Weed Management in Organic Crops, Problems and Best Practices

Final Report, April 2004

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TO
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SUMMARY

In the third and final year of the project, two replicated field trials in winter wheat and one in peas were conducted to study the effect of different tine weeding treatments in these crops. In wheat, pre-emergence tine weeding reduced weed density but did not keep the weed levels low for very long. Two passes of tine weeding at pre-emergence and at the 3-leaf stage of wheat were required to control weeds for most part of the season. In peas, two passes of tine either at pre-emergence and 2-leaf stage or at 2- and 3-leaf stage of the crop maintained low weed pressure and significantly increased yield. The results are in line with the previous two years of the study and highlight the importance of early tine weeding.

METHODOLOGY

GENERAL

Two field experiments in wheat were conducted at Rakaia and Aylesbury and one experiment in peas at Southbridge. All experiments were laid out in randomised blocks with four replicates. In addition, a non-replicated trial was established in spring wheat at Hororata. Tine weeding treatments were designed according to the crop-weed situation and will be described under each crop.

MEASUREMENTS

Effectivity and selectivity of tine weeding treatments was measured by counting both weeds and crop plants in fixed quadrats (0.5 x 0.5 m) before and one week after each tine weeding. Two quadrat measurements were taken from each plot and percent mortality of weeds and crops was calculated.

At maturity, wheat was harvested by hand. Two quadrat samples (1 m^2 each) were taken for threshing and grain yield measurement. For peas, weed biomass and crop

yield were measured at harvest using two 1 m^2 -quadrats per plot. Peas were shelled with a stationary viner before weighing and measuring the TR values.
All data were analysed with Microsoft Excel through the ANOVA and where F test was significant, $LSD_{0.05}$ values were calculated for mean comparison.

WHEAT

Rakaia

The trial was conducted at Philip Rushton's farm in Overdale, Rakaia. Wheat cv. Monad was drilled at 130 kg/ha on 20 May 2003. The experiment had four replicates positioned on both sides of a pivot track which gave easy access to the plots. Each plot was 20 m long and 6.5 m wide (width of the tine weeder).
Seven treatments were compared as described in Table 1:

Table 1:Treatments and dates for tine weeding operations in wheat in Rakaia.

Tine Weeding Treatment	Date	Crop Stage
Nil, no weeding	-----	
Pre-emergence	17/6/03	0
Early post-emergence	29/8/03	3 leaf
Late post-emergence	6/10/03	5 leaf
Pre-emergence + Early post-emergence	17/6/03 + 29/8/03	0 + 2.5 leaf
Pre-emergence + Late post-emergence	17/6/03 + 6/10/03	0 + 5.5 leaf
Early + Late post-emergence	29/8/03 + 6/10/03	3 + 5.5 leaf

Aylesbury

The trial was conducted at Andrew Brooker's farm. Wheat cv. Regency was drilled at 135 kg/ha on 14 May 03. The experiment had four replicates and plot size was 10 m x 12 m (width of the tine weeder).
Four treatments were compared as described in Table 2:

Table 2:Treatments and dates for tine weeding operations in wheat in Aylesbury.

Tine Weeding Treatment	Date	Crop Stage
Nil, no weeding	-----	
Early post-emergence	31/7/03	4 leaf
Late post-emergence	17/9/03	6 leaf
Early + Late post-emergence	31/7/03 + 17/9/03	4 + 6 leaf

Hororata

A non-replicated trial was established on spring wheat at John and Kelvin Hicks' farm sown on 5/9/03. Three tine weeding treatments were imposed in large blocks which allowed multiple sampling in each. Pre-emergence tine was performed on 15/9/03 and post-emergence tine on 19/10.03. Weed and wheat data were collected as described and final grain yield was estimated by sampling 1 m^2 from each plot.

PEAS

A trial in processing peas was conducted at John Christey's farm in Southbridge. Peas cv. Aladdin were drilled on 21/11/03. The experiment had four replicates and plot size was 10 m x 6 m (width of the tine weeder).
Nine treatments were compared as described in Table 3:

Table 3: Treatments and dates for tine weeding operations in peas.

Tine Weeding Treatment	Date	Crop Stage
Nil, no weeding	-----	
Pre-emergence	26/11/03	0
Early post-emergence	5/12/03	2 leaf
Mid post-emergence	12/12/03	3 leaf
Early + Mid post-emergence	5/12/03 + 12/12/03	2 + 3 leaf
Late post-emergence	18/12/03	5 leaf
Pre-emergence + Early post-emergence	26/11/03 + 5/12/03	0 + 2 leaf
Pre-emergence + Mid post-emergence	26/11/03 + 12/12/03	0 + 3 leaf
Pre-emergence + Late post-emergence	26/11/03 + 18/12/03	0 + 5 leaf

RESULTS

WHEAT

Rakaia

Plant population for wheat measured on 29 August 03 showed no difference between treatments. Wheat population ranged from 168 to 188 plants/m^2 with no significant difference between tine weeding treatments.

Weed infestation was patchy with most weeds in the front portion of plots along the pivot track. The major weed species up to October were chickweed, fumitory, spurrey, shepherd's purse and field pansy. Later on fathen became the dominant weed especially along the edges of the field. On 29 August, weed density was significantly lower in plots which had a pre-emergence tine weeding compared to the control plots, a reduction of 53%. At the second measurement date, this difference was not significant any longer because the numbers in the control plots were lower. At this date, early post-emergence and pre-emergence + early post showed significant reductions in weed density. The only treatments at the third measurement (16 October) with significant reduction from the control were pre-emergence + early post and pre-emergence + late post. Late post-emergence weeding on its own was not controlling large weeds, but following a pre-emergence or early post tine, it had some effect as the weeds were smaller.

Table 4: Effect of tine weeding treatments on weed density measured at three dates in the Rakaia trial.

	Number of weeds / m^2		
Tine weeding	**29/08/03**	**6/10/03**	**16/10/03**
Nil	136	83	97
Pre-emergence	64	68	92
Early post	*	51	84
Late post			88
Pre + Early		43	46
Pre + Late			56
Early + Late			67
$LSD_{0.05}$	49.4	23.5	35.9
C.V.	32.6	25.5	31.4

*Data in plots which did not receive the treatments at each date were pooled with similarly treated plots.

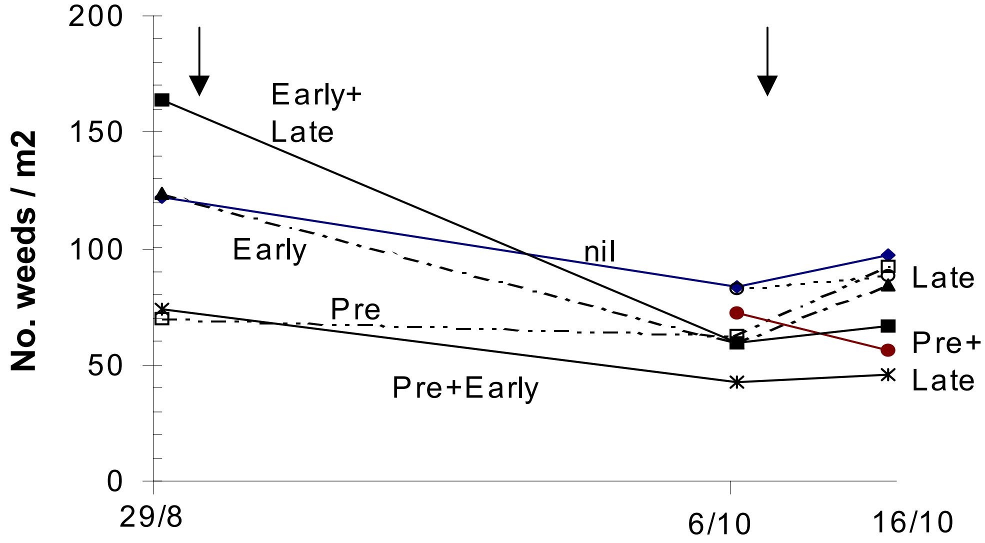

Fig. 1: Weed density in different treatments in the Rakaia trial during the growing season. Data not pooled to show initial densities for each treatment.

The graph in Fig.1 makes it easier to follow changes in weed density in different treatments during the growing season. It is worth mentioning the decline in weed numbers even in the control plots. This is due to strong competition from the crop. Plots which received a pre-emergence and an early post-emergence weeding maintained the lowest weed density during the season.

New weeds were defined as the ones at cotyledon or 2-leaf stage at the time of measurement. There was no significant difference in the number of new weeds emerging on 16 October, ten days after the final tine weeding (Table 5).

Table 5: Effect of tine weeding treatments on number of new weeds in the Rakaia trial measured on 16 October 03.

Tine weeding	Number of new weeds
Nil	18
Pre-emergence	31
Early post	28
Late post	22
Pre + Early	16
Pre + Late	18
Early + Late	20
$LSD_{0.05}$	ns

Weed biomass or dry weight measured on 3 November was significantly reduced by all tine weeding treatments (Table 6). The lowest weed dry weight was observed in plots receiving pre-emergence + early post-emergence tine (a reduction of 93%) or the ones with a pass of tine pre-emergence (a reduction of 86%). Dry weight of wheat was not different between treatments. Similarly, wheat grain yield did not show any significant difference between treatments (Table 6) despite higher yields in most tine weeding treatments. For example, grain yield in pre-emergence + early post tine was 1.7 T higher than the control.

Table 6: Effect of tine weeding treatments on dry weight of weeds and wheat in Rakaia on 3 November 03 and on final grain yield measured on 2 February 04.

	Dwt weeds		Dwt wheat	Grain Yield
Tine weeding	g/m2	% reduction	g/m2	T/ha
Nil	52.4	0	413	5.25
Pre-emergence	7.25	86.2	521	5.87
Early post	13.3	74.6	454	5.42
Late post	23.1	55.9	507	5.54
Pre + Early	3.5	93.3	495	6.99
Pre + Late	9.8	81.3	497	6.48
Early + Late	21.2	59.5	470	4.83
$LSD_{0.05}$	15.4		ns	ns
C.V.	26.1		18.5	18.4

Aylesbury

The major weed species were shepherd's purse, spurrey, mouse-ear chickweed and fathen with poa and clover also present. Plots assigned to early post-emergence treatment had a mean weed density of 219 plants /m^2 just before tine weeding. This was reduced to 109 plants /m^2 after a pass of tine, a reduction of 50% (Table 7). At this date, the control plots had a mean weed density of 198 plants/m^2. At the third measurement on 15 September, the weed density in early post-emergence treatment was still significantly lower than the control. Late post-emergence tine weeding was performed on 17 September and did not result in weed control on its own, but when performed on plots with a previous tine weeding, it was quite effective (Table 7).

Table 7: Effect of tine weeding treatments on weed density measured at four dates in the Aylesbury trial.

	Number of weeds / m^2			
Tine weeding	**31/07/03**	**20/08/03**	**15/09/03**	**17/10/03**
Nil		198	160	130
Early post	219	109	105	119
Late post				189
Early + Late				91
$LSD_{0.05}$		58.90	20.9	28.1
C.V.		25.4	10.5	14.1

*Data in plots which did not receive the treatments at each date were pooled with similarly treated plots.

There was no increase in the number of new weeds as a result of early post-tine on 20/8/03, almost three weeks after tine weeding (Table 8). However, more new weeds were counted in these plots on 15/9/03. More new weeds were also found in plots with two passes of tine (early + late) at the last measurement, one month after the final tine weeding.

Table 8: Effect of tine weeding treatments on the number of new weeds measured at three dates in the Aylesbury trial.

	Number of new weeds / m^2		
Tine weeding	**20/08/03**	**15/09/03**	**17/10/03**
Nil	25	123	15
Early post	23	184	26
Late post			26
Early + Late			45
$LSD_{0.05}$	ns	40.6	20.5
C.V.		29.6	26.5

One month after the final tine weeding, there was no reduction in weeds dry weight in treatments that received only one pass of tine, irrespective of its timing (Table 9). Plots with early + late tine weeding showed a non-significant reduction of 26.5% in weeds dry weight.
Dry weight of wheat was similar across the treatments. Similarly grain yield was not affected by tine weeding treatments (Table 9).

Table 9: Effect of tine weeding treatments on dry weight of weeds and wheat measured on 17 October 03 and on final grain yield on 19 January 04.

	Dwt weeds		Dwt wheat	Grain Yield
Tine weeding	g/m2	% reduction	g/m^2	T/ha
Nil	18.65	0	164.95	2.45
Early post	19.8	0	188.4	2.85
Late post	25	0	152.4	2.55
Early + Late	13.7	26.5	165.1	2.51
$LSD_{0.05}$	ns		ns	ns
C.V.	32.2		17.7	16.1

Hororata

This trial showed a small and non-significant reduction in wheat population in plots where post-emergence tine weeding was performed (Table 10). The greatest reduction in weed density was observed in plots with both pre and post-emergence weeding (86%) followed by plots with post-emergence tine (74%). Sampling the plots did not show any difference in grain yield which ranged from 2.2 to 2.5 T/ha.

Table 10: Effect of tine weeding treatments on the number of wheat and weed plants measured on 22 October 03.

Tine weeding	Wheat population	Weed density Plants/m^2	% reduction
Nil	231	152	0
Pre-emergence	230	76	50%
Post-emergence	205	40	74%
Pre + Post	194	21	86%
$LSD_{0.05}$	ns	79.4	

PEAS

Number of pea plants were counted one week after each tine weeding operation. Tine weeding pre-emergence or early post-emergence at the 2-leaf stage did not affect number of pea plants as measured on 5th and 12th of December (Table 11). Post-emergence tine weeding at the 3-leaf stage caused a significant reduction in pea population whether alone or following a pre-emergence or early post-emergence tine (data on 18/12/03). Late post-emergence tine at the 5-leaf stage caused a small and non-significant reduction in pea population, but following a pre-emergence tine weeding, late post tine caused a significant reduction (data on 29/12/03).

Table 11: Effect of tine weeding treatments on pea population.

	No. peas/ m2			
Tine weeding	5/12/03	12/12/03	18/12/03	29/12/03
Nil	116	115	118	118
Pre-emergence	120	111	111	111
2 leaf		99	101	101
3 leaf			77	79
2 + 3 leaf			73	73
5 leaf				88
Pre + 2 leaf		84	88	88
Pre + 3 leaf			73	73
Pre + 5 leaf				82
$LSD_{0.05}$	ns	ns	33.9	31.1
C.V.	21.8	19.2	24.5	22.8

One pass of tine weeding pre-emergence caused a significant reduction of 57% in weed density (Table 12). Post-emergence tine at the 2-leaf stage was even more effective and gave 91% reduction in weed density. When this treatment followed a pre-emergence tine, the reduction in weed density rose to 95%. As the season progressed, tine weeding treatments became less effective. Post-emergence tine at 3- and 5-leaf stage caused weed reduction of 74% and 72%, respectively.

The greatest reduction in weed density was achieved by two passes of tine at 2 and 3-leaf stage. This treatment caused 98% reduction in weeds bringing their numbers down to only 16 plants/m^2. No difference was found in the number of new weeds counted on 29/12/03.

Weed density data are also plotted in Figure 2 to show changes during the growing season.

Table 12: Effect of tine weeding treatments on weed density.

	No. weeds/ m^2			
Tine weeding	5/12/03	12/12/03	18/12/03	29/12/03
Nil	1115	905	912	912
Pre-emergence	482	472	456	456
2-leaf		85	113	113
3 leaf			237	245
2 + 3 leaf			16	38
5 leaf				258
Pre + 2leaf		42	75	85
Pre + 3leaf			170	117
Pre + 5leaf				196
$LSD_{0.05}$	234.7	167.9	162.5	150.8
C.V.	12.5	21.6	28.2	27.1

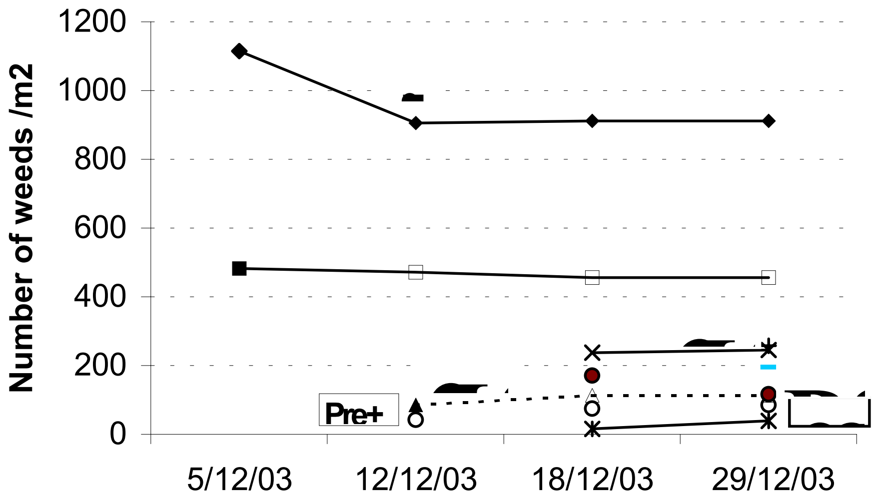

Fig. 2: Weed density in different treatments in the Southbridge trial during the growing season. Data not pooled to show initial densities for each treatment.

Measurement at the end of the season showed that all tine weeding treatments caused significant reductions in dry weight of weeds (Table 12). The greatest reductions in weeds dry weight was obtained by two passes of tine at 2 and 3-leaf stage (96%) or two passes of tine at pre-emergence and 2-leaf stage (90%). One pass of tine at 2-leaf stage caused a significant reduction of 80% in weeds dry weight.

Most tine weeding treatments gave significant increase in pea yield. The greatest yield increase of 1.6 T was obtained in plots which had a pre-emergence and a post-emergence tine at 2-leaf stage (Table 12). This was followed by plots with a pass of tine at 2-leaf and those with two passes at 2- and 3-leaf stage. Pea yield was not significantly different from the control in treatments with one pass of tine at 3- or 5-leaf stage or two passes at pre-emergence and 3-leaf stage.

Tenderometre Readings (TR values) show the maturity of peas and ranged from 95 to 120 with no significant difference between treatments.

Table 12: Effect of tine weeding treatments on pea yield and on dry weight of weeds at the harvest time.

Tine weeding	Weed Dwt g/m^2	Yield kg/ha
Nil	622	1692
Pre-emergence	305	2675
2-leaf	123	3195
3 leaf	280	2006
2+3 leaf	25	3161
5 leaf	261	1952
pre+2leaf	61	3293
pre+3leaf	186	2431
pre+5leaf	164	3001
$LSD_{0.05}$	147.4	893.3
C.V.	33.4	24.8

DISCUSSION

WHEAT

Pre-emergence tine weeding at Rakaia gave 53% reduction in weed density as measured early in the season (Table 4). However, new flashes of weeds appeared in these plots and there was no difference between this treatment and the control towards the end of the season. When pre-emergence tine was followed by an early post tine at 3-leaf stage, the low weed density was maintained throughout the season (Fig. 1). This treatment also gave the highest reduction (93%) in weed biomass when measured towards the end of the season (Table 6).
Late post-emergence weeding on its own was not controlling large weeds, but following a pre-emergence or early post tine, it had some effect as the weeds were smaller (Tables 4&7).

One concern about tine weeding during the season is the possibility of encouraging more seed germination due to soil disturbance. The data showed that this depended on the situation and was not always important. At the Rakaia site, although more new weeds were counted following some of the tine weeding passes, there was no difference between treatments (Table 5). On the other hand, in Aylesbury, significantly more new weeds were observed in tine weeded plots (Table 8). There were some difference in the weed species spectrum between the two sites, but both contained spurrey, shepherd's purse and fathen. A noticeable difference between the two crops was in their height and vigour. The crop in Rakaia was tall and had a good stand while the one in Aylesbury was shorter and more open. This probably allowed more light penetration into the canopy and stimulated weed seeds to germinate during the season.

There was some improvement in wheat growth and yield as a result of tine weeding at both Rakaia and Aylesbury trials, however, this was not statistically significant, partly due to variation in weed density in the trial sites. Nevertheless, an increase of 1.7 T/ha in grain yield was achieved in Rakaia by two passes of tine weeding at pre-emergence + early post.

The results from this year are in line with previous two years of the study and highlight the ability of a good wheat crop to compensate for early weed competition later in the season. In most experiments the differences between tine weeding and control treatments were not statistically significant. However, there were some increases in grain yield as a result of tine weeding. The best treatment appears to be two passes of tine at pre-emergence and at 2-3 leaf stage of wheat. This combination maintained a low weed level throughout the season and gave the highest grain yield.

The results of the three years of study show that early passes of tine weeding control weeds better but also cause more crop damage. To compensate for the loss, higher sowing rate should be considered. However, a good wheat crop is able to tolerate some loss without yield penalty. The trials in 2002-03 (see Annual Report, April 2003) clearly demonstrated the importance of crop vigour in weed suppression when two contrasting situations where compared. Therefore, a sound weed management strategy should include practices for best crop husbandry to encourage crop growth.

As suggested last year, inter-row cultivation, a practice commonly used in Europe, needs to be tested in New Zealand. This will provide cereal growers with additional weed management tools to use in situations where tine weeding is not very effective.

PEAS

A more detailed experiment in peas was established to fine tune timing of tine weeding treatments. Similar to the last year results, no benefit was obtained when tine weeding was delayed until 5 leaf stage of peas (Table 12). The small reduction in weed density and biomass was achieved too late in the season to benefit the crop.
The best treatments, both for reduction in weed biomass and improving pea yield, were two passes of tine either at pre-emergence and 2-leaf stage or at both 2 and 3-leaf stage of the crop. If for soil conservation or economic reasons one pass only is preferred, or in situations where the weather does not allow a pre-emergence tine weeding, the post-emergence weeding should be done as early as peas can withstand the implement, i.e. 2-leaf stage. Any delay in weed control during the crop growth would allow a longer period of competition and is likely to result in yield loss. In peas as well, higher sowing rates and more uniform planting should be tested to minimise gaps in the crop.

TECHNOLOGY TRANSFER

Several meetings were held with members of the farmer group and other interested parties to review and discuss the results and to decide on trial plans. An Arable Update on Peas was published by the Foundation for Arable Research with recommendations for growers. This was mailed to more than 2800 subscribers (copy attached).
A scientific paper[1] was presented to the Agronomy Society of New Zealand in August 2003 and was published in their proceedings.

FURTHER WORK

It is recommended to take this study further in the following areas:
Research:
- Testing feasibility of inter-row cultivation in wheat.
- Optimising plant population and sowing procedure for peas.

[1] Dastgheib, F. 2003. Timing and frequency of tine weeding in organic wheat and pea crops. *Proceedings of the Agronomy Society of New Zealand.*(June 24-26, 2003), vol 33:43-49.

– Determining the critical weed density in wheat and peas which affect yield.

Extension:

– Demonstrating the best treatments to both organic and conventional farmers so they can improve their practices.

ACKNOWLEDGEMEN

The project was jointly funded by AGMARDT, Foundation for Arable Research (FAR) and Heinz Watties. It should be mentioned that Philip Rushton, Andrew Brooker, John Christey and John & Kelvin Hicks offered fields, machinery and help for running the experiments. Their contributions were crucial in the progress of this project.

Weed Management in Organic Crops, Problems and Best Practices

Supplemet to
Final Report, 2004

SUMMARY

A number of observations, results and relationships are reported below. Some are from previous annual reports and some are the results of more detailed analysis of the data collected over the past three years.

- **Weed species and tine weeding**

The effect of tine weeding on different weed species was reported in the first year report (Annual Review, April 2002). A section of that report is presented here:

WHEAT

The major weeds in the trial site were fumitory, annual poa and chickweed, while shepherd's purse, speedwel, clovers and tare comprised the bulk of other weeds (Table 3). It was found that the efficacy of tine weeding depended upon the species and the age of weeds. Chickweed produces branching roots early in its growth, providing the plant with a good anchorage in the soil. This means early tine weeding is necessary to control chickweed. Fumitory, on the other hand, has a less branching root and continuous seed germination. That may be a reason that fewer fumitory were counted in the late post-emergence tine weeding.

Table 3: Early-season counts of weed species, data (number/m2) taken on 4/9/01

Tine weeding	Fumitory	Chickweed	Annual poa	Others	Total
Nil	95	28	96	19	238
Pre-em.	35	8	19	3	65
Early post	64	7	31	3	105
Late post	29	20	48	3	100
Pre-em. + Late Post	17	1	3	3	24
F test	ns	0.05	0.01	0.05	0.01
$LSD_{0.05}$	---	13.6	20.7	10.7	86.1

PEAS

Rakaia

The most abundant weed species in this site was clover, even though fathen and fumitory seemed to be more prominent because of their rampant growth. Number of clovers decreased significantly by all tine weeding treatments compared with the nil control (Table 8). Most other weeds were not affected by tine weeding to the same extent. In fact, late post-emergence tine weeding (5/10/01) caused an increase in the number of fathen (significant at 10% level) and fumitory (not statistically significant). This can be due to the fact that seed germination in most weeds is enhanced by light especially at optimum temperatures in spring when this tine weeding was performed.

Table 8: Mid-season results on weed species, data (number/m2) taken on 1/11/ 01

Tine weeding	Fathen	Fumitory	Chickweed	Others	Clover
Nil	9	9	21	32	297
Pre-em.	9	13	11	24	107
Early post	4	11	13	9	83
Late post	32	24	6	45	100
Pre-em. + Late Post	11	17	11	24	68
F test	0.1	ns	ns	ns	0.05

Hororata

Clovers and shepherd's purse were the most abundant weed species in this site and both of them showed significant reductions in their density with some of the weeding treatments (Table 12). For both shepherd's purse and clover, number of plants was reduced significantly by both early and late post-emergence tine weeding. On the other hand, pre-emergence weeding did not reduce the density of these weeds. It maybe that majority of seeds of shepherd's purse and clover germinated after the pre-emergence weeding and escaped the control.
For the other weed species, high variability or low numbers resulted in the differences to remain statistically non-significant.

Table 12: Mid-season results on weed species, No./m2, data taken on 26/11/01

Tine weeding	Fathen	Shepherd's purse	Pansy	Speedwell	Chick-weed	Clover	Others
Nil	8	104	21	20	26	106	90
Pre-em.	12	122	5	18	14	92	78
Early post	4	20	11	6	8	24	32
Late post	4	30	16	12	16	34	22
Pre-em. + Late Post	0	82	24	22	14	34	32
F test	ns	0.002	ns	ns	ns	0.06	ns
$LSD_{0.05}$	---	51.2	---	---	---	68.7	---

Kowhai Farm

The major weed species at Kowhai farm were fathen and field pansy, while scentless chamomile and black nightshade were also abundant (Table 16). 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, however this was significant only at $p < 0.14$. Black nightshade numbers was significantly reduced by all treatments except for the late post-emergence tine weeding. There was no significant difference between treatments in the number of field pansy, chamomile and chickweed.

Table 16: Mid-season results on weed species, data taken on 4 Dec. 01

Tine weeding	Fathen	Black Nightshade	Pansy	Chamo mile	Chick -weed	Others
Nil	72.5	20.5	49	23	2.5	15
Pre-em.	34.5	11.5	31.5	20.5	4.5	11
Early post	14	7.5	9.5	9.5	3.5	6.5
Late post	32.5	15	30.5	9.5	0.5	10
Pre-em. + Late Post	14.5	5	6.5	13.5	1	7
F test	0.14	0.01	ns	ns	ns	0.14
$LSD_{0.05 \& 0.2}$	31.5	6.9	---	---	---	4.6

- ## Wheat population and height

Again, sections from previous reports on the effect of tine weeding treatments on wheat population are copied here. No difference in wheat height due to treatments was observed in any of the experiments.

Rakaia, 2001

Tine weeding treatments did not show any effect on wheat growth. Number of wheat plants per m^2 ranged from 194 to 251 with no difference between treatments (See Table 5 in Annual Report 2002). Although wheat plants in the weedy plots (Nil treatment) produced slightly lower number of tillers, the difference was not statistically significant. Moreover, dry weight of wheat plants was similar between treatments.

Rakaia 2002

The paddock did not have a strong weed pressure. An average of 130 weed seedlings per m^2 was counted, 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, chickweed and shepherd's purse.

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 5). The reduction in the number of wheat plants, however, was not serious considering the high population density of the crop.

Table 5: Weed control and crop mortality after each tine weeding treatment in Rakaia.

Tine weeding	Wheat, no./m^2 and (% reduction)		Weeds, no./m^2 and (% reduction)	
	Before	After	Before	After
Early post	263	216 (18%)	130	54 (62%)
Late post	191	189 (1%)	129	101 (22%)

1. Each number is the mean of two quadrats and four replicates.

Dunsandel 2002

The crop at this site was weak with low population density and was very weedy. Tine weeding at 2.5 leaf stage (early post) and 3.5 leaf stage (mid-post) caused the same reduction in wheat population (12%), but tine weeding at 5.5 leaf stage (late post) caused only 5% reduction in wheat population (Table 6). The highest reduction in weed density (45%) was obtained by mid-post tine weeding. Early post and late post weedings resulted in smaller reductions in weed density of 39% and 33%, respectively.

Table 6: Weed control and crop mortality before and after each tine weeding treatment in Dunsandel.

Tine weeding	Wheat, no./m^2 and (% reduction)		Weeds, no./m^2 and (% reduction)	
	Before	After	Before	After
Early post	151	133 (12%)	575	352 (39%)
Mid post	132	116 (12%)	767	425 (45%)
Late post	144	136 (5%)	915	612 (33%)

1. Each number is the mean of two quadrats and four replicates.

• Relationships and Regression Analysis

Relationship between weeds and pea yield was examined in previous reports, a section of Annual Report 2003 is copied here.

Peas 2002

Fig. 3 shows a schematic representation of the relationship between yield increase and weed biomass decrease using values from Table 13. The datapoint for the control (a) seems out of place. Without the values for the control, a correlation coefficient of 0.89 and an R^2 value of 0.79 were calculated between the yield increase and weed biomass reduction.

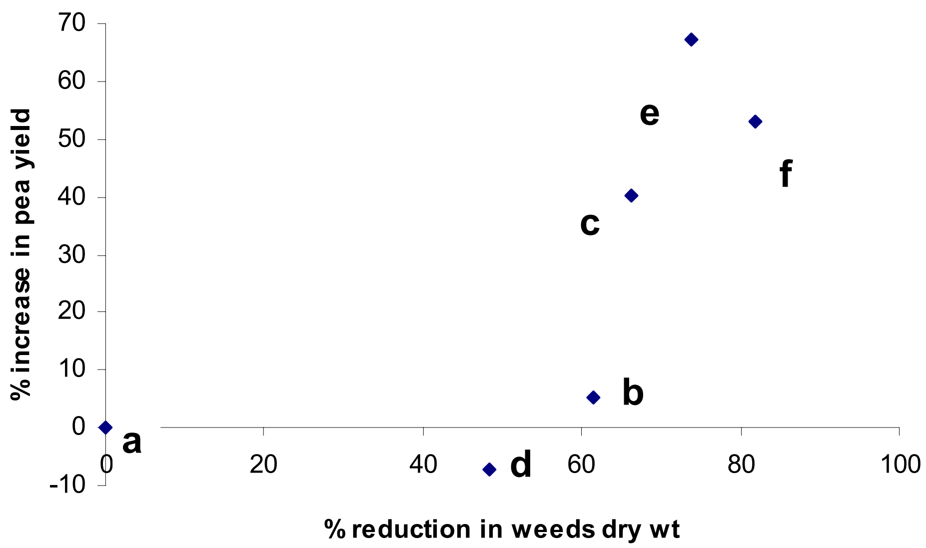

Fig. 3. Relationship between reduction in weeds biomass and increase in pea yield in Southbridge. For a description of letters see the original report.

Further analysis of pooled data from all five experiments on peas was undertaken and a summary is reported here.

Weed density and Yield loss

Yield reduction data in different experiments were standardised by calculating percentage reduction from the maximum yield in each trial. The plotted data in Figure A shows a positive increase in yield loss as weed density goes up. Analysis of the Regression showed a highly significant F highlighting a true relationship. The regression equation below was established:

Predicted Yield Loss (%) = 6.66 + 0.044 * Weed Density

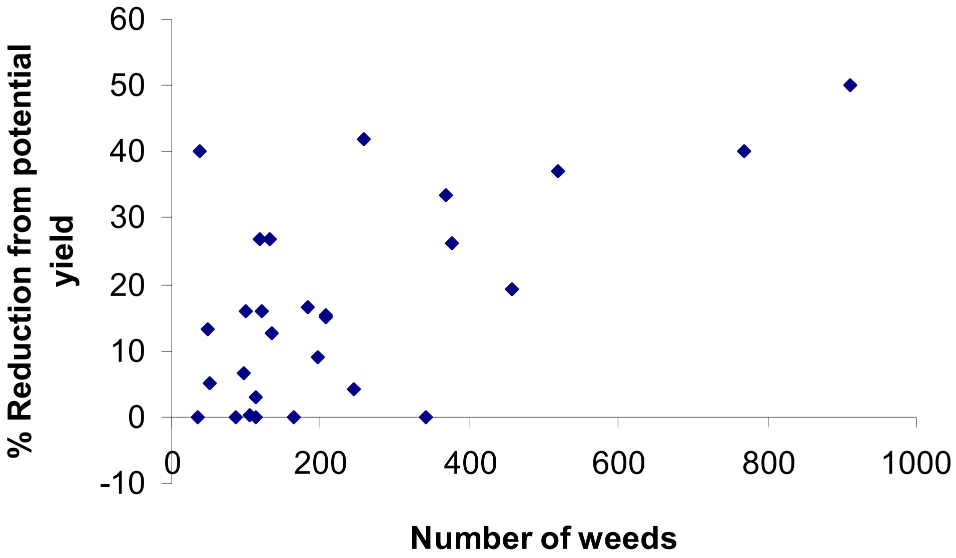

Fig. A Scatter diagram showing the relationship between weed density and reduction in potential yield. Data are pooled from five experiments over three years.

Using the above regression equation predicted values for yield loss were calculated. These will give a straight-line relationship as shown in Fig. B:

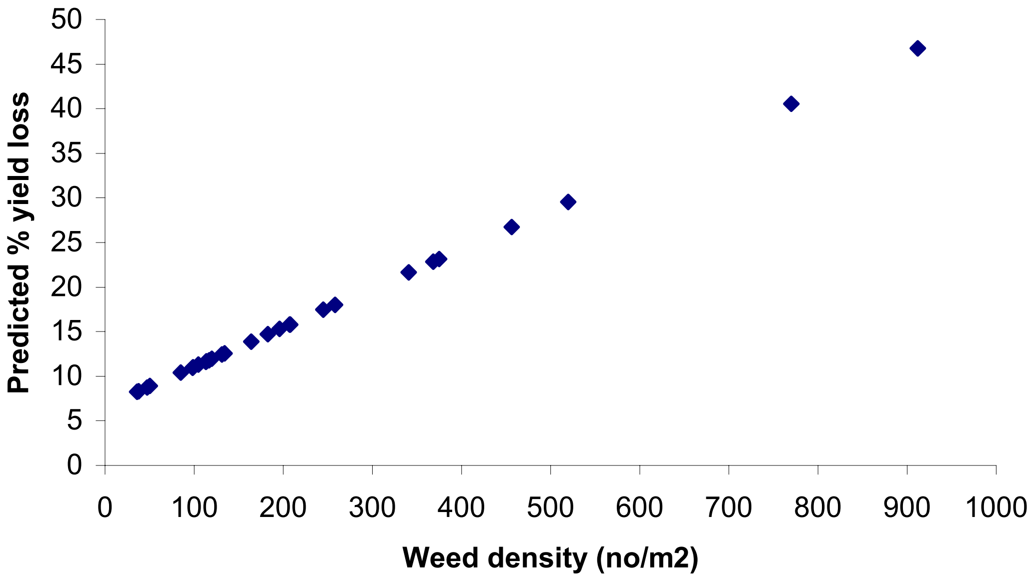

Fig. B: Predicted values from the regression equation fitted through the data in Fig. A.

The above equation estimates 4.4% yield loss for every 100 additional weeds. This may seem a moderate yield loss. Some workers have stipulated higher yield loss for peas due to weeds. However, severity of weed competition depends on other factors such as crop and weed vigour. Other variables should be built into the model for more accurate estimate of yield loss. The present study was not designed to explore this.

Relationship between pea population and yield loss

Pooled data from all experiments were used to examine the relationship between pea population and yield. Fig. C shows that for the range of pea populations in different treatments, no meaningful relation with yield could be found. The line fit plot showed a straight line and the regression analysis showed no significance. Previously, a hyperbolic relationship was reported between pea yield and plant population ranging from 40 to 100 (Arable Update No. 7, August 2002). The lowest pea population in the present data points was 73 with most values above 90 plants m^2, so they were within the flat region of the curve in that report.

One of the recommendations for further research in the Final Report 2004 was to determine the critical weed density in wheat and peas which affect yield. This can be done with a more practical view in mind looking at the most common weeds in early and late crops, rather than a single species at a time as usually reported in the literature. The information would provide farmers with a practical measure to decide on their weed control plan.

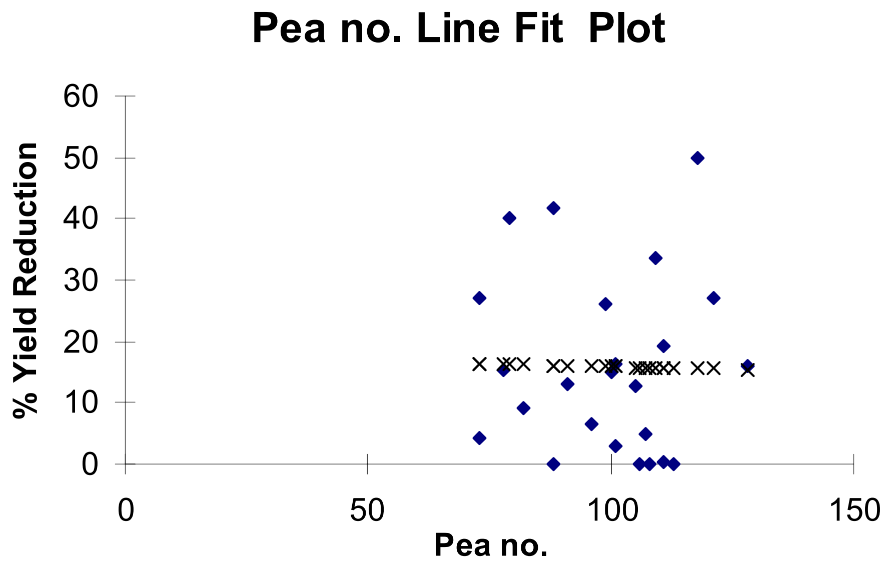

Fig. C: Relationship between % yield loss and pea population, observed data from five experiments over three years (◆) and predicted values (x)