Timing and frequency of tine weeding in organic wheat and pea crops

Farhad Dastgheib

IWM Consultancy, 58 South Belt, Lincoln 8152, Farhad@inet.net.nz

Abstract

Field trials in winter wheat (*Triticum aestivum*) and process peas (*Pisum sativum*) were conducted over two years to compare different tine weeding treatments. Performance of tine weeding depended upon the weed species and their age, and timing was critical in selectivity and effectivity of tine weeding. In wheat, pre-emergence tine weeding provided satisfactory weed control for some time, but needed a second tine weeding for the late emerging weeds. Despite reducing weed pressure, tine weeding treatments did not increase grain yield of wheat. In peas, late post-emergence tine weeding was significantly less effective in decreasing weed density than the earlier treatments. The greatest increases in pea yield were obtained in the pre-emergence or early post-emergence tine weeding treatments. It is suggested that in many cases, it should be possible to reduce the number of tine weeding operations without risking yield.

Additional key words: harrow, integrated weed management, mechanical weed control, organic farming, spring-tine harrow.

Introduction

Organic farmers face a great challenge for selective weed control in arable crops. The main method of weed control in organic arable crops during the growing season is mechanical weeding mostly performed with spring-tine harrow, also known as tine weeder. Very few reports are available in New Zealand on mechanical weed control in organic crops. Stiefel & Popay (1990) studied the effect of tine weeding in cereals and peas (*Pisum sativum*). They reported reductions in weed density as much as 80 % without any damage to the crops from one or two passes of tine weeder. Reddiex *et al.* (2001) compared tine weeder, spoon weeder and inter-row hoe in four crops and found that the performance of the above tools depended on the crop. Rasmussen (1991) from Denmark emphasised the need for more research to adjust timing and intensity of harrowing for mechanical weed management. In the UK, Welsh *et al.* (1997) reported that the efficacy of spring-tine weeding in wheat (*Triticum aestivum*) depended on the timing of use and the weed species present.

Most organic growers carry out several tine weeding operations during the season to control weeds. It is useful to reduce the number of tine weeding operations as they are damaging to the soil and the crop. For the farmers to make a better judgement on timing and frequency of tine weeding, information on its impact on weeds and crops is needed. This study was undertaken to compare different times and numbers of tine weeding in wheat and process peas under farmers conditions in Central Canterbury. The paper reports results from a number of field experiments conducted over two years.

Methodology

General

The experiments were conducted during 2001 and 2002 on certified organic farms at different sites in mid-Canterbury and received the same crop management as that of farmers. All experiments were laid out in randomised complete block designs with four replicates except the first year trials at Rakaia which had three replicates.

First year

One field experiment in wheat in Rakaia and three field experiments in peas were conducted at different sites namely Rakaia, Hororata and Lincoln (Kowhai Farm). In all experiments five treatments were compared as follows:

1. Nil treatment, no weeding
2. Pre-emergence tine weeding, In the first week after drilling but before crop emergence.
3. Early post emergence tine weeding, wheat was at 1-2 leaf stage and peas at 2-3 node stage.

4. Late post emergence tine weeding, wheat at 4-5 leaf stage with 2 tillers, peas at 5-6 node stage.
5. Pre-emergence + Late post emergence tine weeding, two weeding was done as described above for 2 and 4.

Second year

Two experiments in wheat were conducted at Rakaia and Dunsandel and two experiments in peas at Rakaia and Southbridge. Tine weeding treatments were designed according to the crop-weed situation and are described under each crop.

Wheat

Rakaia

Wheat cv. Monad was drilled at 120 kg/ha on 27 May 2002. Experimental plots were 20 m long and 6.5 m wide (width of the tine weeder) and six treatments were compared, namely: 1) Nil, no weeding; 2) Pre-emergence; 3) Early post emergence, at 2.5-leaf stage; 4) Late post emergence, at 5.5-leaf stage; 5) Pre-emergence + Early post emergence and 6) Early + Late post emergence.

Dunsandel

Wheat cv. Torlesse was drilled at 130 kg/ha on 20 July 2002. Experimental plots were 15 m long and 12 m wide (width of the tine weeder). Six treatments were compared as follows: 1) Nil, no weeding; 2) Early post emergence at 2.5 leaf; 3) Mid-post emergence at 3.5-leaf stage; 4) Late post emergence at 5.5-leaf stage; 5) Early + Mid-post emergence and 6) Early + Late post emergence.

Peas

Rakaia

Peas cv. Princess was drilled on 25 August 2002. Experimental plots were 20 m long and 6.5 m wide (width of the tine weeder) and four treatments were compared namely: 1) Nil, no weeding; 2) Pre-emergence; 3) Mid post-emergence at the 4-node stage and 4) Pre-emergence + Mid post-emergence

Southbridge

Peas cv. Aladdin was drilled on 23 November 2002. Experimental plots were 20 m long and 6.5 m wide (width of the tine weeder). Six treatments were compared: 1) Nil, no weeding; 2) Pre-emergence; 3) Early post emergence at 2.5-node stage; 4) Late post emergence at 5.5-node stage; 5) Pre-emergence + Early post and 6) Pre-emergence + Early post + Late post.

Measurements

Comparison of tine weeding treatments was made by determining number of weeds as well as shoot biomass of weeds and crops in two randomly placed quadrats (0.5 x 0.5 m) per plot during the growing season. At maturity, wheat grain yield was measured using a Wintersteiger 'Elite' plot combine with 1.65 m swath and adjusted to 14 % moisture. For peas, weed biomass and crop yield were measured at harvest using two randomly placed, 2 m^2 quadrats per plot.

Data were analysed using Microsoft Excel ANOVA and where the F test was significant, $LSD_{(p<0.05)}$ values were calculated for mean comparison.

Results

Wheat

First year, Rakaia

The major weeds in the trial site were fumitory (*Fumaria officinalis*), annual poa (*Poa annua*) and chickweed (*Stellaria media*), while shepherd's purse (*Capsella bursa-pastoris*), field speedwell (*Veronica arvensis*), clovers (*Trifolium* spp.) and vetch (*Vicia sativa*) comprised the bulk of other weeds. comparison of tine weeding treatments in mid-season (Table 1) showed that all treatments reduced the number and total biomass of weeds compared with the control. Weed density was reduced significantly by tine weeding. The combination of pre-emergence + late post-emergence was the most effective treatment in reducing weed density. Only 71 weed plants/m^2 were counted in this treatment, which is a reduction of 82 %.

Although there was some pulling of wheat plants by the harrow, tine weeding treatments did not affect number of wheat plants or their tiller number significantly (data not presented). Grain yield of wheat ranged from 4228 kg/ha (Control) to 4492 kg/ha (early post-emergence tine weeding) with no statistical difference between treatments (Table 1).

Table 1. Mid-season results on weeds in wheat at Rakaia and grain yield of wheat at harvest in 2001.

Tine weeding	No. weeds /m2	Weed dry weight (g/m2)	Grain yield (kg/ha)
Nil	444	22.9	4228
Pre-em.	149	8.9	4391
Early post	210	13.1	4492
Late post	188	7.8	4273
Pre-em. + Late Post	71	2.5	4365
$LSD_{0.05}$	283	16.8	ns

Second year

Rakaia

The paddock did not have a strong weed pressure. An average of 130 weed seedlings per m^2 was counted in October, most of which succumbed to the competition by a vigorous crop with a high density of more than 210 plants per m^2. The main weed species were fumitory (*Fumaria officinalis*), chickweed (*Stellaria media*) and shepherd's purse (*Capsella bursa-pastoris*).

The comparison of the two main post-emergence tine weeding treatments showed that early post emergence (2.5-leaf stage of the crop) was more effective in controlling weeds but caused more damage to the crop (Table 2). The reduction in the number of wheat plants, however, was not serious considering the high population density of the crop. Due to low weed pressure, all treatments looked similar at harvest time and yield data were not taken.

Table 2. Weed control and crop mortality in wheat after tine weeding treatments in 2002.

Tine weeding	% weed kill		% wheat mortality	
	Rakaia	Dunsandel	Rakaia	Dunsandel
Early post	62%	39%	18%	12%
Mid post	---	45%	---	12%
Late post	22%	33%	1%	5%

Dunsandel

The crop at this site was weak with low population density and was very weedy. The major weed species were wirewed (*Polygonum aviculare)*, fathen (*Chenopodium album*) and chickweed. Other weeds comprised field speedwell, cornbind (*polygonum convolvulus*) and scarlet pimpernel (*Anagallis arvensis).* Later in the season, perennial weeds, namely Californian thistle (*Cirsium arvense*) and couch (*Elytrigia repens)* dominated most of the plots. Tine weeding at 2.5- or 3.5-leaf stage (early or mid-post) caused the same reduction of 12 %, but tine weeding at 5.5-leaf stage (late post) caused only 5 % reduction in wheat population. The highest reduction in weed density (45 %) was obtained by mid-post tine weeding.

Biomass of wheat measured in mid December was similar between the control and late post-emergence tine weeding (Table 3). All other treatments produced a biomass greater than the control. Weed biomass in the control, mid post-emergence and late post-emergence tine weeding were similar. Weed biomass was significantly reduced in early post-emergence tine weeding and treatments with two tine weeding operations. Wheat grain yield was not affected by any of the treatments (Data not presented).

Table 3. Biomass of weeds and wheat in different tine weeding treatments measured on 19/12/02 at Dunsandel.

Tine Weeding Treatment	Weeds dry wt. (g/m2)	Wheat dry wt. (g/m2)
Nil, no weeding	214.7	319.5
Early post emergence	109.3	443.5
Mid-post emergence	184.0	462.5
Late post emergence	201.3	326.5
Early + Mid-post emergence	121.3	491.0
Early + Late post emergence	127.3	469.0
$LSD_{0.05}$	55.9	104.1

Peas

First year

In general, tine weeding resulted in a marked reduction in the number of weeds but the extent of reduction depended on timing of the operation (Table 4). In all the three trials in 2001, late post-emergence tine weeding was significantly less effective in decreasing weed density than early post-emergence treatment. At Rakaia and Hororata, a single tine weeding at early post-emergence was more successful in reducing weed density than two tine weeding operations at pre and late post-emergence. At Lincoln, these treatments gave similar reduction in the number of weeds and both were better than either pre-emergence or late post-emergence tine weeding. Average dry weight of weeds, which is a measure of their size, was significantly reduced by pre-emergence or early post-emergence weeding at Hororata and Lincoln.

The most abundant weed species in Rakaia was clover, even though fathen and fimitory seemed to be more prominent because of their rampant growth. Number of clovers was decreased significantly by all tine weeding treatments compared with the nil control. In Honorata, clovers and shepherd's purse were the most abundant weed species and both of them showed significant reductions in their density with some of the weeding treatments. The major weed species at Lincoln were fathen and field pansy (*Viola arvensis*), while scentless chamomile (*Matricaria inodora*) and black nightshade (*Solanum nigrum*) were also abundant. Black nightshade is particularly important because there is no tolerance on its berries in peas. Number of fathen plants was reduced by all tine weeding times and black nightshade numbers were significantly reduced by all treatments except for the late post-emergence tine weeding (data not presented).

Table 4. Weed density and average weed dry weight (DWt.) in peas as affected by different weeding treatments in 2001.

Tine weeding	Rakaia		Hororata		Lincoln	
	Density No./m2	DWt. mg/plant	Density No./m2	DWt. mg/plant	Density No./m2	DWt. mg/plant
Nil	367	98	370	241	182	303
Pre-em.	162	120	340	102	113	79
Early post	119	49	102	98	50	118
Late post	207	165	130	133	98	197
Pre-em. + Late Post	130	64	202	72	47	104
$LSD_{0.05}$	128.8	ns	177.6	98.0	63.6	161.4

Even though all tine weeding treatments produced higher seed yields than the weedy control (nil treatment), the differences were significant only at Rakaia (Table 5), partly because of variability between replicates. Nevertheless, yield increases from 4 % to 50 % were measured in these trials when weeds were controlled by tine weeding. At Rakaia and Lincoln, the greatest increases in yield were observed in the pre-emergence treatment. At Hororata, both pre-emergence and early post-emergence tine weeding gave the highest yields.

Table 5. Pea yield (kg/ha) as affected by different weeding treatments in 2001. Numbers in brackets show percent increase in yield over the nil treatment.

Tine weeding	Rakaia	Hororata	Lincoln
Nil	3956	4561	4920
Pre-em.	5949 (50%)	6170 (35%)	5887 (20%)
Early post	5002 (26%)	6154 (35%)	5594 (14%)
Late post	5058 (28%)	5386 (18%)	5504 (12%)
Pre-em. + Late Post	4346 (10%)	5228 (15%)	5112 (4%)
$LSD_{0.05}$	1431.2	ns	ns

Second year

At Rakaia, weed dry weight measured at harvest was significantly reduced by all treatments. A single weeding pre-emergence to the crop resulted in 54 % reduction in weed biomass (Table 6). Greater reduction of 84 % was obtained when both pre- and mid-post tine weedings were performed. Pea yield in the control plots was significantly lower than other treatments, but there was no significant difference between the tine weeding treatments (Table 6). The highest increase in pea yield (67 %) was obtained in pre + mid post-emergence tine weeding.

Table 6: Pea yield (kg/ha) and weed dry weight. (g/m2) in different tine weeding treatments in 2002.

Tine Weeding Treatment	Rakaia		Southbridge	
	Weed dry wt. and (% reduction)	Pea yield and (% increase)	Weed dry wt. and (% reduction)	Pea yield and (% increase)
Nil, no weeding	312.8 (0)	3400 (0)	473 (0%)	3268 (0%)
Pre-emergence	143.5 (54)	5170 (52)	191 (61%)	3438 (5%)
Early post emergence			178 (66%)	4587 (40%)
Mid post	104.5 (66)	4767 (40)		
Pre + Mid post	51.0 (84)	5677 (67)		
Late post emergence			276 (48%)	3037 (-7%)
Pre + Early post-emergence			146 (74%)	5463 (67%)
Pre + Early + Late post-emergence			100 (82%)	5007 (53%)
$LSD_{0.05}$	102	1155.4	117	1054.7

At Southbridge, weed dry weight at harvest was significantly reduced by all treatments (Table 6). The biggest reduction was measured in the treatment with three tine weedings (82 %) followed by the one with two weedings (74 %). Pea yield was significantly increased in early post-emergence (40 %), in pre + early post-emergence (67 %) and in pre + early + late post-emergence (53 %) tine weeding treatments (Table 6). There were no significant differences in pea yield between the control and either pre-emergence or late post-emergence tine weeding treatments.

Discussion

Wheat

The two wheat paddocks used for the trials in the second year had contrasting crop and weed situations. The trial at Rakaia had a vigorous wheat crop with low weed population while the Dunsandel trial had a weak crop of low density and extremely high weed pressure. No significant effect on yield was observed from tine weeding in either of the sites but apparently for different reasons. A vigorous wheat crop such as the one at Rakaia is very competitive and can suppress weeds as soon as canopy closure starts. Similarly, Stiefel & Popay (1990) obtained no yield increase from one or two tine weeding in wheat due to low weed pressure. Moreover, an analysis of 59 wheat crops in Canterbury revealed that (chemical) weed control was likely to be uneconomic in 24 % of the fields (Bourdôt *et al.* 1996). At Dunsandel, early and mid season results showed a positive effect of tine weeding on wheat growth (Table 3). Improved growth of the crop, however, did not translate into increases in grain yield. The main reason was that the crop was thin with slow canopy development. As a result, weeds continued to germinate and compete with the crop in all treatments. Another problem in this paddock was that at the time of the early post-emergence weeding, the crop did not have a strong root system and suffered losses from tine weeding (Table 2). This was especially important in a thin crop and contributed to the tine weeding treatments not being able to show any yield increase. A situation like this probably needs a more selective weeding strategy. In some European countries, where cereals are drilled at wider row-spacing, selective inter-row cultivation is practiced (Bo Melander, pers. com.). There seems to be a case for testing the same method here. This might add another option to the limited tool box available to organic farmers. Inter-row cultivation will be especially useful in situations where weeds have an early start as it allows entering the crop at an early stage.

Peas

Pea trials, over two growing seasons, were conducted in four farms with different weed populations, sowing times and soil conditions. In general, tine weeding resulted in a marked reduction in the number and biomass of weeds. In all the experiments, late post-emergence tine weeding was significantly less effective in decreasing weed pressure than the early post-emergence treatments, obviously because larger weeds tend to survive the weeding operation. At Rakaia and Hororata, a single tine weeding at early post-emergence was more successful in reducing weed density than two tine weeding operations at pre-emergence and late post-emergence (Table 4). At Lincoln, these treatments gave similar reduction in the number of weeds and both were better than either pre-emergence or late post-emergence tine weeding.

Both Stiefel & Popay (1990) and Reddiex *et al.* (2001) reported no yield increase in peas from tine weeding. This was mainly due to low weed populations in both studies. In the present study significant yield increases were obtained where weed pressure was high, but the study also found that timing of weeding was critical. In the first year, pre-emergence or early post-emergence weeding gave yield increases from 35 % to 50 %. In the second year, in both pea experiments, the highest yield was obtained with two tine weeding at pre-emergence + early post-emergence of peas. At Southbridge, an extra tine weeding at the late post-emergence resulted in yield depression (Table 6). This was consistent with the yield reduction when only one tine weeding was performed at the late post-emergence. The yield depression in the late post-emergence tine weeding treatment occurred despite reduction in weed biomass (Tables 6). The effect can be due to two different factors. Late post-emergence weeding allows weeds to grow during the early period of pea growth when they are more sensitive to competition. This can explain why only one weeding at this time did not result in yield increase. When late post-emergence weeding was performed following two previous tine weedings, the slight yield reduction compared to pre-emergence + early post was more likely due to damage to large pea plants. This was especially noticeable in the cultivar Aladdin planted at this site. This is a semi-leafless cultivar with more tendrils which tend to twine into each other. This means passing through the crop at 5.5-leaf stage is more likely to damage the plants compared to normal cultivars.

In general, the study showed the importance of timing in the success of tine weeding. Some organic growers carry out three or more weeding operations aiming at a very clean crop thinking that it is a cheap operation. This may be true in dollar terms, but the negative effects through soil compaction, soil erosion, and crop damage should be given more weight. It seems that in many situations it should be possible to reduce the number of tine weeding without risking the yield. Enhancing canopy closure and regular surveillance of the weed population and density are important in optimising tine weeding time.

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