Weed population dynamics for contrasting organic pasture establishment techniques

K.C. Harrington, P.D. Kemp, D.J. Horne and X.Z. He

Institute of Agriculture and Environment, Massey University, Private Bag 11-222, Palmerston North 4442, New Zealand

Corresponding author: K.Harrington@massey.ac.nz

Abstract A trial was conducted on an organic dairy farm in Manawatu, New Zealand, to determine how well perennial weeds are controlled during pasture renewal. Changes in weed populations were monitored following three different non-chemical methods of regrassing. Regrassing by planting pasture 4 weeks after ploughing the old pasture (“grass-to-grass”) was compared for spring and autumn cultivation. The third method involved ploughing in spring, growing turnips over summer then regrassing in autumn. All three techniques caused significant increases in broad-leaved dock (*Rumex obtusifolius*) and creeping buttercup (*Ranunculus repens*) populations. Although both these species regrew from vegetative organs, it was the establishment of new seedlings following cultivation that appeared to increase populations most. This build-up of dock seedlings occurred more when using a crop than just grass-to-grass systems. A 2-week fallow after ploughing gave better control of perennial weeds than having no fallow, but a 4-week fallow gave little further improvement.

Keywords pasture weeds, dock, *Rumex obtusifolius*, buttercup, *Ranunculus repens*, *Ranunculus sardous*, regrassing, ploughing.

INTRODUCTION

In organic farming systems where glyphosate cannot be used, regrassing pastures generally involves cultivation in order to control existing weeds and old pasture species so that new pasture cultivars can be established. This regrassing process is also an opportunity to introduce extra species alongside the traditional perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) used in New Zealand pastures, such as chicory (*Cichorium intybus*) and narrow leaved plantain (*Plantago lanceolata*), to help increase the diversity of the pastures.

Old dairy pastures often have many perennial weed species present within them, such as broad-

leaved dock (*Rumex obtusifolius*), creeping buttercup (*Ranunculus repens*) and Californian thistle (*Cirsium arvense*) (Harrington et al. 2008). They also often have low producing grass species, such as browntop (*Agrostis capillaris*), creeping bent (*Agrostis stolonifera*) and couch (*Elytrigia repens*). Although these species increase diversity within an organic pasture, they are not wanted in systems in which high levels of pasture production are required to maximise milk production (Matthews et al. 1999).

If glyphosate cannot be used to kill these species prior to sowing new pastures, then mouldboard ploughing is often considered

the best way to control existing weed species, burying the vegetative organs more deeply than other cultivation methods (Melander et al. 2012). For many perennial weeds, a single ploughing event will not be sufficient to kill them. Usually ploughed paddocks are left fallow for a number of weeks to allow time for the buried vegetation to either die or begin to regrow, followed by secondary cultivation to prepare the seed-bed and disturb any weed regrowth that may be occurring (Ross & Lembi 1985). However, having land out of production for extra weeks for this fallow within high producing dairy systems can have an impact on the amount of feed available for the dairy herd, compared with conventional dairy farms where regrassing often involves applying glyphosate then direct drilling the next pasture almost immediately (Hampton et al. 1999).

The two main times that new pastures get established in New Zealand dairy farms are in autumn and spring (Hampton et al. 1999). Observations made during the monitoring of a trial comparing organic dairying with conventional dairying for 10 years at Massey University in Manawatu found that weeds establishing after spring sowing can differ from those after autumn sowing (Harrington et al. 2008, 2012). Another option is to plough in spring, grow a crop over summer such as turnips, then resow in autumn, allowing further tillage of perennial weeds.

The objective of this research was to compare the effect of different techniques for establishing new pastures on an organic dairy farm on weed control. Autumn sowing was compared with spring sowing. Different lengths of fallow were compared following ploughing. Resowing with pasture immediately after ploughing ("grass-to-grass") was compared with planting a crop before re-establishing pasture.

MATERIALS AND METHODS

The trial was conducted on two separate paddocks (Paddocks 31 and 55) of the Dairy Cattle Research Unit at Massey University, Palmerston North. Both paddocks had been in dairy pasture for several decades, comprising

mainly perennial ryegrass and white clover but also many weed species such as broad-leaved dock and creeping buttercup. Paddock 31 (0.95 ha) had not been ploughed for at least 10 years prior to this work commencing. Paddock 55 (1.15 ha) was regrassed in March 2006, but the pasture productivity following this regrassing was poor due to weed ingress so it was regrassed again as part of this project. The soil in both paddocks is Tokomaru silt loam, which has poor natural drainage. Both paddocks were artificially drained using mole-pipe drainage systems.

Each paddock was divided into five similar sized sections (approximately 0.2 ha each). Transects were set up for each of the sections in each paddock by stretching measuring tapes between pegs, and 20 permanent quadrats 1 m × 1 m in size were established along these transects so that they could be found again after cultivation and grazing events. This gave a total of 200 quadrats that were monitored from the five treatments replicated two times each.

During October 2010, the percentage cover of each plant species within each quadrat was visually estimated by the same assessor. One of the five sections of each paddock remained in pasture grazed by dairy cows over the following 3 months (Treatment 1, autumn ploughed). The remainder of each paddock was mouldboard ploughed, with two sections in each paddock ploughed on 8 October 2010 then fallowed for 4 weeks (Treatments 2 and 3), one section in each was ploughed on 21 October and left fallow for 2 weeks (Treatment 4), and the remaining section in each paddock was ploughed on 2 November and given no fallow period (Treatment 5). All ploughing was done to a depth of 15 cm, and then rolled with a Cambridge roller immediately after ploughing. On 3 November, all ploughed sections received two passes of a power-harrow cutting 8–10 cm deep, then were Dutch harrowed to a depth of 2–3 cm. Treatments 3, 4 and 5 in each paddock (one of the 4-week fallow sections, a 2-week fallow and the no fallow) were planted with turnips (*Brassica rapa* ssp. *rapa* cv. Barkant) at 2.5 kg/ha at a depth of 1 cm using a Vee-ring roller drill and chain harrows. The other 4-week

fallow section was sown into pasture (Treatment 2), also on 3 November, using the same sowing technique, using 15 kg/ha perennial ryegrass (cv. Halo), 4 kg/ha white clover (cv. Apex) and 5 kg/ha narrow-leaved plantain (cv. Tonic).

The presence of weeds in the quadrats was assessed from October 2010 until December 2011 at approximately 2-month intervals, mainly with visual estimates of percentage cover by various components, but there were also some counts of plant numbers. The new pasture received its first grazing after 2 months, whereas grazing of the turnips began after 3 months. The turnips were break-fed each day. The section of each paddock left in old pasture over summer (Treatment 1) was mouldboard ploughed on 8 February 2011 and left fallow for 4 weeks. These sections plus all sections that had been sown in turnips were power-harrowed twice on 8 March, then sown into pasture using the same technique and seed mixture used on 2 November. The weed composition of all fixed quadrats continued to be monitored until December 2011.

The rainfall at the site was much higher than average in September 2010 (Figure 1), which caused a delay in starting the trial until October. There was then much less rainfall than usual for the next 3 months, after which rainfall was fairly normal, though quite high during autumn.

Data on percentage of quadrats with the species present before ploughing or with any

regrowth present 4 weeks after sowing (Table 1) and percentage of quadrats with dock regrowth (Table 2) were analysed using a Chi-square test followed by the Marascuilo procedure for multiple comparison (Daniel 1990). Other density and frequency data in Tables 2 and 3 were not normally distributed (goodness-of-fit test, i.e. Kolmogorov-Smirnov test) and thus analysed using the non-parametric Kruskal-Wallis test followed by the Bonferroni multiple comparison.

RESULTS

The perennial weeds that commonly regrew 4 weeks after sowing across both paddocks following the different lengths of fallow are shown in Table 1. Some species such as couch and creeping buttercup were found in similar numbers of quadrats regardless of whether there was no fallow, or the fallow was 2 or 4 weeks. However, for the other species, having a fallow of at least 2 weeks seemed to improve their control, though often there was no significant improvement by waiting until 4 weeks after ploughing before sowing the crop. Results obtained 7 weeks after sowing were very similar to those measured after 4 weeks (data not shown). However, each of those regrowing plants continued to get bigger over time. There was little evidence that length of fallow affected the establishment of turnip seedlings 7 weeks after sowing (Table 2).

Figure 1 Monthly rainfall (mm) from July 2010 to December 2011 (bars), compared with the 20-year average for Palmerston North (line). (Source: Grasslands AgResearch, Palmerston North.)

Table 1 The occurrence of perennial species within fixed quadrats located in dairy paddocks before and after ploughing in spring 2010 followed by 0, 2 or 4 weeks of fallow then sown into turnips or back into pasture. Values are percentage of quadrats with the species present before ploughing or with any regrowth present 4 weeks after sowing. Values with the same letter in the same row are not significantly different ($P>0.05$).

	Before	Length of fallow		
		0 weeks	2 weeks	4 weeks
couch	NM ¹	90.0 ab	72.5 b	96.3 a
creeping buttercup	100.0 a	85.0 ab	65.0 b	70.0 b
browntop	NM	40.0 a	27.5 ab	15.0 b
perennial ryegrass	100.0 a	70.0 b	27.5 c	15.0 d
dock species	75.0 a	27.5 b	5.0 d	10.0 c
white clover	92.5 a	25.0 b	2.5 c	1.3 c
No. quadrats	160	40	40	80

¹NM = not measured.

Table 2 presents data on densities of dock weeds over the months following this initial regrowth. Although there was not much regrowth of dock following the spring cultivation, there were a lot of seedlings that established in the bare, tilled soil, so the vast majority of dock plants in each quadrat 7 weeks after the spring sowing were seedlings. Most of these seedlings developed successfully into plants, so that there were densities of 7-9 plants per m² at the assessment in early March 2011 following the grazing of the turnips and before the next cultivation. Following the power-harrowing of the turnip crop and resowing of grass later in March, many of these dock plants survived, as there were still approximately 3-6 regrowing plants per m², much more than the regrowths per m² after the spring ploughing and with dock regrowth in a higher percentage of quadrats (Table 2). However, 52% of quadrats of autumn-sown grass-to-grass pasture also had dock regrowth (Table 2), compared with 10% for spring sowing following the 4-week fallow (Table 1).

Another cohort of seedlings also established in the bare soil in autumn as the new pasture was establishing, increasing dock densities further. Thus in December 2012, the net effect of regrassing was to cause a significantly higher dock infestation than occurred previously (Table 3). Although all regrassing strategies resulted in

significantly higher ($P<0.01$) dock densities than were present beforehand, regrassing by using a turnip crop caused significantly higher dock densities than by grass-to-grass strategies in either spring or autumn.

The dynamics of buttercup regrowth was more difficult to study because regrowth was not through discrete plants like docks but rather parts of stolons, and also seedlings were a mixture of creeping buttercup and hairy buttercup (*Ranunculus sardous*), which are very difficult to tell apart when young. However, as with dock, there tended to be more creeping buttercup regrowth in pastures sown in autumn from areas that had been in crop over summer than the area that had remained in pasture, although variability in data meant this difference was not statistically significant ($P>0.05$) (Table 2). But in contrast to dock, which had more seedlings in ex-crop new pasture than in the grass-to-grass pasture, there were significantly more buttercup seedlings in the grass-to-grass pasture than in pasture previously in crop. Much of this was hairy buttercup, a winter annual species, although in one paddock it was creeping buttercup that dominated in the first winter whereas in the other, it was mainly hairy buttercup growing. Buttercup was up to 25-35% of the entire pasture cover at times. The hairy buttercup had almost all died off by the

Table 2 Plant densities within monitored fixed quadrats located in dairy paddocks following ploughing in spring 2010 with 0, 2 or 4 weeks of fallow then sown into turnips or back into pasture. All turnip plots were resown into pasture in autumn 2011, and re-establishment of weeds was compared with plots in which new pasture was established after ploughing pasture also in autumn. Means with the same letter in the same row are not significantly different ($P>0.05$).

Length of fallow	Turnips			New grass ¹
	0 weeks	2 weeks	4 weeks	4 weeks
7 weeks after November sowing (20/12/10)				
% cover by turnips	39.4 a	39.1 a	46.0 a	-
dock regrowth (no./m ²)	0.53 a	0.05 b	0.10 b	0.20 ab
dock seedlings (no./m ²)	7.4 bc	11.0 ab	12.6 a	4.4 c
17 weeks after November sowing (4/3/11)				
dock plants (no./m ²)	7.8 a	6.9 a	9.2 a	3.4 b
5 weeks after March sowing of grass (20/4/11)				
% quadrats with dock regrowth	90.0 a	95.0 a	97.5 a	52.5 b
dock regrowth (no./m ²)	3.5 b	5.0 a	5.8 a	1.2 c
dock regrowth (% cover)	6.1 a	7.6 a	9.7 a	2.1 b
dock seedlings (no./m ²)	39.6 a	42.4 a	47.4 a	13.8 b
buttercup regrowth (no./m ²)	7.9 a	11.7 a	12.1 a	3.1 a
buttercup seedlings (no./m ²)	32.7 b	37.1 b	35.0 b	186.3 a

¹New grass for April measurements was from March sowing (Treatment 1); other new grass measurements were from November sowing (Treatment 2).

time of the final measurements shown in Table 3 for December 2012, at which time creeping buttercup was at similar levels across the three main treatments (grass-to-grass in spring, or in autumn, or cropping then regrassing), but in all cases, the buttercup had increased significantly compared with original covers (Table 3).

All three systems of regrassing caused significant increases in the white clover and narrow-leaved plantain components of the swards (Table 3), which was one of the objectives of regrassing. The narrow-leaved plantain was particularly dominant in the swards established in spring because both the perennial ryegrass and white clover seedlings struggled during the dry months after sowing (Figure 1) compared with narrow-leaved plantain. In early February 2011, the average ground covers for the spring-sown pastures of plantain, grass and clover were 56.7%, 7.6% and 3.6%, respectively. The remaining 32% of cover was made up of weeds, with the main species being docks, buttercups, black nightshade (*Solanum nigrum*),

willow weed (*Persicaria maculosa*), creeping yellow cress (*Rorippa sylvestris*) and twin cress (*Lepidium didymum*).

In contrast, in late June, 16 weeks after the grass-to-grass autumn sowing, the average ground covers for plantain, grass and clover were 7.0%, 51.6% and 2.4%, respectively. The remaining 39% of area was made up mainly of buttercup, some dock and small amounts of other species like twin cress and hawkbit (*Leontodon taraxacoides*) (data not shown).

Although the creeping buttercup and dock densities increased as a result of regrassing, as measured in December 2012, most of the minor weed species were less evident, such as daisy (*Bellis perennis*), dandelion (*Taraxacum officinale*), catsear (*Hypochaeris radicata*), turf speedwell (*Veronica serpyllifolia*), broad-leaved plantain (*Plantago major*) and selfheal (*Prunella vulgaris*) (Table 3). However, hawkbit did increase significantly, albeit still remaining below a total cover of 2.5%. The density of couch

Table 3 The mean percentage cover of dairy pasture quadrats by various species both in October 2010 before regrassing and 14 months later after either being sown back into grass in spring following ploughing, from grass-to-grass after ploughing in autumn, or ploughed in spring, cropped over summer and regrassed in autumn. Means with the same letter in the same row are not significantly different ($P>0.05$).

		Dec 2011		
	Oct 2010	Grass-to-grass in spring	Grass-to-grass in autumn	Grass-to-grass via turnips
Sown species:				
grasses	94.5 a	39.3 b	44.0 b	45.7 b
white clover	1.1 c	11.7 b	24.7 a	12.0 b
narrow-leaved plantain	0.2 c	22.7 a	9.9 b	8.8 b
Perennial weeds:				
creeping buttercup	1.51 b	12.39 a	6.49 a	8.96 a
couch	NM ¹	3.26 a	1.71 a	7.80 a
docks	0.33 c	2.70 b	2.90 b	6.38 a
hawkbit	0.12 b	1.54 a	2.28 a	2.28 a
dandelion	0.12 a	0.03 b	0.02 b	0.03 b
daisy	0.23 a	0.01 b	0.01 b	0.03 b
turf speedwell	0.12 a	0.00 b	0.01 b	0.01 b
catsear	0.11 a	0.00 b	0.00 b	0.02 b
broad-leaved plantain	0.06 a	0.03 b	0.03 b	0.01 b
selfheal	0.03 a	0.00 b	0.00 b	0.02 b
Annual weeds:				
toad rush	NM	0.10 b	4.48 a	4.89 a
hairy buttercup	NM	0.80 b	1.58 a	1.47 ab

¹NM = not measured.

was not measured initially as it was not noticed among the perennial ryegrass due to its similarity in appearance. However, as with the docks, it benefited from the regrassing particularly for the parts of the paddocks that were cropped (Table 3). Annual weeds increased markedly soon after planting pasture both in spring and autumn, but by December 2012 they had died off and there were mainly just a few toad rush (*Juncus bufonius*) and hairy buttercup plants remaining.

DISCUSSION

When replacing a pasture, often it is considered that planting a fodder crop as part of the resowing exercise gives more opportunities to control perennial weeds. In conventional agriculture,

where herbicides can be used, this is usually true. Glyphosate, with other herbicides added such as thifensulfuron, tribenuron or dicamba, can be used both when killing off the pasture and also before sowing the next pasture to properly kill perennial weeds that may be present, such as broad-leaved dock, creeping buttercup or couch. Use of selective herbicides such as aminopyralid within brassica crops or MCPB in new pastures can also deal with seedlings that emerge.

Data presented above suggest that in organic pastures when none of these herbicides can be used, growing a crop before regrassing a pasture may actually encourage some perennial weed species such as broad-leaved dock. There is usually some regrowth from vegetative organs,

and also establishment of new seedlings of such species. When a crop is left for several months before being grazed, this can allow these perennial weeds to become more dominant than in a tightly grazed pasture situation. Under the conditions of this trial, most of the dock problems came from new seedlings establishing rather than from the regrowth of old root systems. When regrassing by going straight from one pasture to another, there was less opportunity for this build-up in dock populations.

The situation was more complicated with buttercup populations because of the mixture of the annual hairy buttercup and the perennial creeping buttercup, which were difficult to tell apart at times. However, it was noticeable that there were considerably more buttercup seedlings establishing in the grass-to-grass treatment planted in autumn than in areas that had been in crop through summer (Table 2), probably because many of the buttercup seeds had germinated in spring for the cropped paddocks and had not been replaced in the soil seed bank due to hard grazing then power-harrowing of the crop before plants could set seed. Thus, use of a crop did cause a decrease in buttercup seedling populations in autumn-sown pastures, some of which would have been creeping buttercup, although regrowth from stolons in cropped areas was also strong in autumn. All techniques for regrassing caused large increases in creeping buttercup by the end of the trial, partly through the regrowth from stolons and partly from seedling establishment.

Although control of perennial species was better in spring when a 2-week fallow was used before sowing rather than no fallow, there appeared to be no further advantage to using a 4-week fallow. In the case of docks, the amount of regrowth from old root systems was negligible as the seedlings that established were much more important in determining how many docks were causing problems in the crop by the end of summer. Given that a delay in getting crops or pastures sown while fallowing results in lost production to the overall farming system, organic farmers could benefit from decreasing fallow length from 4 weeks to

2 weeks. They may even find having no fallow at all will not have any major effect on the final outcome of their pasture or crop due to regrowth from vegetative organs being less important than establishment of new seedlings of docks.

As herbicide use is prohibited, weeds will always be common in newly sown organic pastures. These could be reduced by establishing crops more rapidly than occurred in this trial, which experienced problems from firstly late establishment due to wet weather then dry weather. Increasing ryegrass sowing rates above the 15 kg/ha used with this trial could help, as shown by Seefeldt & Armstrong (2000). However, this lower rate was used to improve establishment of plantain and clover. If regrassing is not attempted, then it becomes difficult to get new cultivars of clover and ryegrass established, and to incorporate species such as plantain and chicory into the sward. Past results have shown that weed densities decrease 2 years after resowing (Harrington et al. 2012). Also, having some of these weed species growing alongside the sown pasture species increases the biodiversity of pastures, and many of the species have high mineral contents and good feed value (Harrington et al. 2006). Species with deep root systems, such as docks and couch, may be less likely to die back during drought.

Thus, this trial has shown that organic farmers regrassing their pastures should expect to see an increase in densities of some perennial weed species as a result of the regrassing. They may be better to simply plough then resow the pasture rather than establishing a crop first. Fallowing after ploughing can give a small improvement in control of perennial weeds, but the fallow need not be longer than 2 weeks.

ACKNOWLEDGEMENTS

The authors wish to thank Petra Stein for her invaluable assistance with the field work, also Mark Osborne for his cultivation work, Kerry Miller and other farm staff for help with coordinating grazing events, and also the C A Elliott Charitable Trust and DairyNZ for funding the work.

REFERENCES

- Daniel WW 1990. Applied nonparametric statistics. PWS-Kent Publishing Company, Boston, USA. 635 p.
- Hampton JG, Kemp PD, White JGH 1999. Pasture establishment. In: White JGH, Hodgson J ed. New Zealand pasture and crop science. Oxford University Press, Auckland, New Zealand. Pp. 101-115.
- Harrington KC, Osborne MA, Kemp PD 2008. Weed cover unaffected after converting a dairy farm to organic production. New Zealand Plant Protection 61: 116-120.
- Harrington KC, Osborne MA, Kemp PD 2012. Effect of 10 years of organic dairy farming on weed populations. Proceedings of the 18th Australasian Weeds Conference: 159-162.
- Harrington KC, Thatcher A, Kemp PD 2006. Mineral composition and nutritive value of some common pasture weeds. New Zealand Plant Protection 59: 261-265.
- Matthews PNP, Harrington KC, Hampton JG 1999. Management of grazing systems. In: White JGH, Hodgson J ed. New Zealand pasture and crop science. Oxford University Press, Auckland, New Zealand. Pp. 153-174.
- Melander B, Holst N, Rasmussen IA, Hansen PK 2012. Direct control of perennial weeds between crops – Implications for organic farming. Crop Protection 40: 36-42.
- Ross MA, Lembi CA 1985. Applied weed science. Burgess Publishing Co, Minneapolis, Minnesota, USA. 340 p.
- Seefeldt SS, Armstrong ML 2000. Impact of perennial ryegrass seeding densities on weed emergence, growth and development. New Zealand Plant Protection 53: 38-43.