover scores from the second year on were significant ($P<0.001$). There was an initial separation in percentage ground cover between the high and low FD classes after only 6 months of hard grazing (Figure 4). Over the next 3 years, the rate of decline in percentage ground cover was slow for the lowest FD class and faster ($P<0.001$) for the highest FD class. Least dormant classes lost 90% of their initial ground cover over 4 years, whereas the most dormant lost 10%, and the FD4 line lost 33% ground cover (Figure 4).

Discussion

Comparison of the high and low grazing frequency trials showed that over time, the ability of all lucerne cultivars to produce DM yield was severely limited by hard grazing. These trials were not designed to demonstrate best practice, but rather to test the limits of adaptation across a range of fall dormancy classes when exposed to severe stress from over-grazing.

More winter-active lucerne cultivars showed a distinct disadvantage in persistence when compared to more winter-dormant cultivars. It is well known (Lodge 1991; Brummer & Bouton 1992) that the grazing of lucerne stands over the autumn limits the ability of the plant to store reserves. This storage is essential to fuel above-ground growth in the next growing season (Moot *et al*. 2003). More winter-active cultivars of lucerne put less of an emphasis on storing underground reserves, and instead prioritise above-ground vegetative growth. This growth response puts these cultivars at a disadvantage with respect to persistence, as they were less likely to have the resources to survive if hard grazing continued.

The high frequency grazing regime was much more severe than recommended. However, it has been demonstrated that using such a regime is a quick and effective way of differentiating within and among lucerne populations on the basis of grazing tolerance (Brummer & Moore 2000). This seems to have occurred in the present study, and therefore the technique can be used to exert selection pressure to develop populations with improved grazing tolerance.

After 4 years of their respective grazing regimes, the plots in the high frequency grazing trial yielded significantly less than those in the low frequency grazing trial. The DM yields in this case are influenced by two factors: the persistence of the plants in each plot and the growth of each individual plant. The drop-off in overall yield was mostly due to plant death, but yield per plant may have also been a factor. The plants in the high frequency grazing trial had been forced to continually mobilise their carbohydrate reserves, so that they were unable to recover from defoliation in the same way that the plants in the low frequency grazing trial were. Physical damage to the crowns from over-grazing and increased susceptibility to pests and diseases may also have been factors contributing to plant death. The current study did not look at pests and diseases, but this area should not be neglected in future work, particularly when new germplasm is introduced. The relationship between fall dormancy and plant persistence has been demonstrated in Australian research (Humphries *et al*. 2006). Results from the current trial further confirm this negative correlation between fall dormancy and plant persistence under grazing. In farming systems where plant persistence is a priority, it would be important to keep this relationship in mind when selecting a cultivar to sow, and when establishing grazing policies on farm.

The main advantage of higher FD lucerne cultivars is their ability to produce higher DM yields. However, the results of these trials show that this yield advantage was only important in this environment during the cooler months of the year. The difference in yield was at maximum only 11% of the overall annual dry matter production. Furthermore, this extra production was at a time of year when the stand should have been rested so that the plant could build up below-ground energy reserves (Moot *et al*. 2003). When these results are considered alongside the data in Figures 2 and 3, it can be argued that the production gained from using high FD cultivars in the first autumn would be lost in the future as plants failed to persist under grazing and the stand was unable to effectively recover after defoliation, since it was unable to store reserves effectively in its roots.

Grazing tolerance in lucerne has long been a desirable trait for breeders, and variation has been demonstrated in persistence of different cultivars under hard grazing, even among the same FD classes (Sewell *et al.* 2011). However, all lucerne cultivars, regardless of winter activity or grazing tolerance, need to store carbohydrate in their roots during the autumn, which affects their DM yield in future growing seasons. For this reason we suggest that grazing tolerance can be more accurately described as persistence under grazing. Results from these trials show that any benefit that farmers receive in using higher FD lucerne cultivars in the first year to graze stock is lost when a reduction in stand persistence and yield in subsequent years is taken into account. Also, the extra yield afforded by higher FD cultivars is realised at a time of year when the stand should not be grazed anyway. These data indicate that under lowland South Island conditions, lucerne cultivars of FD3–5 are most suitable for grazing systems, and that farmers should emphasise grazing tolerance when selecting a cultivar to plant.

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