Non-chemical weed management in linseed

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Abstract

Several field experiments were conducted on certified organic farms in Canterbury over two growing seasons to test different methods for weed management in linseed. Methods included tine weeding at different growth stages, thermal weeding and sheep grazing. The results showed no significant benefit from tine weeding under low weed pressure. If tine weeding is required with high weed pressure, then higher sowing rate of linseed should help to overcome population loss caused by the operation. One experiment compared flame weeding and steam weeding at different stages of linseed growth. Linseed was extremely sensitive to heat at post-emergence and moderately sensitive at pre-emergence stage. Sheep grazing at two intensities, lax and hard grazing, was tested and resulted in reductions in populations and biomass of both weeds and linseed. Weeds were able to take advantage of the opened canopy and grew faster. None of the grazing treatments improved yield and a second grazing at either intensities caused yield reductions in excess of 17%. Grazing increased the number of branches on linseed stems and may have a place in prevention of lodging.

Additional keywords: Flax, tine weeding, flame weeding, steam weeding, sheep grazing, integrated weed management, organic farming.

Introduction

Organic farmers face a great challenge for selective weed control in arable crops. Mechanical weed removal during the season in organic cereal and pulse crops is usually achieved with spring tine harrows, also known as tine weeders (Dastgheib, 2004 a & b). However, the usefulness of this technique in linseed *(Linum usitatissimum)* has not been tested extensively. A study reported that tine weeding at 37 days after sowing increased linseed yield by 22% (Reddiex *et al.,* 2001).

Linseed is a minor crop in New Zealand, but since it is one of the richest plant sources of omega-3 essential fatty acids (Bloedon & Szapary, 2004), it has great potential as a functional food ingredient. Particularly when grown organically, linseed is a profitable cash crop and will appeal to many farmers if certain management issues are solved.

This study was undertaken with the aim of finding feasible management practices for weed control in linseed. The study was conducted during two growing seasons of 2003-04 and 2004-05 with two field experiments each year and examined tine weeding, thermal weeding as well as sheep grazing as potential methods for weed management in linseed.

Methodology

Implements used

Tine weeder used in the experiments consisted of four rows of spring tines on a metal frame and was 6-m wide. Flame weeder used LPG fuel and delivered flame close to the soil surface through burners under a metal panel hood about 130-cm wide. Steam weeder was a local prototype design, made through the farmers group consertium and used diesel to generate steam which was delivered to plants through nozzles under a metal panel hood about 180 cm wide. Flame or steam weeders were mounted on a tractor and driven at a speed of 5 km/h.

First year

In the first year different tine weeding treatments were compared in two field experiments at Rakaia (sown on 16/10/03) and Lincoln (sown on 4/11/03). Experimental plots were 10 x 6m and tine weeding treatments were imposed at cotyledon stage, early post-emergence (linseed 5-7 cm, with 4 leaf nodes), late post-emergence (linseed 9-12 cm, with >7 leaf nodes) and combinations of these. Both experiments were laid out in randomised complete blocks with four replicates.

Second year

Two field experiments were conducted. The one in Rakaia (sown on 19/11/04) was used to examine tine weeding and thermal weeding treatments while another field in Ashburton (sown on 15/11/04) was used for a grazing management experiment. Growth stages of linseed for tine and thermal treatments were similar to the first year except that late post-emergence treatments were imposed when linseed was 15-cm tall. In the Ashburton experiment two grazing times were compared: early grazing at approximately 12-cm crop height (on 29/12/04) and late grazing at approximately 35-cm crop height (on 11/01/05). At each time two grazing intensities, namely lax grazing (4 sheep per plot) and hard grazing (8 sheep per plot) were compared. Plots (12 x 12 m) were blocked off by electric flexi-fence to contain the sheep. Romney mixed-age ewes were used and the duration of grazing was 20 hours each time. At each time an area adjacent to the trial site was mowed to compare defoliation with sheep trampling and feeding. Both experiments were laid out in randomised complete blocks with three replicates.

Measurements

Visual scores were used for weed control and crop vigour assessments. Moreover, both weeds and crop plants were counted in two fixed quadrats (0.5 x 0.5 m) per plot before and a few days after each tine weeding in the first year and in two or three randomly placed quadrats in the second year. Weed dry matter was determined by sampling two random quadrats per plot. At maturity linseed plants were cut above the soil surface in three 1-m^2 quadrats and placed in a warm glasshouse for drying. Seed was threshed by hand and grain yield at 9% moisture was determined. All data were analysed by Microsoft Excel through ANOVA and where the F test was significant, $LSD_{0.05}$ values were calculated for mean comparisons.

Results

First year

The main weed species in the Rakaia site was fathen *(Chenopodium album)* with a few cornbind *(Fallopia convolvulus)* and cleavers *(Galium aparine)* plants. Linseed growth was rapid and caused strong competition to the weeds. One pass of the tine weeder at cotyledon stage caused a reduction of 40% in the number of weed plants on 10 November (Table 1), however this was not statistically significant due to block variability. Weed density at the second measurement date was significantly reduced by all tine weeding treatments with the largest reduction (85%) in plots receiving two passes of tines at cotyledon and at early post-emergence stage. On 3 December, weed density was significantly reduced by all treatments with the largest reductions in plots with two passes of the tine weeder.

There was a non-significant reduction in linseed population on 10 November in plots receiving the first tine weeding operation at the cotyledon stage (Table 1). Measurements on 21 November (just prior to the late post-emergence tine weeding operation) showed a significant reduction in linseed population as a result of tine weeding at cotyledon (27%) or at early post-emergence stage (30%). At the last measurement date, all treatments showed significant reductions in linseed populations with the highest reduction of 50% in cotyledon + early post-emergence tine weeding.

Table 1: Linseed and weed density (plants/m²) in different tine weeding treatments during the season in the first year experiment at Rakaia.

	Weeds			Linseed		
Tine weeding	**10 Nov.**	**21 Nov.**	**3 Dec.**	**10 Nov.**	**21 Nov.**	**3 Dec.**
Control	213	250	175	737	737	737
C	127	104	92	576	536	536
E	212	101	92	691	512	512
C + E	--	38	33	--	330	370
C + L	--	87	37	--	510	425
E + L	201	69	36	730	490	457
$LSD_{0.05}$	*ns*	*44.8*	*30.6*	*128.7*	*90.8*	*120.4*

Each number is the mean of two quadrats and four replicates.
Tine weeding dates: Cotyledon stage (C) 22/10/03; Early post-emergence (E) 10/11/03;
Late post-emergence (L) 21/11/03

Weed species composition at the Lincoln site was more diverse and comprised primarily fathen, wireweed (*Polygonum aviculare*), fumitory (*Fumaria officinalis*) and wild turnip (*Brassica rapa*). Detailed results for this site are not presented for brevity. Tine weeding at the cotyledon stage caused a significant reduction of 50% in weed density but new weed seedlings soon appeared in these plots. Two passes of tines at cotyledon and at early post-emergence stage caused more than 80% reduction in weed density. The lowest weed density with 89% reduction from the control was measured in plots receiving three tine weeding passes. One pass of the tine weeder at the cotyledon stage caused some reduction, though not statistically significant, in linseed population (data not presented). A second pass of tines at early post-emergence caused further reduction in linseed population amounting to 53%. Late post-emergence tine weeding did not cause serious loss to the crop.

Visual scores taken approximately one month before harvest showed relative performance of tine weeding treatments. At Rakaia, the cleanest plots were those which received two passes of tines, one of which at the cotyledon stage. These plots also had the lowest weed dry matter at harvest (Table 2). At Lincoln, again similar treatments, i.e. two passes of tine weeder with one at the cotyledon stage performed very well. However, plots with three passes of the tines were still cleaner. The crop in some treatments looked greener because of new branching. Plots which received tine weeding at cotyledon + early post-emergence stage and those with three passes of the tine weeder were much behind in maturity compared to the control plots (Table 2).

Table 2: Weed control score (1= weedy, 10= clean) and weed dry matter (DM, g/m^2) at harvest and crop maturity score (1= green, 10= dry) in the first year experiments.

Tine weeding	Rakaia		Lincoln	
	Control score	Weed DM	Control score	Crop maturity score
Control	2	145	3	6.2
C	5	76	5	3.8
E	3	132	5	5.5
C + E	7	38	8	1.5
C + L	6	52	7	4.5
E + L	5	106	6	5.8
C + E + L	--	--	8	2.5
$LSD_{0.05}$	*1.7*	*60.1*	*2.2*	*1.5*

Treatment designation as in Table 1

Table 3. Effect of weeding treatments on weeds and linseed during the season in the second year experiment at Rakaia.

Treatments	Crop vigour 3/2/05	Weed control Score 3/2/05	No. Linseed/m^2 9/2/05	Yield as % of control
Control	10	1.7	629	100
Tine Pre	10	3.7	557	99
Tine C	10	5.3	592	126*
Tine E	10	6.3	570	113
Tine L	10	5.3	562	93
Tine Pre+E	10	7.0	528	116
Tine Pre+L	10	4.3	561	100
Tine C+E	10	6.7	535	114
Flame Pre	8	4.3	478	81
Flame Pre+E	1	5.7	13	0*
Flame Pre+L	4	5.7	363	52*
Steam Pre	8	6.3	526	83
Steam Pre+E	1	5.0	11	0*
Steam Pre+L	5	6.7	203	44*
$LSD_{0.05}$	*2.5*	*ns*	*115.1*	

* indicates a significant difference from the control
Pre-emergence (Pre): 23/11/04, Cotyledon stage (C): 19/12//04
Early post-emergence stage (E): 30/12/04, Late post-emergence stage (L): 11/01/05

No significant difference in yield was observed between treatments at either the Rakaia or Lincoln experiments (data not presented). However, there was a trend for tine weeding at cotyledon + early post-emergence stage of linseed to improve yield (10% increase at Rakaia and 32% increase at Lincoln).

Second year
Mechanical and thermal weeding experiment

Crop vigour, measured approximately three weeks after the final weed control operation, was similar to the control in all tine weeding treatments but was significantly reduced when thermal weeding was performed post-emergence (Table 3). Flame or steam weeding pre-emergence did not affect crop vigour significantly. The trial site had a low weed population and the main weed species was fathen. Visual assessment at this time did not show significant differences in weed control between treatments. Nevertheless, tine weeding at pre-emergence + early post-emergence, cotyledon + early post-emergence and steam weeding at pre-emergence + late post-emergence received better scores. Tine weeding at pre-emergence + early post-emergence and cotyledon + early post-emergence can be considered promising treatments.

The linseed population was significantly affected by some treatments. All thermal weeding treatments, with the exception of steam pre-emergence, significantly reduced linseed populations. Pre-emergence flame reduced the linseed population by 24% and pre-emergence steam by 16%. Linseed was very vulnerable to heat at its early growth stage; flame or steam passes at this time left only a few survivors (Table 3).

Grazing experiment

The major weeds at the site were clovers *(Trifolium* spp.), fathen, field speedwell *(Veronica arvensis),* shepherd's purse *(Capsella bursa-pastoris)* and storksbill *(Erodium cicutarium).* Sheep did not show a particular preference for any species and grazed both weeds and linseed. However, shepherd's purse seemed to suffer more damage, maybe from trampling. One day after the first grazing, the biomass of weeds left behind was significantly lower in grazed plots than the un-grazed ones, irrespective of the grazing level (data not shown). The second grazing did not result in significant reductions in weed dry weight.

Linseed height, plant population and biomass were significantly reduced by sheep grazing irrespective of timing or level (data not shown). It was observed that sheep chewed from the top, pulled some plants out of the soil and broke many others. The damage was in a haphazard manner causing the grazed plots to look patchy. Crop observations made during the growing season showed signs of recovery from sheep damage but grazed linseed remained shorter, less vigorous with more open spaces in the canopy compared to the control plots. The dry weight of linseed was significantly reduced in all grazing treatments, but more so for the first grazing (Figure 1).

Weeds took advantage of the open canopy produced by sheep and grew faster. Assessment on 21 January showed higher weed dry weight in the first grazing treatments than the control (Figure 1). Moreover, weeds in the control plots were shaded by linseed and were less vigorous than weeds in grazed plots. Harvest assessment showed a non-significant trend towards yield reductions due to grazing in both levels and times. The second grazing, when the crop was 35-cm tall was more damaging than the first grazing and caused yield reductions in excess of 17% (Figure 2). The second mowing caused significant yield reduction, while linseed in the first mowing (at approximately 12-cm crop height) produced similar yields to the control.

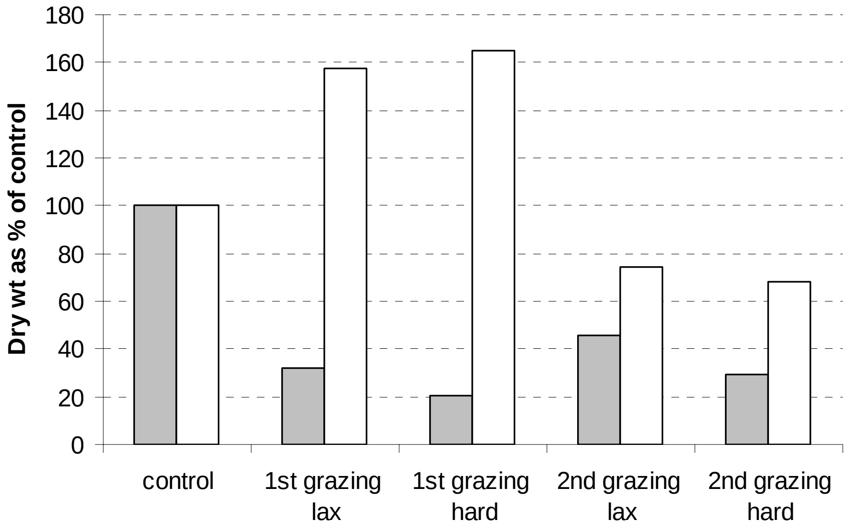

Figure 1. Dry weights of linseed (grey bars) and weeds (white bars) as percentage of non-grazed control measured on 21/1/05. $LSD_{0.05}$ values for weeds 49.8 and for linseed 15.5

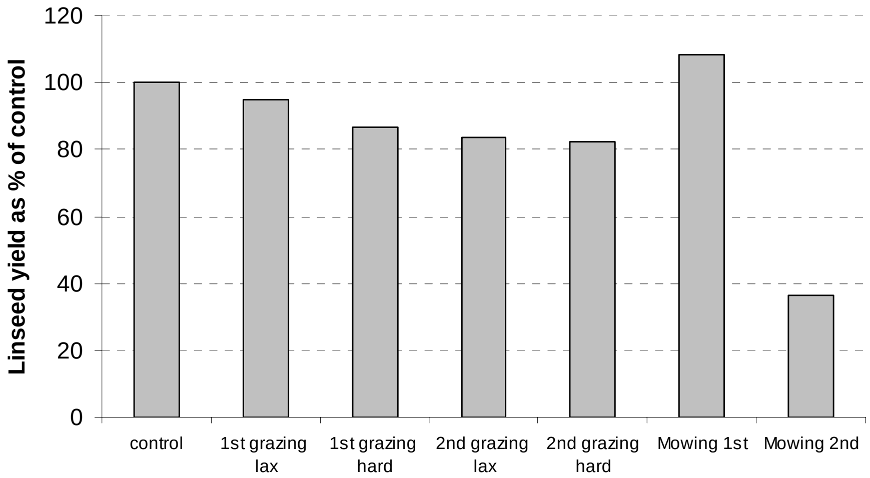

Figure 2. Linseed yield as percentage of non-grazed control measured on 10/3/05. $LSD_{0.05}$ value for linseed yield 19.9

Discussion

The study was focused on three methods of weed management in linseed namely: mechanical, thermal and sheep grazing. The results showed that two tine weeding passes at the cotyledon and early post-emergence stage of linseed growth gave effective reduction in weed density but did not give significant yield increase. Another study reported 22% increase in linseed yield as a result of tine weeding (Reddiex *et al.,* 2001). In experiments reported here, weed pressure was not very high and linseed competition suppressed their growth. It can be expected that under stronger weed pressure, greater increases in yield would have been obtained from tine weeding.

Linseed seems to be more sensitive than other arable crops to tine weeding. In another study, wheat and peas suffered between 1 to 15% mortality as a result of one pass of tine weeder depending on their growth stage (Dastgheib, 2003). Results from these experiments showed 27 to 31% mortality after one pass of tines at cotyledon or early post-emergence stage, respectively (Table 1). Two passes of tines at cotyledon + early post-emergence stage caused 50% crop mortality. Moreover, linseed seems to be very sensitive to wheel pressure especially at late stage of its growth. This makes mechanical weed control in linseed more difficult.

Both flame and steam weeding were lethal to linseed when performed early post-emergence. Even, passage of the tractor with flame weeder lifted approximately 50 cm above the crop burned the top of plants. At later growth stages (height 15-20 cm), linseed showed more tolerance to thermal weeding with better survival rates. The survived plants, however, were behind in growth and produced only half as much yield as plants in the control plots. Flame or steam pre-emergence to linseed produced approximately 80% yield of the control. The reduction in linseed population by these thermal treatments shows the sensitivity to heat of germinating seeds close to the soil surface.

Sheep grazing has been utilized in cereals as a way to supply feed and control weeds. Even in wheat, the benefits of grazing depend on several conditions and yield reduction is likely (Anon., 2004). Grazing treatments used in this trial damaged linseed, did not control weeds and opened the crop for more vigorous weed growth. However, linseed recovered to some extent, partly through more branching. In fact, this could be considered as a positive effect. Linseed has a weak stem and is vulnerable to lodging, especially under high fertility, high wind and moist conditions. Breaking the stems or cutting the tops by sheep might shorten the stem or produce a bushy type growth by branching, which can assist in prevention of lodging.

In conclusion, the study showed no benefit from tine weeding in linseed is likely if weed pressure is low. Under high weed pressure, a maximum of two tine weeding passes, one at cotyledon stage and another when average crop height is 5-7 cm, should be adequate. Higher sowing rate is recommended if tine weeding is in the plan to compensate for population loss.

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