Weed ingress in perennial ryegrass (*Lolium perenne*) and tall fescue (*Schedonorus arundinaceus*)-based swards under dairy grazing

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Abstract Weed ingress was assessed monthly over four years in a total of six swards of perennial ryegrass (*Lolium perenne*) or tall fescue (*Schedonorus arundinaceus*) to which were added a legume (2 species mix), legume and forage herbs (4 species mix), or legumes + herbs + other grasses (8 species mix). Unsown species (weeds) present were from 13 families, of which Asteraceae was the most abundant. Asteraceae species increased from <1% to 18% of total basal cover in ryegrass-based swards and from <1% to 14% in tall fescue-based swards over the study period. Asteraceae reached 81% of total weed basal cover in perennial ryegrass- and 82% in tall fescue-based swards in the final year. While the basal cover of total unsown species was lower in perennial ryegrass- than tall fescue-based swards in the first three years of the study, increasing the number of sown species (from a 2-species to an 8-species mix) had little effect on the ingress of Asteraceae or other weed species.

Keywords pasture persistence, weed invasion, diverse pasture mixes.

INTRODUCTION

Poor persistence of sown species and ingress of unsown weedy species is a concern for many farmers with stock on upper North Island dairy pastures (Kelly & Smith 2011). In a survey of dairy, and sheep and beef pastures, weeds were listed as one of the most important factors contributing to a loss of pasture persistence (Tozer et al. 2011). The negative impact of weeds on pasture production and profit in New Zealand has been well-documented (Bourdôt et al. 2007). Given these issues, methods are required to reduce weed ingress and the negative impact of weeds on pasture performance.

The choice of species included in a perennial

pasture mix can affect weed ingress, with some studies showing that weed ingress is less in a pasture sown with a diverse mix than in a more simple two species mix (Pembleton et al. 2015). This is most likely due to the identity and traits of the species in the mix, rather than the number of sown species *per se*, and the species ability to occupy the same ecological niche as the weeds, thereby excluding them from the pasture community (Pembleton et al. 2015). Increasing the number of species in the mix increases the likelihood that the sown mix will have characteristics that occupy the same niche as a weed and thus increases the likelihood that weeds will be excluded.

Additionally, changing the key species on which the perennial pasture mix is based may also reduce weed ingress. For example, tall fescue (*Schedonorus arundinaceus*) is more drought tolerant than perennial ryegrass (*Lolium perenne*) and less susceptible to some insect pests (Rollo et al. 1999). Thus tall fescue may be better adapted than perennial ryegrass to summer-dry regions (Fraser 1994) in the North Island. If so, greater production of tall fescue than perennial ryegrass in these environments may lead to greater pasture cover and the exclusion of weeds.

To determine the impact of the sown mix on the identity and ingress of weeds in grazed dairy pastures, a field study was established and weed presence was monitored over four years. We tested the hypotheses that weed ingress is lower in tall fescue- than perennial ryegrass-based swards and in swards sown with four or eight species than with two species.

METHODS

Site establishment

A site was established at DairyNZ's Scott Farm, Hamilton, New Zealand (37°47'S, 175°19'E) on a Matangi silt loam (Stiles & Singleton 1997) in autumn 2010, as part of a larger study to compare the performance of a range of pasture types on pasture performance and milk production (Woodward et al. 2013). Site establishment began with soil testing in mid-February 2010. Soil pH was 5.8, Olsen P: 37 ppm, K: 5 MAF QT units and Sulphate-S: 15 ppm. Herbicide (2.2 kg ai/ha glyphosate (Glyphosate 510SL)) was applied to the existing sward on 22 February and 16 March 2010, along with an application of 9 mm liquid effluent. After ploughing, 2 t/ha lime and 635 kg/ha maintenance fertiliser (50P: 58S: 18Mg: 122Ca: 20Na) were applied. The site was then power harrowed and rolled. Plots (with dimensions of 9×7 m) were drilled using a Taege direct-seed drill to a depth of approximately 5–10 mm with a range of seed mixtures and the seed bed rolled on 30 March 2010. Although 14 treatments (pasture types) were

established, this study focused on six of them.

The standard treatments ('ryegrass standard' and 'tall fescue standard') comprised either perennial ryegrass ("One50 AR1" sown at 10–23 kg/ha depending on the treatment, hereafter referred to as 'ryegrass') or tall fescue ("Advance Max P", 13–30 kg/ha), and white clover (*Trifolium repens* "Kopu II", 1.5–5 kg/ha). To these standard treatments were added chicory (*Cichorium intybus* "Choice", 1–2 kg/ha) and plantain (*Plantago lanceolata* "Tonic", 0.75 kg/ha) for the 'ryegrass herbs' and 'tall fescue herbs' treatments. To these herb treatments were added prairie grass (*Bromus catharticus* "Atom", 15 kg/ha), timothy (*Phleum pratense* "Charlton", 3 kg/ha), lucerne (*Medicago sativa* "Torlesse", 4 kg/ha) and red clover (*Trifolium pratense* "Colenso", 4 kg/ha) for the 'ryegrass complex' and 'tall fescue complex' treatments. The sowing rate of perennial ryegrass, tall fescue, chicory and plantain decreased as the number of the species in the mix increased.

Annual rainfall at Scott Farm in 2010, 2011, 2012 and 2013 was 1384, 1485, 1277 and 1184 mm respectively, compared with the long term average annual rainfall of 1156 mm (30 year average, 1975–2004, at the nearby Ruakura weather station). Rainfall over summer (December and February) was lower than the long-term average of 259 mm in the latter two of the four years (2010–2011: 334 mm, 2011–2012: 376 mm, 2012–2013: 151 mm, 2013–2014: 134 mm).

Experimental design

The plots were established in a completely randomised design consisting of three replicates of six pasture treatments, made up of all combinations of two pasture types (ryegrass, tall fescue) and three diversity treatments (standard, herbs, complex mix).

Site management

Maintenance fertiliser was applied to the site each autumn based on soil test results from the previous spring. Nitrogen fertiliser (urea) was applied after each grazing at a rate of 25 kg N/ha per application with an annual maximum of 200 kg N/ha. No herbicide was applied to the site after sowing.

Each plot was fenced and individually grazed

Figure 1(a) Basal cover **Figure 1(b)** canopy cover of weeds expressed as a percentage of total ground cover, in tall fescue- and perennial ryegrass-based swards, in a grazed field study in the upper North Island. Data are averaged over each 12-month period. Bars are the standard error of difference.

by three mixed-aged Holstein-Friesian dairy cows when forage cover had reached 2800-3000 kg DM/ha as determined by visual assessments. Cows were removed once the pasture height was reduced to 40-50 mm (1500-1600 kg DM/ha). Plots were grazed six times in 2010 (between the first grazing at the end of March and the end of December), ten times in each of 2011 and 2012, eight times in 2013, and five times in 2014 before the final assessment in October 2014.

Measurements

The percentage of basal and canopy cover was determined every four weeks from 19 May 2010 until 17 October 2014 inclusive.

Basal and canopy cover were monitored in four permanent 300×300 mm quadrats randomly positioned in each plot to determine any changes in botanical composition (i.e. ingress of unsown species (weeds)). Each quadrat was divided into 36 cells, of dimensions 50×50 mm, giving a total of 144 cells in each plot. Accurate quadrat placement was aided by four coloured weed mat pins permanently inserted into the ground at the corners of each quadrat.

For each assessment, a pen was lowered in the centre of each cell and the first species that contacted the tip of the pen recorded (canopy cover). The canopy was pushed aside using

the pen to determine if any rooted vegetation was present in the cell centre and the identity of the vegetation was recorded (basal cover).

Statistical analyses

Basal and canopy cover of unsown species (all unsown grasses, legumes and herbs hereafter termed 'weeds') were totalled for the four quadrats within each plot. Data were averaged over three months that corresponded with calendar seasons (summer, autumn, winter and spring) and seasonal data analysed by analysis of variance using GenStat, 16th edition, fitting pasture type, diversity and the interactions. A repeated measures analysis of variance using the Greenhouse-Geisser correction including all times was performed. Data were angular-transformed when necessary to equalise the variance to better meet the normality assumptions of the analysis. Arithmetic treatment means are presented but statistical inferences are based on transformed data when transformations were undertaken. This study focused on weeds from the Asteraceae (daisy) family, as these were the most dominant species. Note that basal and canopy cover of Asteraceae species were very low in Year 1 and not analysed (<1% of basal cover).

Table 1 Change in percent canopy cover of Asteraceae species, in perennial ryegrass- and tall fescue-based swards grazed by dairy cattle. Swards were assessed mid-monthly, over three years from May 2011 until October 2014. Data averaged over each year, beginning in spring. Perennial ryegrass and tall fescue sown as either a two ('standard'), four ('herbs') or eight ('complex') species mix in March 2010.

Percentage cover	Pasture type				Diversity		
	Ryegrass	Tall fescue	SED	P value	Standard	Herbs	Complex
Asteraceae species expressed as a percentage of total cover							
Basal cover	Yr 2 (2011-2012)	0	1	0.2	ns	1	0
	Yr 3 (2012-2013)	4	3	1.1	ns	3	4
	Yr 4 (2013-2014)	18	14	1.5	0.024	17	18
	Change (over 3 y)	17	13	1.5	0.018	16	17
Canopy cover	Yr 2 (2011-2012)	1	2	0.6	ns	2	1
	Yr 3 (2012-2013)	4	4	1.9	ns	3	5
	Yr 4 (2013-2014)	19	12	3.7	ns	16	19
	Change (over 3 y)	18	11	3.8	ns	14	19
Asteraceae species expressed as a percentage of weed cover							
Basal cover	Yr 2 (2011-2012)	13	28	6.3	0.035	27	17
	Yr 3 (2012-2013)	53	47	7.4	ns	44	57
	Yr 4 (2013-2014)	81	82	4.2	ns	78	85
	Change (over 3 y)	69	55	6.2	0.045	50	69
Canopy cover	Yr 2 (2011-2012)	26	36	4.4	ns	30	30
	Yr 3 (2012-2013)	59	53	8.2	ns	50	60
	Yr 4 (2013-2014)	82	79	4.3	ns	78	85
	Change (over 3 y)	55	43	6.2	ns	49	55

ns: not significant (P<0.05). SED: standard error of difference of the means. Year 4: spring 2013 – winter 2014.

RESULTS

Weed presence expressed as a percentage of total cover

Basal and canopy cover of weeds was lower in ryegrass than tall fescue-based swards in Years 1, 2 and 3 ($P < 0.05$), but there was no difference between pasture types in Year 4 (averaging 28% of total ground cover (Figure 1a)) and 33% of total canopy cover (Figure 1b). Canopy cover of weeds was greater in the standard than herbs and complex mixtures in Year 2 (19 vs 7%), and basal cover of weeds was greater in the standard than herbs mixture in Year 3 (18 vs 11%, $P < 0.05$). There was no interaction between pasture type (ryegrass vs tall fescue) and diversity.

The most prevalent broadleaf weeds included hawksbeard (*Crepis capillaris*), dandelion (*Taraxacum officinale*), chickweed (*Stellaria media*), purple cudweed (*Gamochaeta coarctata*) and dock (*Rumex* spp.). The most dominant unsown grass in the tall fescue swards was perennial ryegrass, with annual poa (*Poa annua*) and summer grass (*Digitaria sanguinalis*) present to a lesser extent in both sward types. The basal cover of perennial ryegrass in the tall fescue swards averaged 3% while in the canopy perennial ryegrass averaged 9% (which equated to 3% in the first year, 11% in the second and 16% in the third). Unsown species (weeds) present were from 13 families, of which the Asteraceae family was the most prevalent.

Asteraceae species expressed as a percentage of total cover

The most prevalent weed from the Asteraceae family was hawksbeard which comprised 88% of Asteraceae weeds in the final year, and purple cudweed, dandelion and lawn daisy (*Bellis perennis*), which comprised a further 12%. Basal cover of Asteraceae species was higher in perennial ryegrass than tall fescue-based swards in Year 4 ($P < 0.05$), but there was no difference between perennial ryegrass and tall fescue-based swards in years 2 or 3 (Table 1). The increase in basal cover of Asteraceae over three years was greater in ryegrass than in tall fescue-based swards (with an increase of

17% and 13% for perennial ryegrass and tall fescue respectively, $P < 0.05$). There was no effect of pasture type on the canopy cover of Asteraceae species and no interactions between pasture type and diversity.

Asteraceae species expressed as a percentage of weed cover

Basal cover of Asteraceae species was 66% lower in ryegrass than tall fescue-based swards in Year 2 (13 vs 28% of weed basal cover, $P < 0.05$), but there was no significant difference between ryegrass and tall fescue-based swards in Years 3 and 4 (averaging 50% and 81% of weed basal cover respectively). However, the increase in basal cover of Asteraceae species between Years 2 and 4 was greater in ryegrass than tall fescue-based swards (69% and 55% of weed basal cover respectively, $P < 0.05$, Table 1). There were no effects of diversity on the proportion of Asteraceae species in weed basal and canopy cover and no interactions between pasture type and diversity.

DISCUSSION

Weed ingress was initially much greater in tall fescue than ryegrass-based swards, with over double the canopy cover of weeds in the tall fescue-based swards in each of the first three years of the study. This was contrary to the expectation that there would be fewer weeds in tall fescue compared with perennial ryegrass-based swards as tall fescue was expected to perform better, with greater ground cover than perennial ryegrass in a summer-dry environment. One of the most likely reasons for greater weed ingress in the tall fescue-based swards is differences between tall fescue and perennial ryegrass in seedling growth. Tall fescue seedlings grow more slowly than perennial ryegrass (Easton et al. 1994), giving greater opportunity for weeds from the seedbank to colonise gaps between the establishing pasture species. Further, there was only one severe drought during this study, which was in the final year. Had there been droughts in the first few years of this study, during which tall

fescue would presumably have been able to perform better than perennial ryegrass, results might have been different. Further research under conditions of moisture stress would be needed to confirm this.

Herbicide was not applied during this study after the seed mixtures were sown, which enabled differences between the two species in preventing weed ingress to be compared. Results demonstrate the importance of weed control, particularly in tall fescue-based swards, to enhance establishment success and to reduce the impact of weeds on pasture persistence. Management options include post-emergent herbicide application or a cropping phase prior to establishing a pasture. This would allow control of grass and broadleaf weeds through selective herbicide application to reduce the size of the soil weed seedbank.

Weed basal cover remained low in the first two years, averaging 6% of total basal cover, but increased much more rapidly in the final two years. While weeds from 13 different families were present in one or more years of the four-year study, those from the Asteraceae family became the most prevalent over the study period. Many of these weeds, commonly known as flatweeds, form basal rosettes and have a high proportion of their vegetation below the grazing horizon. These species demonstrate grazing avoidance strategies, which enables them to survive in grazed pastures. This is in contrast to the sown grasses that often have their apical meristems above the grazing horizon and can more easily be damaged by grazing (Briske 1996). By the final year, hawksbeard was the most prevalent species at the experimental site and particularly in the laneways surrounding the plots, where cattle were kept on the days that plots were grazed. The prevalence of this weed in the laneways further suggest that grazing pressure was a critical factor in determining which weeds become most dominant.

We observed hawksbeard flower over several months during spring and into summer. While hawksbeard recruitment from seeds from outside the experimental site cannot be eliminated, the most likely source of seed was from the flowering plants from within the experimental site.

By the final year of the study, differences in weed ingress between pasture types had disappeared. Weed species averaged 28% of basal cover and 33% of canopy cover, of which weeds of the Asteraceae family comprised approximately 81%. Further, the increase in Asteraceae weeds over the study was greater in perennial ryegrass than tall fescue-based swards. The high proportion of weeds highlights problems with weed ingress in North Island pastures, regardless of the pasture type. This is consistent with other upper North Island studies based on perennial ryegrass pastures (Thom et al. 1998) in which large declines in pasture performance over the first few years have been documented. Insect pest pressure may contribute to this decline in performance (Zydenbos et al. 2011). Sowing ryegrass cultivars with endophytes such as AR37 or NEA2 may help to reduce pest damage, sown species mortality and weed ingress in these upper North Island environments, which are particularly prone to insect pest damage (Anon 2012).

Species other than perennial ryegrass or tall fescue may be better suited to these environments with respect to reducing weed ingress, although the effects of using alternative species on pasture quality and livestock production must also be taken into account. Alternatively, dairy farmers may need to accept that pastures based on perennial ryegrass or tall fescue, regardless of how many other species are included in the mix, may be rapidly invaded by weeds. While appropriate endophyte selection and herbicide use may reduce weed ingress, renewal may be required within five years of sowing to prevent weeds from becoming prevalent in pastures.

Increasing the number of the species in the mix had little effect on the ingress of weeds or prevalence of Asteraceae species. This was the case for each of the years assessed, as well as for the change over the study period. The only exception was in the canopy cover in the second year. However, while there were statistically significant differences between the two, four and eight species-mix in weed ingress, canopy cover of Asteraceae remained under 2% of total weed cover regardless of the number of species in the

mix. Thus, the perennial pasture base (ryegrass or tall fescue) was more important than the additional species in the mix in preventing Asteraceae ingress. In this study, the additional species (e.g. timothy, prairie grass, red clover, chicory, plantain) were relatively minor components of the pasture sward.

Given these results, we suggest that the traditional perennial ryegrass-white clover mixture may be the simplest and best choice of the six pasture treatments assessed, for Waikato dairy pastures, if the primary goal is to reduce the ingress of Asteraceae and other weeds. This is because perennial ryegrass-based swards had the lowest ingress of flatweeds in the first three years after sowing and that management requirements of a two-species mix are simpler than those of a pasture sown with four or eight species.

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