Tolerance of newly sown cocksfoot-clover pastures to the herbicide imazethapyr

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Abstract
In New Zealand, subterranean clover is recommended as a companion legume in mixed swards, particularly in dryland cocksfoot-based pastures. However, establishment of cocksfoot is slower than perennial ryegrass and therefore weed ingress is more common. An experiment at Lincoln University, Canterbury showed imazethapyr applied when clover was at the 3-4 trifoliate leaf stage, and cocksfoot at the 2+ leaf stage, increased the subterranean clover content of the pastures by at least 1000 kg DM/ha, despite initial visual phytotoxicity responses. Balansa and white clover pasture yields were not different to their unsprayed unweeded controls. Imazethapyr application controlled broadleaf weeds from early in the season. The herbicide application reduced cocksfoot yields by 70% in early spring, but yields recovered and were not different to the unsprayed unweeded controls at 1350 ± 260 kg DM/ha after grazing. Imazethapyr application improved subterranean clover pastures through an increase in clover content by suppressing weeds and temporarily reducing the rate of cocksfoot growth.

Keywords: subterranean clover, Spinnaker® herbicide, seedling, white clover, balansa clover

Introduction
Subterranean clover (*Trifolium subterraneum*) is the most commonly sown annual clover species in New Zealand (Monks *et al*. 2016; Stewart *et al*. 2006). Under appropriate management, it can provide gains in quality and dry matter yields of pastures where the performance of perennial legumes is limited by summer dry conditions (Dodd *et al*. 1995; Smetham 2003). In these regions, cocksfoot (*Dactylis glomerata*) has been identified as a suitable perennial companion species. For example, the 'MaxClover' grazing experiment from February 2002 until 2011 identified cocksfoot-subterranean clover ('Denmark') mixtures as the most productive and persistent of the dryland pastures tested, with yields second only to lucerne (*Medicago sativa*) over 9 years (Mills *et al.* 2014). A field experiment at Lincoln University in 2014 investigated cocksfoot growth with 10 subterranean clover cultivars and found that 'Antas', and 'Narrikup' produced the highest yields at 750 kg DM/ha by September. By November 'Antas' had yielded 2700 kg DM/ha, with 'Narrikup' at 1500 kg DM/ha (Lucas *et al*. 2015). With appropriate management, establishment ensures productivity and persistence of the pasture for future years. However, cocksfoot is slow to establish compared with most other grasses (Moot *et al*. 2000) and while this offers opportunity for the clovers to establish, it can also allow weed ingress, particularly when autumn-sown. Therefore, to maximise establishment, and yield through to the spring, early autumn weed control after sowing is important. Dear & Sandral (1999) assessing the phytotoxicity of imazethapyr on seedling lucerne/clover pasture mixes, found yield losses of up to 21% compared to a weed-free, unsprayed sward, but concluded herbicide application was justified as the subterranean clover showed the capacity to recover from the phytotoxicity damage to produce higher seed set.

Imazethapyr is an acetolactate synthase (ALS) inhibiting compound, with symptomatic responses to application in susceptible species generally presenting as a reduction in growth rate and loss of plant vitality (Fedtke & Duke 2004). ALS inhibiting herbicides are both foliar and soil active, and control a wide spectrum of both annual and perennial grass and broadleaf weeds at low dosages (Cobb & Reade 2010). Imazethapyr applied at a rate of 75 g/ha to annual ryegrass (*Lolium multiflorum*) plants at the 3-4 leaf stage has been shown to suppress growth by 16-54% (Clemmer *et al*. 2004). Another experiment found full recovery of seedling perennial grasses such as cocksfoot and ryegrass (*Lolium perenne*) has been observed following imazethapyr application at 25 g/ha, while the annual ryegrass (*Lolium rigidum*) showed susceptibility (Dear *et al.* 2006).

Currently there is little specific information available on newer herbicide options to control broadleaf weeds when establishing subterranean clover pastures in New Zealand (Teixeira *et al*. 2015). The most promising herbicide identified from the literature with the potential for aiding establishment of subterranean clover by eliminating weeds was Raptor® (a.i. 700 g/kg imazamox) (Sandral & Dear 2005), an ALS inhibiting herbicide which was also recommended by Australian pasture scientists (L. Bell pers. comm.). As Raptor® is not, and will not become commercialised in New Zealand, Spinnaker® (a.i. 240 g/L imazethapyr), also an ALS inhibiting herbicide was identified to be

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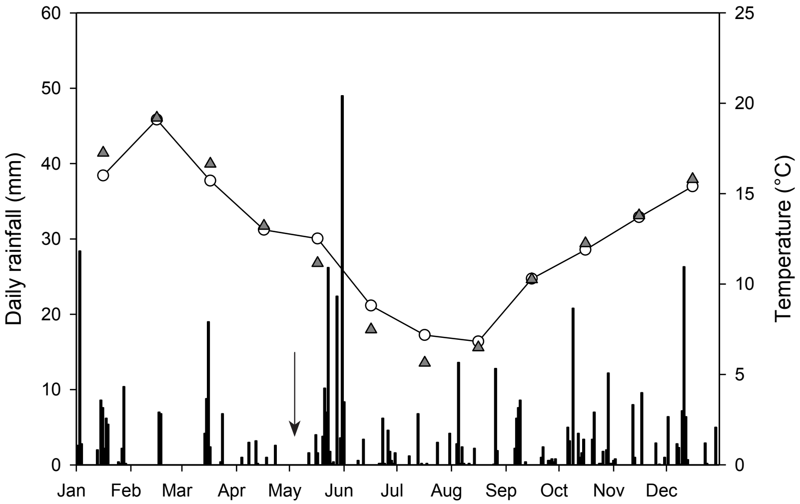

Figure 1 Daily rainfall (■) and mean monthly air (-○-) and 2 cm soil depth (▲) temperatures for January - December 2016, from Iversen 2 datalogger (temperature) and Broadfields (rainfall) for Lincoln University. Arrow indicates application of ~ 20 mm irrigation.

the closest commercially available herbicide in New Zealand for investigation at the time of commencing the experiment.

The aim of this experiment was to determine if imazethapyr (currently sold in New Zealand as Spinnaker®, Equate®, and Kyte™ 700WG), a herbicide commonly used for broadleaf weed control in establishing lucerne stands and on some other legume stands, could be used on newly sown cocksfoot-clover pastures.

Methods

An experiment was conducted in Iversen field 1 at Lincoln University, Lincoln, Canterbury, New Zealand (43°38'57.4"S 172°28'07.8"E, 11 m a.s.l.). The soil at the site is predominantly a Wakanui silt loam (Cox 1978), a deep, stoneless, poorly draining soil (Hewitt 2010). The site was used as non-renewed pasture and was grazed over the past 20 years.

On 22 February 2016, the site was sprayed out with 5 L/ha Buster® herbicide (200 g a.i./L glufosinate-ammonium) in 200 L water to kill the resident vegetation in preparation for direct- drilling into a weed-free undisturbed surface. Subterranean clovers 'Antas' (thousand seed weight (TSW) 11.06 g), 'Denmark' (TSW 6.92 g), and 'Narrikup' (TSW 9.16 g) were sown separately at 20 kg/ha while, 'Nomad' white clover (TSW 1.08 g) (*Trifolium repens*) and 'Bolta' balansa (TSW 1.04 g) (*Trifolium michelianum*) clover were sown at 10 kg/ha. Sowing rates were above commercial recommendations to maximise legume seedling density and ensure adequate populations for treatments. Clovers were direct-drilled on 1 March 2016 into soil with 2 kg/ha of 'Greenly II' cocksfoot (TSW 1.02 g) using a Flexi-seeder® drill at 2 cm depth in 15 cm drill rows. Cultivar plots were 8 x 2.1 m, with five replicates in a randomised complete block design. Cultivar plots were split into three plots of 2.6 x 2.1 m for herbicide application in strips across the plots. This created a strip-split plot (criss-cross plot) design (Montgomery 2013).

The site received an accumulated rainfall of 346 mm over the experimental period from March to October 2016 (Figure 1). However, rainfall in April following herbicide application was only 11 mm, 44 mm below the long term average (Table 1). Therefore, plots were irrigated with approximately 20 mm on 13 May 2016, using a RM 540 gx pivot irrigator, to represent a more 'normal' autumn.

Seedling emergence commenced on 25 March 2016, and a representative 1 m section of drill row was permanently marked in the centre of each sub-plot. On 7 April 2016, when clover plants were at the 3-4 trifoliate leaf stage and cocksfoot seedlings were at the 2 leaf stage, imazethapyr was applied at a rate of 96 g a.i./ha (400 ml/ha Spinnaker®), with 50 ml/L

Table 1 Monthly long-term averages from 1960 to 2015 for mean (T_{mean}) air temperature, rainfall, and Penman potential evapotranspiration (PET). Taken from the CliFlo database, measured at the Broadfields Meteorological Station, Lincoln, Canterbury.

Month	T_{mean} (°C)	Rainfall (mm)	EP (mm)
Jan	16.7	48.2	157.4
Feb	16.5	42.4	125.8
Mar	14.8	52.9	102.9
Apr	12.0	55.5	64.7
May	9.2	56.8	45.1
Jun	6.6	61.8	33.1
Jul	6.1	61.7	36.3
Aug	7.3	62.1	51.9
Sep	9.4	39.8	74.9
Oct	11.4	47.2	109.8
Nov	13.2	50.2	133.0
Dec	15.2	52.6	151.8
Annual	11.5	631.2	1086.5

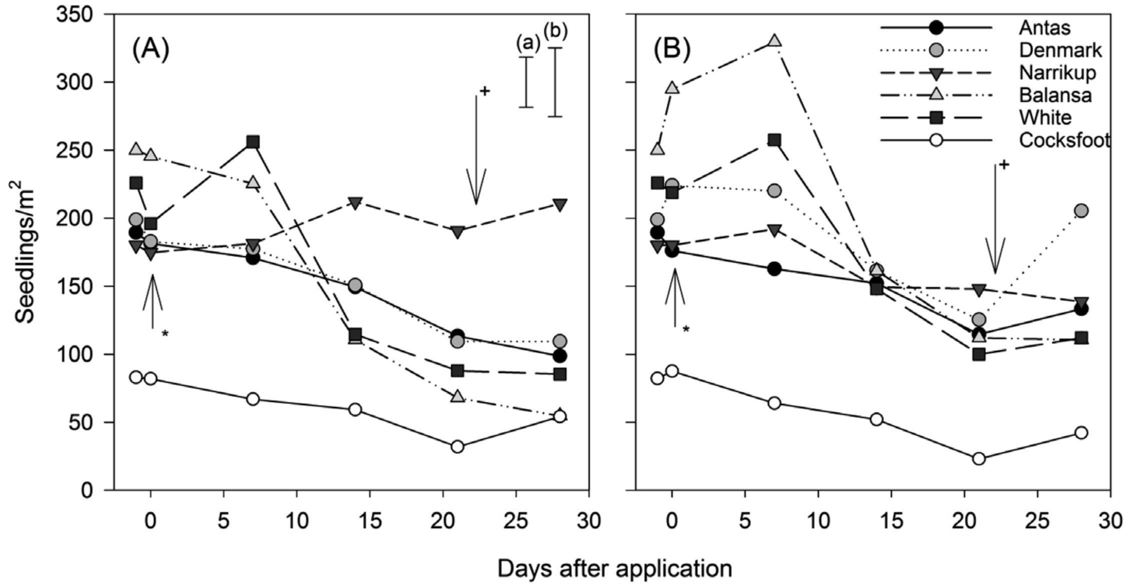

Figure 2 Seedling number/m^2 for all clover cultivars and cocksfoot in (A) untreated unweeded controls and (B) imazethapyr treated plots. Error bars are LSD for (a) main effect of herbicide on seedling number at a single time point; (b) herbicide x time interaction for seedling number. Arrows with * indicate herbicide application; arrows with + indicates application of 20 mm irrigation.

Hasten™ (704 g/L ethyl and methyl esters of vegetable oil). Herbicide was applied using a knapsack sprayer with a 2 m width in strips at right angles across the cultivar plots, leaving a 2 m unsprayed, unweeded control strip in each plot, randomised for each replicate. Wind direction at spraying was a prevailing northerly, with an average speed 8-12 km/h for the duration of application. Average air temperature was 17.9 ˚C, and average soil temperature at 2 cm depth was 15.7 ˚C.

Seedling counts of sown clover for each plot were carried out weekly until one month post-herbicide application, when the seedling counts were stable. All plots were visually scored on 2, 5, 7, 10 and 14 days after application (DAA) and weekly thereafter until the first harvest, using the EWRS phytotoxicity scoring system (Table 2).

Plots were sampled for biomass on 9 September and 27 October 2016 by cutting 0.2 m^2 samples with electric clippers to grazing height from the centre of each plot. A subsample of ~50 g fresh weight was sorted into sown clover, cocksfoot, broadleaf weed, grass weed and dead matter components. Samples were then oven-dried for at least 48 hours at 60 °C and weighed. Plots were heavily grazed for a week with a mob of 100 ewe lambs from the 12 September 2016 following the first harvest. Post-grazing the residual herbage was cut and carried using a Fieldmaster forage harvester and cage to remove the unpalatable weeds, particularly from the unsprayed controls. This enabled regrowth to be isolated and measured in the October harvest. Results were analysed using a two-way split-strip plot ANOVA of cultivar by herbicide, with herbicide as rows and cultivar as columns using Genstat 16.1. Repeated measures ANOVAs of seedling counts and EWRS score were used to analyse changes over time. When significant, Fisher's protected Least Significant Difference (LSD) tests were used to separate means at α=0.05.

Table 2 European Weed Research Society (EWRS) phytotoxicity damage score.

Score	Damage symptoms
1	No damage / healthy plants
2	Very mild symptoms
3	Slight, but clearly visible symptoms
4	Severe visible damage, e.g. chlorosis, which do not lead to a negative effect on yield
5	Thinning, severe chlorosis, leaf burn or suppression, some yield reduction expected
6-9	Above commercial threshold, symptoms range from severe damage to total plant death.

(OEPP/EPPO 2014)

Results

Seedling establishment

Seedling numbers of all sown clover before herbicide application were 210 ± 20/m^2 and not different (P=0.080) among cultivars. Clover numbers reduced (P<0.001) over the 28 day measurement period post-herbicide application (Figure 2). There were differences among

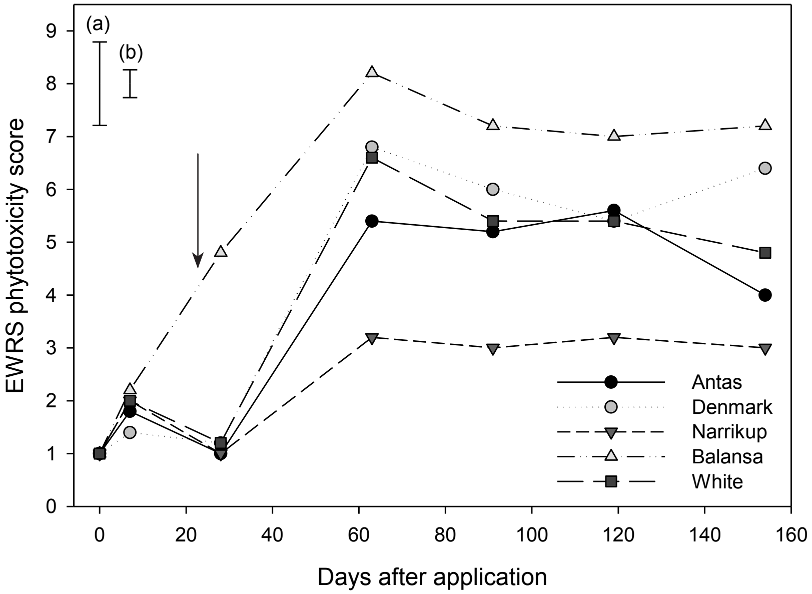

Figure 3 EWRS phytotoxicity scores (relative to untreated controls) for all imazethapyr treated plots from application on 7 April 2016 to first harvest on 9 September 2016. Error bars are LSD for (a) herbicide x time interaction; (b) herbicide x cultivar interaction at a single time point. Dotted line indicates commercial EWRS score threshold; arrows indicates application of 20 mm irrigation.

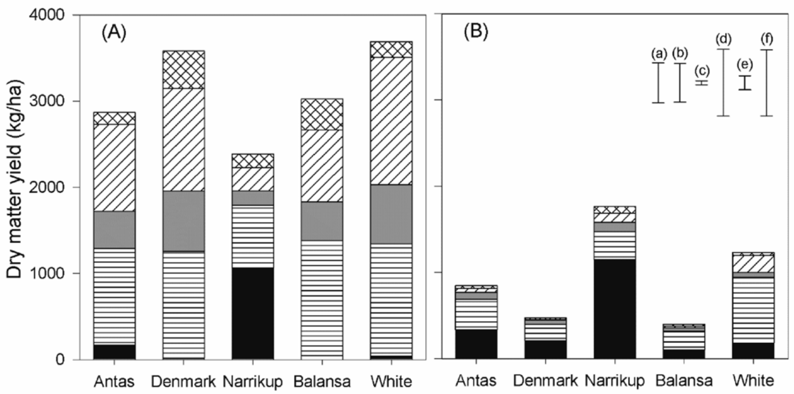

Figure 4 Mean dry matter yields and composition for growth of five clover cultivars at the first harvest on 9 September 2016 at Iversen 1, Lincoln University, Canterbury, New Zealand for sown clover (■), cocksfoot (▤), broadleaf weed (■), grass weed (▨) and dead matter (▩) components of cultivar plots. (A) is unsprayed, unweeded controls, and (B) is imazethapyr treatments. Error bars are LSD for main effect of (a) cultivar on clover yield; (b) herbicide on cocksfoot; (c) herbicide on broadleaf weeds; (d) herbicide on grass weeds; (e) herbicide on dead matter; (f) herbicide on total dry matter yields.

cultivars (P<0.001) over time, but no effect (P=0.537) of imazethapyr application on seedling number/m^2. Balansa and white clover at 85-100 ± 29 seedlings/m^2 had lower densities after the measurement period than 'Denmark' and 'Narrikup' at 155-175 ± 29 seedlings/m^2, while 'Antas' at 115 ± 29 seedlings/m^2, was not different to any of the cultivars, but was reduced compared with pre-application seedling numbers (Figure 2).

Cocksfoot seedling numbers at 85 ± 9 seedlings/m^2 were not different among treatments (P=0.785) or cultivars (P=0.357) before herbicide application (Figure 2). Cocksfoot seedling numbers reduced (P<0.001) over time to 55 ± 8 seedlings/m^2, but there was no effect of cultivar (P=0.387) or herbicide application (P=0.993) on this reduction.

Phytotoxicity assessment

EWRS scores for imazethapyr-treated balansa clover showed less tolerance, with a score of 5.0 by 28 DAA, which increased (P<0.001) to a final score of 7.0 by 154 DAA (Figure 3). All other imazethapyr treated cultivars were not different to their unsprayed controls at 28 DAA, but all EWRS scores had increased by 63 DAA, with only 'Narrikup', at 3.0 scoring lower than 5.0. By 153 DAA, 'Antas' and white clover had recovered (P<0.001) with EWRS scores of 4.0-5.0 (Figure 3).

Harvest 1: 9 September 2016

At the first harvest, sown clover yields were not different (P=0.125) between imazethapyr and the unsprayed unweeded control (Figure 4). 'Narrikup' clover yields of 1100 kg DM/ha were higher (P=0.006) than all other cultivars which produced <250 kg DM/ha. Sown cocksfoot grass yields in imazethapyr treated plots were <350 kg DM/ha, and lower (P=0.003) than unsprayed controls at 1100 kg DM/ha. Broadleaf weed yields of imazethapyr treatments were <50 kg DM/ha, which was

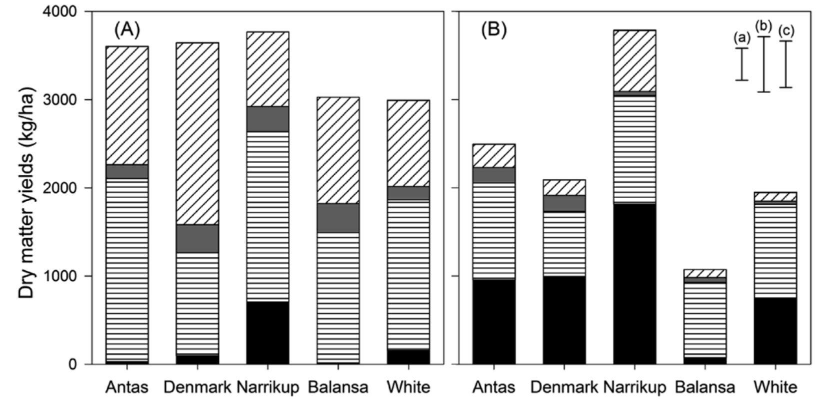

Figure 5 Mean dry matter yields and composition for growth of five clover cultivars at harvest 2 on 27 October 2016 at Iversen 1, Lincoln University, Canterbury, New Zealand for sown clover (■), cocksfoot (▤), broadleaf weed (■), grass weed (▨) and dead matter (▩) components of cultivar plots. (A) is unsprayed, unweeded controls, and (B) is imazethapyr treated plots. Error bars are LSD for main effect of herbicide on (a) sown clover; (b) grass weeds; (c) total dry matter yields.

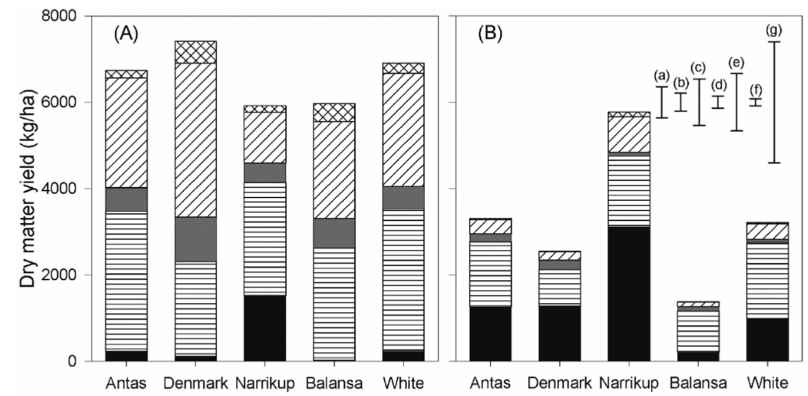

Figure 6 Total mean dry matter yields and composition for growth of five clover cultivars from 1 March to 27 October 2016 at Iversen 1, Lincoln University, Canterbury, New Zealand for sown clover (■), cocksfoot (▤), broadleaf weed (■), grass weed (▨) and dead matter (▩) components of cultivar plots. (A) is unsprayed, unweeded controls, and (B) is imazethapyr treated plots. Error bars are LSD for (a) main effect of cultivar on clover yields; (b) main effect of herbicide on clover yields; (c) main effect of herbicide on cocksfoot yield; (d) main effect of herbicide on broadleaf weed yields; (e) main effect of herbicide on grass weed yields; (f) main effect of herbicide on dead matter; (g) cultivar*herbicide interaction for total dry matter yields.

less than their respective unsprayed controls with 400 kg DM/ha. Broadleaf weeds identified were broadleaved dock (*Rumex obtusifolius*), clustered dock (*R. conglomeratus*), chickweed (*Stellaria media*), dandelion (*Taraxacum officinale*), fathen (*Chenopodium album*), hawksbeard (*Crepis capillaris*), mallow (*Malva nicaeensis*), spurrey (*Spergula arvensis*), twin cress (*Lepidium didynum*), wireweed (*Polygonum aviculare*), and yarrow (*Achillea millefolium*). Only broadleaved and clustered dock remained in the imazethapyr treatments, and these were stunted in size.

Grass weed yields of <100 kg DM/ha were lower (P=0.014) in imazethapyr treated plots than their untreated unweeded controls at 1100 kg DM/ha (Figure 4). Grass weeds identified were annual ryegrass, phalaris (*Phalaris aquatica*), and annual brome (*Bromus hordeaceus*).

Harvest 2: 27 October 2016

By the second harvest, clover yields were higher (P=0.001) at 750-1800 kg DM/ha in the sprayed plots than in their respective controls (Figure 5). The exception was balansa clover, which had no difference in yield between treatments at <100 kg DM/ha. Sown cocksfoot grass yields were 1000-1650 kg DM/ha after September grazing and were not different (P=0.099) between imazethapyr and the controls. Broadleaf weed yields were 100-250 kg DM/ha with no difference (P=0.128) between imazethapyr and the controls. Grass weed yields were higher (P=0.005) in controls, with 1300 kg DM/ha, while imazethapyr treatments had 250 kg DM/ha. Remaining grass weeds were predominantly annual ryegrass.

Total season yields

Total dry matter yields (harvest 1 plus harvest 2) for the season showed a cultivar x herbicide interaction, with only imazethapyr treated 'Narrikup' producing the same total DM as its control with 6000 kg DM/ha (Figure 6). Imazethapyr treated 'Antas', 'Denmark', white, and balansa clovers produced total DM yields lower (P=0.021) than their controls.

Sown clover yields of 'Narrikup' were higher (P=0.001) than all other cultivars. Imazethapyr treated 'Narrikup' produced 3100 kg DM/ha sown clover, which was greater (P<0.001) than its control at 1500 kg DM/ha. Sown clover yields of imazethapyr treated 'Denmark' and 'Antas' yielded 1250-1275 kg DM/ha, and were greater (P<0.001) than their unsprayed controls with 120-230 kg DM/ha. White and balansa clovers were consistently the lowest (P=0.001) yielding clovers, and not different (P<0.001) to their controls.

Sown cocksfoot grass yields were lower (P=0.013) in imazethapyr treatments, at 1300 kg DM/ha, than in the controls with 2800 kg DM/ha (Figure 6). This reduction was not consistent for the season, and only an early response to imazethapyr treatment (Figure 4) as the yields recovered to be not different by the second harvest (Figure 5).

Broadleaf weed yields were 150 kg DM/ha for imazethapyr treated plots, lower (P=0.002) than the unsprayed controls with 650 kg DM/ha. Grass weed yields were consistently reduced (P=0.006) by imazethapyr treatments with 350 kg DM/ha, and only the annual ryegrass remained, compared with the unsprayed control at 2400 kg DM/ha containing annual ryegrass, brome and phalaris.

Discussion

Phytotoxicity effects and sown clover yields

Sown balansa and white clover had lower seedling numbers following establishment compared to the three subterranean clover cultivars, which sustained minimal seedling losses over the 28 days (Figure 2). This failure to thrive both in the control and after imazethapyr application suggests that balansa and white clover were unable to establish as successfully with cocksfoot in the dry autumn conditions, despite the elimination of weeds. Thus the imazethapyr treatment failed to provide them with an advantage in the dry environment despite broadleaf weed control.

EWRS scores showed that clover cultivars responded differently to imazethapyr treatment (Figure 3). 'Narrikup' was the only cultivar with a final EWRS score of 3.0, which was higher than the control, but lower than the threshold of 5.0 from which plants are expected capable of recovery. This low EWRS score for 'Narrikup' was associated with only mild phytotoxicity symptoms as a result of imazethapyr treatment on the cultivar in these conditions, and a September harvest yield for the clover component the same as the unweeded control. This September yield was more than four times higher than the yields for all other clover cultivars. In contrast, the high EWRS scores of 'Denmark' and balansa clover (Figure 3) indicates that they were affected by imazethapyr application. 'Antas' and white clover showed less effect of the herbicide. Despite the indications provided by the EWRS scores across these four cultivars, their early spring yields were consistent at <250 kg DM/ha, with no differences between the sprayed and unsprayed plots (Figure 4). Phytotoxicity effects of imazethapyr were not easily visible on the white and balansa clover plants, but were marked as a reduction in plant number, while subterranean clover effects primarily presented as discolouration and leaf distortion. Confounding of the EWRS system has been noted by Dear & Sandral (1997), with symptoms such as leaf distortion providing a less reliable indication of yield loss.

The yields of all subterranean clover cultivars were lower than expected for a March sowing date, as mid-September yields for subterranean clover monocultures of 7000 kg DM/ha have been measured at this site (Moot *et al*. 2003). These yields were observed in irrigated, hand-weeded environments, and illustrate the impact of the late autumn rain in the current experiment. It seems that the low rainfalls in March following establishment, and in April following treatment application affected the growth rate of 'Antas' and 'Denmark' more severely than that of 'Narrikup'. The higher phytotoxicity response of 'Antas' may be a result of its larger seedling leaf size, allowing greater herbicide absorption than the 'Narrikup', which has a more pubescent leaf and petiole, which could afford it an additional barrier to herbicide absorption.

There was no residual effect of imazethapyr on subterranean clover after grazing, following the early spring harvest. After 1 month of recovery post-grazing, imazethapyr treated 'Narrikup' was again the highest yielding (Figure 5). Imazethapyr treated 'Antas', 'Denmark' and white clover recovered despite initial low yields, as has been previously reported in Australian evaluations of various subterranean clover cultivars (Dear *et al*. 1995; Sandral & Dear 2005). This recovery is indicative of a variation of susceptibility of subterranean clover cultivars to the foliar activity of imazethapyr, but no susceptibility to the 6 month residual soil activity (BASF 2011). In contrast, the failure of balansa clover to recover (Figure 5) shows that imazethapyr did not provide the establishing balansa clover and cocksfoot pasture mix with an advantage over the control, and potentially prevented subsequent emergence during the experimental period.

Cocksfoot

Imazethapyr application had no effect on cocksfoot seedling numbers, but appeared to reduce growth rates, with higher early-season cocksfoot dry matter yields in the unsprayed controls (Figure 4). Despite this, the cocksfoot recovered from the effect of imazethapyr after grazing in the late October harvest (Figure 5). This shows that the effect of imazethapyr on cocksfoot at this site was temporary, with no long-term yield reduction. Previous studies (Clemmer *et al*. 2004; Dear *et al*. 2006) confirmed initial phytotoxicity responses of grasses, before full recovery. The recovery of cocksfoot before subterranean clover set seed for the season would have provided feed after the subterranean clover life cycle had ended, and the pasture could continue to be grazed through the summer.

Broadleaf weed control

Imazethapyr markedly reduced broadleaf weeds in the early season by more than 85%, with <50 kg DM/ha remaining (Figure 4). Following grazing, remaining broadleaf weeds recovered and were not different between sprayed and unsprayed plots in the later harvest (Figure 5). It is likely that interspecific competition for light occurred in the control plots between cocksfoot and the broadleaf weeds. The dense grass canopy appeared to suppress the later growth of the broadleaf weeds following grazing and mowing. Despite this broadleaf weed suppression, clover yields in the controls were not higher as the grass also out-competed the sown clover species.

Grass weed control

Brome and phalaris grass weeds were eliminated by the imazethapyr application (Figure 4), while annual ryegrass persisted after imazethapyr application, but remained supressed (Figure 5). This control of annual ryegrass is in line with previous observations (Clemmer *et al.* 2004), however, its lack of recovery following grazing compared with the cocksfoot (Figure 5) suggests it was not as tolerant of imazethapyr treatment at the applied rate as the sown cocksfoot.

Total dry matter yields

Total DM yields for the 2016 growing season were dependent on how the sown clover cultivar tolerated imazethapyr treatment, because the other components only had a primary response to herbicide treatment, with no significant differences between cultivars (Figure 6).

Imazethapyr treated 'Narrikup' yielded 6000 kg DM/ha with 50% clover. This was the only sprayed treatment that yielded the same as the control, but controls contained only 25% clover. The increase in clover content in the imazethapyr treated 'Narrikup' yields was offset by reductions in cocksfoot (15%), broadleaf (8%), and grass weeds (5%). Total DM yields for imazethapyr treated 'Antas' and 'Denmark' were reduced by 50% compared with their controls, but they contained 40% sown clover compared with less than 5% in controls. This shows that the removal of broadleaf weeds and the reduction in grass when the clover was in the seedling phase reduced competition and allowed them to thrive. The increased seedling survival of subterranean clover could be expected to provide high quality feed for lactating ewes and lambs (Smetham 2003; Ates *et al.* 2006) and lead to greater seed set, which is vital for the persistence of subterranean clover in later years (Smetham 2003).

The autumn of 2016 was dry, with less than 50 mm of rainfall including irrigation through emergence and treatment application. This experiment has therefore investigated the effect of imazethapyr in a difficult pasture establishment scenario. With higher rainfalls faster growth was expected with yields more in line with those observed by Moot *et al*. (2003). With faster growth, herbicide action on broadleaf weeds would be more rapid, however, this faster growth would also occur in the sown components. This increase in metabolism could also mean increased herbicide uptake, potentially affecting the ability of the sown cocksfoot and subterranean clover to recover fully, and should be investigated further.

Conclusions

Seasonal yields of sown subterranean clover increased with imazethapyr herbicide treatment at the 3-4 trifoliate leaf stage, and broadleaf weeds were well-controlled from the seedling stage. All subterranean clover cultivars yielded at least 1000 kg DM/ha more clover than their unsprayed, unweeded controls. Grass weeds were well controlled, and remained controlled, while cocksfoot growth was initially checked by the herbicide, but it recovered from the early yield depressions later in the season after grazing. Weed control was effective to improve the overall legume content of the subterranean clover pastures, but there were significant differences between subterranean clover cultivars and their susceptibility to imazethapyr.

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Winter rotation length effect on pasture production and animal performance

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Abstract

Data comparing pasture production in winter pastures subject to 16, 48 or 72-day rotation lengths were recovered from experiments at Massey University to support teaching of grazing management. 'Farmlets' with 16 breeding ewes on 0.8 ha were run from 2011-2016, and herbage production estimated from metabolic energy budgeting (MEB). The data illustrate: the roles of pasture cover and animal body weight as buffers to neutralise the impact of weather variability, the use of controlled cover release via the grazing rotation to partially meet winter feed deficit, and the potential value of MEB in systems research. Grass grown from May to September (early pregnancy to mid-lactation) was 3850, 4220 and 4840 kg DM/ha for 16, 48 and 72-day rotations, respectively. As a result of a reduction in herbage accumulation and the premature release of autumn-saved pasture to animals, the 16-day rotation failed to overwinter the animals in five of the 6 years, the exception being a winter with high pasture growth.

Keywords: winter rotation length, pasture growth rate, teaching pedagogy

Introduction

The majority of sheep and beef farms in New Zealand manipulate the grazing rotation length to store autumn-grown feed as increased cover for release back to stock during periods of lower growth rates in winter. This winter management practice is often referred to as a 'controlled grazing system' (CGS) (Milligan 1981; Sheath *et al.* 1987). A key component of a CGS is the rationing of herbage intake of stock to levels that provide for body maintenance and pregnancy requirements, while retaining any pasture growth which is surplus to those requirements as standing herbage mass or 'cover'. Longer rotation lengths are achieved by keeping animals longer on a paddock during a grazing event and result in lower residual herbage mass after grazing. Paradoxically, even though herbage removal (kg DM/ha) is increased when the rotation is lengthened, individual animals consume less feed/head/day. This is because intake per animal is progressively reduced during successive days of a paddock grazing event as herbage height is lowered. Daily herbage intake of animals in a rotational grazing event can be monitored by calculating the herbage removed during grazing and dividing by the grazing intensity (animal. days/ha) (Matthews *et al.* 1999). Herbage consumption at a whole farm level (kg DM/ha/day) is thus determined by the stocking rate and rotation length.

The optimal rotation length depends on a range of site factors and so can vary greatly between farms. The key factor to plan rotation length is expected winter pasture growth rate; for a higher growth rate, increased stocking rate and decreased rotation length would be indicated and vice versa. Compared to set-stocked (continuously grazed) systems typically practiced in the middle of last century, a CGS allows more animals to be overwintered, enhancing farm carrying capacity and profitability. Little definitive research exists on the question of whether the higher stocking rate possible in a CGS than in a set-stocked wintering system arises simply from the reconciliation of mismatches in time between when the feed grows and when animals need it, or whether the longer grazing rotations in a CGS actually increase pasture growth rates.

To assist teaching of grazing management theory and practice at Massey University, a series of 'farmlets' have been maintained for about 25 years, where final year students working in a group create a small scale CGS on a block of 8 x 0.1 ha paddocks with electric fences for subdivision, running from early-May to late-September. Calculations on a per hectare basis are similar to those for a commercial farm. Typically, there are 5 or 8 student groups, each with their own farmlet. For 13 years (2004-2016), 2nd year veterinary students have also been provided with farmlets for the teaching of grazing management theory and metabolic energy based feed budgeting. Farmlet teaching for veterinary students has involved a comparison of outcomes for farmlets commencing with a common herbage mass on 1 May, stocked at 20 ewes/ha, and running 16, 48 or 72-day grazing rotation lengths until lambing in mid-August. Near the start of lambing, sheep are set-stocked until late September when they are weighed and the

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