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PROJECT REPORT No. OS19

WEED CONTROL IN SPRING LINSEED: EFFECTS OF KNOTGRASS, CHICKWEED, FAT HEN AND OATS ON YIELD

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by

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CONTENTS

ABSTRACT

Linseed is a poor competitor with weed plants, so it is important to determine the influence of weed populations on the subsequent performance of linseed.

Four weeds were studied, at different plant populations to determine the relative importance of different weeds, and the reduction in linseed yield that weed populations could cause if left uncontrolled.

The four weed species considered were

Knotgrass (*Polygonum aviculare*)
Chickweed (*Stellaria media*)
Fat-hen (*Chenopodium album*)
Cultivated Oats (*Avena sativa)*

The main conclusions were

- grass weeds are likely to be more damaging to linseed than broad-leaved weeds
- knotgrass is potentially more competitive than fat-hen, and common chickweed is least damaging of the three studied weeds
- bearing in mind the cost of treatment, it would be economic to treat infestations greater than 14 oat, 5 knotgrass, 6 fat-hen and 40 chickweed plant/m^2, in vigorous linseed crops.

These experiments were conducted in three dry summers, two being extremely dry, and so it is possible that weed competition would have been greater in years where moisture was less limiting. Both chickweed and fat-hen were more adversely affected by the moisture stress than the linseed.

1. INTRODUCTION

1.1 The Linseed Crop

Since its widescale re introduction as a viable arable crop in 1985, linseed has experienced mixed fortunes, largely due to growers experiences with the crop. High levels of price support have been countered by difficulties in crop establishment and late harvests. Between 1984 and 1993 the area of linseed grown in the UK increased from just over 1,000 ha, to representing over 90% of the total EU area, in 1993. Since then the area grown has fallen by over 60% as arable aid payments increased for other break crops, such as oilseed rape, to make them financially competitive with the linseed crop.

Despite this, research looking at the value of linseed in the arable rotation has shown it to be a useful break crop. Although it has a short growing season and produces little biomass, it has been shown to confer a yield benefit in a following winter wheat crop of up to **16%** compared to continuous wheat. (Arable Research Centres Result.)

The requirement for linseed oil within the EU and the high level of area aid associated with this, coupled with the suitability of the UK climate to produce the crop and its benefits to the arable rotation, mean that linseed is now an established part of the crop spectrum within the UK and will probably remain so for the forseesable future.

This high level of support for linseed together with the low yields and low produce prices often associated with it, has meant that almost all of the income for the crop comes from an area aid payment, with little coming from the sale of the crop itself. As a result many growers have felt that attention to detail in the agronomy of linseed is unnecessary, and for similar reasons there has been limited research into the crop's agronomic requirements. Yet whilst there is still a price/tonne value attached to the produce, and an area payment calculated using the average overall yields in a given year, there is still a strong case for optimising returns from the crop by acquiring detailed knowledge of its agronomy.

One area of linseed growing which required close attention is that of weed control. The linseed crop produces little biomass and throughout the growing season is a poor competitor with weed plants. A greater emphasis is therefore placed on chemical weed control, but the range of herbicides available for use in the linseed crop is restricted.

It is therefore essential to know the relative importance of the weeds commonly encountered in linseed, in terms of their competitive ability with the crop and the subsequent yield reductions associated with each respective weed. This will aid decision making when putting together a weed control strategy.

1.2 Objectives of the Study

This study was set up to attempt to quantify the competitive effects of a number of weed species on the linseed crop. Field trials were set up at six locations, as follows :

IACR Rothamsted, Herts
Morley Research Centre, Norfolk
Arable Research Centres (Northern) Lincolnshire - Caythorpe
Arable Research Centres (Southern) Hampshire - Andover
Arable Research Centres (Western) Gloucestershire - Cirencester
Arable Research Centres (Southern) Dorset - Wimborne

Four weed species were selected for the experiments, species known to be regularly present in linseed and believed from earlier studies to influence crop yield. The weeds were also selected on their growth habit differences, the oats being erect in comparison to the prostrate habit of the chickweed.

Cultivated oats were chosen as an appropriate mimic for wild oats, which are difficult to establish in trials, and which pose weed problems in subsequent years.

The soil types at the six locations that were used for trials were

Andover - shallow calcareous soil over chalk
Caythorpe - brashy calcareous loam, over limestone
Cirencester - clayey soil over limestone
Wimborne - shallow calcareous soil over chalk
Morley - sandy loam/sandy clay loam
Rothamsted - silty clay loam

Seeds of each species were sown into plots of linseed, at different seeding rates in an attempt to produce differing weed populations. All other weeds were removed to ensure that any effects measured on linseed performance could be attributed to the known weed populations.

The four weed species were :

Chenopodium album (fat-hen)
Stellaria media (common chickweed)
Polygonum aviculare (knotgrass)
Avena sativa (oats)
Avena fatua (wild oats) - small trial at IACR Rothamsted.

In addition to this main investigation, direct measurements of the biomass of the crop and individual weed species were undertaken at IACR Rothamsted. These produced more detailed assessments of the competitive effect of the weed species on the crop, at a range of weed densities.

By determining the influence of different weed species on the yield of linseed, it would be possible to relate the costs for weed control, to the probable effects of the weed if not controlled, and answer questions such as

- could certain levels of weed infestation be tolerated in the linseed crop?

- are the threshold levels, the levels of infestation that are likely to cause financial loss to the crop, similar for different sites and years and for different weed species.

Answers to questions such as these will aid decision making in the linseed crop, with reference to the management of weed control strategies.

2. Experimental Protocol and Procedures

2.1 Weed Population Studies

The variety of linseed was ANTARES drilled at each location at 700 seeds/m^2.

Previous studies at IACR Rothamsted indicated that high numbers of weed seeds would be required to produce the targetted weed populations. Also the target range of weed populations, and the maximum plants/m^2 for each weed species would be different.

The individual seed populations were as follows

Chickweed

0, 62, 250, 500, 1,000 seeds/m^2 which if one assumes a 40% germination would give a maximum of 400 plants/m^2.

Fat-hen

0, 100, 400, 800, 1,600 seeds/m^2 with an assumed germination of only 10% to give a maximum plant population of 160 plants/m^2.

Knotgrass

The seed was pre treated with between 3 and 4 weeks exposure to 3°C in damp sand in a refrigerator. After drying seed was planted at 0, 120, 480, 960, 1,920 seeds/m^2. An assumed germination of only 25% would give a maximum plant establishment of 480 plants/m^2.

Cultivated oats

0, 12.5, 50, 100 and 200 seeds/m^2 with an assumed germination of 50 - 60% to give a maximum plant stand of 100 - 120 plants/m^2.

Wild oat

This was sown at 50 or 200 seeds/m^2.

During the course of the three years these germination values were modified, based on experience, and in the final season the assumed germination levels in the field were

chickweed	10%
fat- hen	5%
knotgrass	5%
oats	50%

Applications of insecticides to control insect damage to the linseed crop, and wire fencing to prevent rabbit damage were required at several locations.

At the Arable Research Centres and Morley locations, oats were always represented by cultivated oats. Previous IACR Rothamsted experimentation had indicated that cultivated and wild oats have similar competitive abilities within crops. In two seasons at IACR Rothamsted it was possible to make limited comparisons between cultivated and wild oats in the trial series.

2.1.1 Visual Assessment of Ground Cover

These assessments were made on the basis of the % of ground covered by the weeds sown into the experimental area. Other weeds which had naturally established had previously been hand weeded from the experimental areas.

2.1.2 Photographic Assessment of Ground Cover (IACR Rothamsted only)

Vertical photographs of the $1m^2$ area in each plot were taken, and the photographs 'digitised' to estimate ground cover of weeds and the crop.

2.2 Weed Biomass Studies

At the IACR Rothamsted location, the biomass of both the crop and the individual weed species were evaluated on several occasions during the growing season.

Samples were removed from areas measuring $1m^2$ and the crop and weed were dried and weighed. The number of individual plants that made up the sample from the $1m^2$ area was also recorded.

These biomass samples were recorded on

	1993	**1994**	**1995**
	16 June	20 June	28 June
	12 July	13 July	2 August
	3 August		
Harvest	12/13 September	2 September	22 August

3 RESULTS

3.1 Weed Population Studies

3.1.1 Knotgrass (*Polygonum aviculare*)

In the three seasons of trials, seven trials were completed on the competitive effect of this weed. However, a useful range of knotgrass populations were achieved at only 4 of those locations ARC (Wimborne) 1993, Rothamsted 1993 and 1995, ARC (Cirencester) 1995, but at this last location the linseed crop was very poor due to the exceptionally dry season.

1 1993

ARC (Wimborne)

Weed seeds/m^2	**weeds/m^2**	**% ground cover**	**Linseed Yield (t/ha)**	**% yield reduction**
		(28/5/93)		
0	0	0	1.31	0
120	10	3.5	1.11	- 15.3
480	10	7	1.05	- 19.9
960	20	7	1.35	+ 3.0
1,920	80	2	1.08	- 17.6

LSD 0.31 t/ha

Seed germination levels were extremely low, and there was not a very clear relationship between established plants and weed seeds sown. Ground cover was measured in late May, and only reached a maximum of 7%, and this was not in the plots with the highest weed plants/m^2. Three of the weed populations produced decreases in the yield of the linseed crop, but none of the yield changes were significant.

Rothamsted

The dry weather affected the germination and establishment of all the weed species at this location in 1993, but knotgrass establishment was the most severely affected.

Weed seeds/m^2.	weeds/m^2.	% ground cover (9/6/93)	Linseed yield (t/ha)	% yield reduction
0	0	0	2.36	0
120	2.2	5	2.39	+ 1.3
480	5.9	5	2.26	- 4.2
960	10.8	8	2.07	- 12.3
1,920	17.8	9	1.94	- 17.8
			LSD 0.40 t/ha	

The ground cover of the linseed crop when weed cover was assessed in early June was 45 - 48%. The maximum cover achieved by knotgrass was 9%, but it should be noted that weed levels were low in this trial, even the highest seed population only producing 18 plants/m^2.

At the highest weed population, knotgrass created significant yield losses in the linseed crop.

1994

Two locations were sown in this season with knotgrass seeds, but the location at Caythorpe (Lincolnshire) failed to produce any knotgrasss seedlings. Only the Wimborne (Dorset) location succeeded, but even here the maximum plant populations were only 10 knotgrass/m^2.

ARC (Wimborne)

Weed seeds/m^2	weeds/m^2	Linseed yield (t/ha)	% yield reduction
0	0	2.0	0
120	0	1.80	- 10%
480	0	2.10	+ 5%
960	3	2.00	0
1,920	10	1.80	- 10%

LSD 0.52 t/ha

This results did not show a relationship between weeds established and weeds sown, or linseed yields to levels of knotgrass infestation.

1995

Four trials were successfully established in this season.

ARC (Andover)

Once again the levels of knotgrass germination from the drilled weed seeds were low, and rather uniform across all seeding rates.

Weed seeds/m^2	weeds/m^2	Linseed yield (t/ha)	% yield reduction
0	0	0.67	0
120	6.7	0.54	- 19.4%
480	6.3	0.56	- 16.4%
960	10.3	0.61	- 9.0%
1,920	8.7	0.61	- 9.0%

LSD 0.31 t/ha

None of the yields were significantly different from the weed free linseed yields, but the extremely dry season did reduce yields overall at this location.

ARC (Cirencester)

A small range in establishment levels of knotgrass and subsequent % ground cover values were obtained at this location, but the dry season gave exceptionally low linseed yields.

Weed seeds/m^2	**weeds/m^2**	**% ground cover** (19/6/95)	**Linseed yield (t/ha)**	**% yield reduction**
0	0	0	0.225	0
120	0.8	5	0.20	-11.9
480	1.4	8	0.23	+ 2.2
960	16.6	10	0.23	+ 2.2
1,920	14.1	10	0.23	+ 2.2

LSD 0.231 t/ha

None of the yield differences resulting from the different weed populations, which achieved a maximum of 10% ground cover, were significantly different from the 'weed free' linseed.

ARC (Caythorpe)

The establishment levels of the knotgrass were very low at this location, with a maximum of only 5 plants/m^2.

Weed seeds/m^2	**weeds/m^2**	**Linseed yield (t/ha)**	**% yield reduction**
0	0	1.47	0
120	0	1.43	- 2.7%
480	2	1.47	0
960	4	1.32	- 10.2%
1,920	5	1.45	- 1.4%

LSD 0.17 t/ha

The apparent yield reductions due to knotgrass infestation were low, and not totally consistent with the actual populations of weeds in the different treatments.

Rothamsted

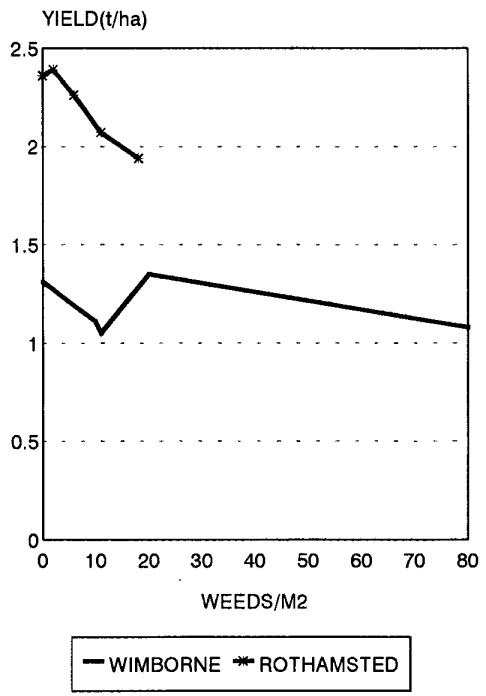
At this location, in this season, the highest levels of knotgrass establishment were achieved . Plant populations of 145 knotgrass/m^2 were obtained from the highest weed seed plots.

Weed seeds/m^2	**weeds/m^2**	**% ground cover**	**Linseed yield (t/ha)**	**% yield reduction**
		(13/6/95)		
0	0	0	1.11	
120	20.3	20	0.89	- 19.8%
480	47.2	43	0.77	- 30.6%
960	74.4	39	0.61	- 45.1%
1,920	145	63	0.58	- 47.7%
			LSD 0.20 1 t/ha	

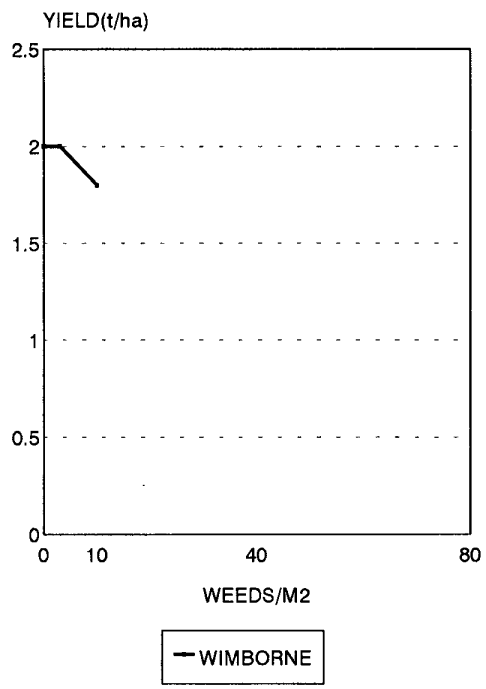
All plant populations of knotgrasss significantly reduced linseed yields.

THE INFLUENCE OF KNOTGRASS ON THE YIELD OF LINSEED

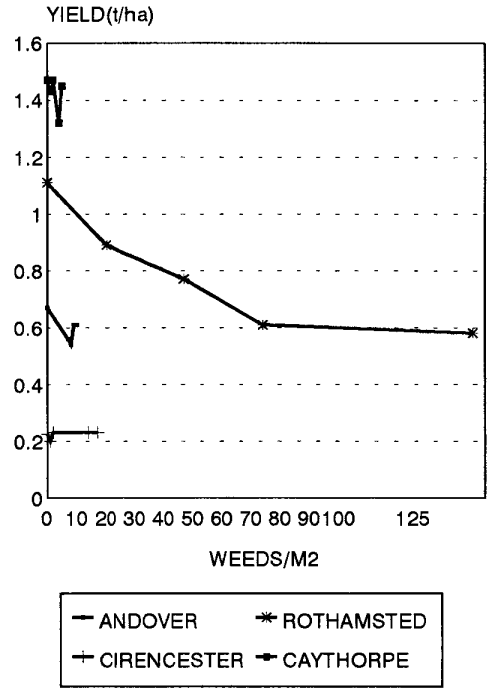
KNOTGRASS (POLYGONUM aviculare) 1993



KNOTGRASS (POLYGONUM aviculare) 1994



KNOTGRASS (POLYGONUM aviculare) 1995



SUMMARY

Whilst knotgrass is known to be a nuisance weed in linseed crops, in this trial series it actually proved to be the most difficult of the five weeds to successfully establish.

In three of the seven trials, no significant yield reductions due to knotgrass infestation were recorded in linseed, but the maximum knotgrass population achieved was 10 plants/m^2.

However in the two other trials, both conducted at Rothamsted, significant linseed yield reductions were recorded from a total of five knotgrass infestation levels of 18, 20, 47, 74 and 145 plants/m^2.

Knotgrass appeared to perform in a similar manner to chickweed in that it showed a high level of intraspecific competition - it competed with other knotgrass plants as well as the linseed. This is borne out by the biomass studies where the dry weight of knotgrass from high plant densities was very little different from that of lower plant densities. (See later.)

The ground covering ability of knotgrass appeared to be low in most cases, and only in the trial with the exceptionally high weed plant number (145/m^2) did it achieve the high ground cover score of 63%.

The first significant reduction in linseed yield was obtained from a knotgrass population of 18 plants/m^2. Whilst higher weed populations did not always result in significant yield losses, in total five of the seven plant populations of knotgrass over 18 plants/m^2 were associated with significant yield loss in linseed. The levels of yield loss ranged from 17.8% to 47.7% in those trials that produced significant responses. The two occasions where knotgrass populations of 20 and 80 plants/m^2 failed to affect linseed yields were at Wimborne in 1993.

3.1.2 Chickweed (*Stellaria media*)

The weed populations, resulting ground cover by the weeds, and corresponding yield effects are presented for each location.

1993

Chickweed was included in trials at ARC (Wimborne) ARC (Cirencester) and MRC (Norfolk)

ARC (Wimborne)

Sown 20th April

Weed seeds/m^2	**weeds/m^2**	**% ground cover**	**Linseed yield (t/ha)**	**% yield reduction**
		(28/5/93)		
0	3	25	1.18	0
62	14	60	1.06	- 10
250	26	85	0.86	- 27
500	37	90	0.99	- 16
1,000	56	92.5	0.66	- 44
			LSD 0.30 t/ha	

Although the level of establishment from the seed numbers sown was low, the ground cover by the weed plants that established was fairly extensive. A low background population of chickweed appeared in the 'no weed' plots, giving 25% ground cover, but these were removed after the assessment. Increasing numbers of weeds led to greater yield losses in the linseed, though at the highest weed numbers this relationship was less direct. Two weed populations, 26 and 56 plants/m^2 gave significant linseed yield reductions.

ARC (Cirencester)

Sown 20th April

Weed seeds/m^2	weeds/m^2	% ground cover (14/5/93)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.67	0
62	13	43	0.62	- 7
250	56	82	0.51	- 14
500	109	93	0.50	- 25
1,000	230	93	0.48	- 28
			LSD 0.23 t/ha	

Here, higher plant numbers were achieved although the level of ground cover peaked at a similar point as in the Dorset trial. Yield effects of the different weed populations appeared more linear and again levelled off at the higher weed populations, but the differences were not statistically significant.

Morley

Sown 31st March - 2nd April

Weed seeds/m^2	weeds/m^2	% ground cover (9/6/93)	Linseed yield (t/ha)	% yield reduction
0	5	0	1.60	0
62	64	6	1.55	- 3
250	46	19	1.35	- 16
500	51	19	1.42	- 11
1,000	83	48	1.36	- 15
			LSD 0.44 t/ha	

Levels of ground cover by the chickweed were not as high as in the Wimborne and Cirencester trials, due to dry weather following sowing which delayed and reduced weed emergence. Corresponding yield effects were not significant and tended to be less than recorded elsewhere.

ARC (Caythorpe)

At the Caythorpe location the chickweed failed to establish irrespective of sowing rate. Ground cover assessments recorded no chickweed in any other plots.

2. 1994

Chickweed was included in trials at ARC (Wimborne) ARC (Cirencester) ARC (Caythorpe) MRC (Morley) and Rothamsted.

ARC (Wimborne)

Sown 5th April

Weed seeds/m^2	weeds/m^2	Linseed yield (t/ha)	% yield reduction
0	0	2.0	0
62	36	2.3	+ 15%
250	128	1.6	- 20
500	215	1.8	- 10
1,000	397	2.0	- 0

LSD 0.52 t/ha

Good establishment of chickweed in this trial led to high weed populations. There was a trend for effects on linseed yields to peak before the highest seed rate, but despite 397 chickweed plants/m^2, the differences in yield were not significant.

ARC (Cirencester)

Sown 21st April

Weed seeds/m^2	weeds/m^2	% ground cover (5/7/94)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.61	0
62	26	65	0.64	+ 5
250	45	70	0.70	+ 15
500	65	95	0.54	- 12
1,000	78	95	0.61	0
			LSD 0.20 t/ha	

Once again, good levels of ground cover from low levels of establishment, but no relationship between weed ground cover and linseed yield reduction. Only one treatment (500 seeds/m^2) caused a reduction in linseed yield, but this was not significant.

ARC (Caythorpe)

Sown 19th April

Weed seeds/m^2	weeds/m^2	% ground cover (3/5/94)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.35	0
62	18	5	0.24	- 31
250	22	10	0.26	- 26
500	46	20	0.28	- 20
1,000	34	27	0.31	- 11
			LSD 0.07 t/ha	

Low levels of establishment from the different seed rates of chickweed resulted in no more than 27% ground cover. After the ground cover assessment was carried out the chickweed started to die owing to hot dry weather conditions. Yields were very low but all populations of chickweed reduced yield, though yield reductions were clearly correlated with the relatively small range of weed densities established in this trial.

Morley

Sown 19th April

Weed seeds/m^2.	weeds/m^2.	% ground cover (26/7/94)	% ground cover (3/8/94)	Linseed yield (t/ha)	% yield reduction
0	0	0	0	4.93	0
62	13	6	8	3.66	- 26
250	38	14	18	3.83	- 22
500	70	20	27	3.20	- 35
1,000	69	27	52	2.89	- 41
				LSD 1.67 t/ha	

Establishment of the chickweed was again poor and ground cover by July 26th was at most 27%. A second ground cover assessment was carried out a week later when higher ground cover scores were recorded, reaching 52% with the highest seed rate, though this had not produced the highest plant population. Yields were good in this trial and all chickweed populations reduced yield, the greatest effect (41%) coming from the highest seed rate.

Rothamsted

Sown 26th April

Weed seeds/m^2.	weeds/m^2.	% ground cover (25/5/94)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.93	0
62	57	45	0.92	- 1
250	87	53	0.80	- 14
500	232	63	0.74	- 20
1,000	261	67	0.79	- 15
			LSD 0.20 t/ha	

Chickweed establishment was good at this site though complete ground cover, seen from lower populations at other sites, was not achieved. As in other trials this year dry weather inhibited the establishment and growth of this weed, and although trends for yield reductions in the linseed were seen, they were not as great as expected from the weed population figures. None of the yield reductions were significant, even from weed populations of over 200/m^2.

1995

Chickweed included in trials at ARC (Andover) ARC (Caythorpe) MRC (Morley) and IACR Rothamsted.

ARC (Andover)

Sown 11th April

Weed seeds/m^2	weeds/m^2	Linseed yield (t/ha)	% yield reduction
0	0	0.67	0
62	40	0.65	- 3
250	64	0.69	+ 3
500	232	0.55	- 18
1,000	529	0.53	- 21

LSD 0.30 t/ha

Very good establishment of chickweed produced over 500 plants/m^2 with the highest seed rate. However a very dry spring and summer caused an early die back of the weed and final yield effects were not as high as expected. There was a trend for higher chickweed populations to give the greatest yield reductions but differences were not statistically significant.

ARC (Caythorpe)

Sown 12th April

Weed seeds/m^2	weeds/m^2	% ground cover (29/6/95)	Linseed yield (t/ha)	% yield reduction
0	0	0	1.47	0
62	6	17	1.40	-5
250	11	30	1.35	- 8
500	142	65	1.31	- 11
1,000	252	88	1.19	- 19
			LSD 0.17 t/ha	

Reasonably good establishment of the chickweed gave stepwise increments in ground cover up to 88%. However severe drought, as in other trials in 1995, caused premature senescence of the chickweed and a second ground cover assessment on 29th July scored zero for all chickweed plots. As a result the yield losses from chickweed infestation, although increasing with increased weed populations, were lower than expected. Only the highest chickweed population produced a significant yield reduction.

Morley

Sown 14th April

Weed seeds/m^2	weeds/m^2	% ground cover (7/8/95)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.82	0
62	8	0	0.53	- 35
250	33	0	0.41	- 50
500	43	0	0.17	- 80
1,000	51	0	0.54	- 34
			LSD 0.31 t/ha	

Although the chickweed established reasonably well, severe drought again prevented further growth and by August all chickweed was dead. A combination of drought and flea beetle attack at this site resulted in variable yields related more to the extent of flea beetle attack than to competition from chickweed. It is difficult therefore to draw conclusions on the effect of chickweed on yield in this case.

Rothamsted

At this location, a larger weed competition trial funded by The Commonwealth Universitites Fellowship also involved some chickweed treatments. The data has been used by kind permisison of Dr R van Acker.

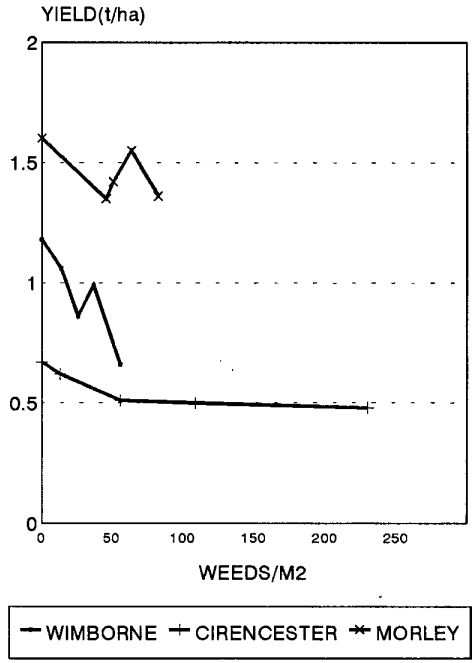
Weeds plants/m^2	Linseed Yield (t/ha)	% Yield Reduction
0	1.31	0
52	1.22	- 6.9
103	1.19	- 9.2
241	0.93	- 29.0
395	0.45	- 65.6
528	0.42	- 67.9

Detailed monitoring of the chickweed biomass indicated that the weed was extremely vigourous in early summer, but at high weed populations the growth of individual plants had virtually ceased by July, with senescence caused by interplant competition. However at lower plant densities, individual chickweed plants continued to grow.

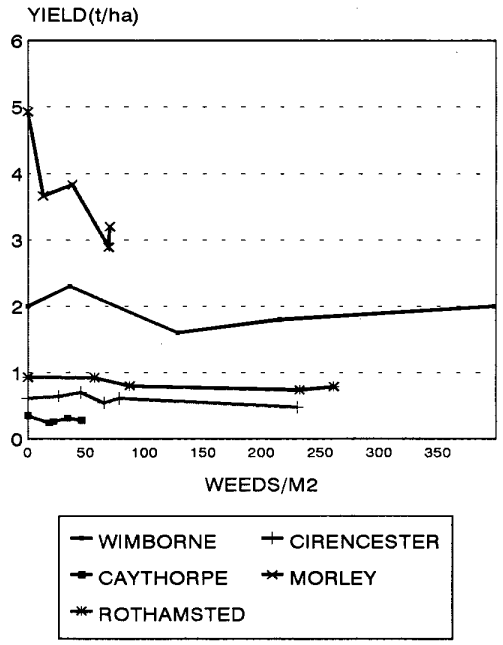
Although linseeds yields were low owing to the dry weather, they were reduced in the presence of the different chickweed populations.

THE INFLUENCE OF CHICKWEED ON THE YIELD OF LINSEED

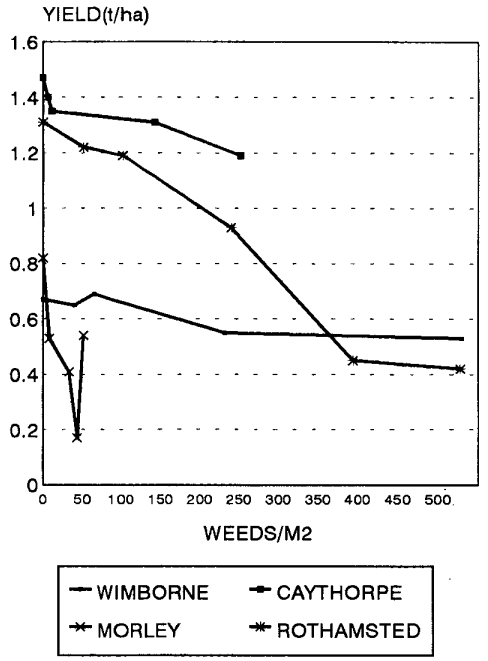
CHICKWEED (STELLARIA media)
1993



CHICKWEED (STELLARIA media)
1994



CHICKWEED (STELLARIA media)
1995



SUMMARY

Chickweed can be a very vigourous plant and its prostrate growth habit can produce extensive ground cover from relatively few plants, an effect consistently seen in this trial series. In four of the twelve trials, chickweed reached almost 100% ground cover. Nevertheless the effects of this on the final yield of linseed were not consistent. Linseed yields often reached a minimum with the middle weed seed rates, 250/m^2, even where ground cover was less extensive.

This ability to cover the ground with few plants means that at higher populations the weed itself may suffer. It has been noted in several trials that where chickweed levels are high, the weed will die back relatively early and therefore competition with the crop ceases. This intraspecific competition was more noticeable in trials affected by drought, where the chickweed seemed to be competing with itself for water more so than with the crop and suffered more as a result. Also, whereas chickweed has a prostrate growth habit, linseed has an erect habit and so competition for light would not be significant.

Evidence from other studies also suggests that linseed has a deeper rooting system, compared to that of the shallow rooting chickweed, and may therefore be better able to exploit deeper sources of water.

From these observations it would appear that although chickweed can be very impressive in its rate of ground cover, its ability to compete with, and reduce the yield of linseed does not correlate with this, owing to

a) differences in growth habit between the crop and the weed

b) tendency of the weed to compete with itself more than the crop

c) greater susceptibility of the weed to drought.

Significant reductions in yield were recorded in five trials (Andover 93, Caythorpe 94 and 95, and Morley 94 and 95), where the weed populations and ground cover levels which produced the greatest yield losses were as follows:

	chickweed/m^2	% ground cover	% yield loss
Wimborne 93	56	92.5	44
Caythorpe 94	18	5	31
Caythorpe 95	252	88	19
Morley 94	69	52	41
Morley 95	43	0	80

The results from Morley in 1995 should be treated with reserve as explained earlier. The other results do not indicate a clear trend but perhaps illustrate again that chickweed is more of a problem at lower than at higher populations. The first significant linseed yield depression was obtained from 18 chickweed plants/m^2. However populations above this level on 7 of the 31 instances gave significant yield reductions.

3.1.3 Fat-hen (*Chenopodium album*)

1993

Fat-hen included in trials at ARC (Wimborne) ARC (Cirencester) MRC (Morley) and Rothamsted.

ARC (Wimborne)

Sown 20th April

Weed seeds/m^2	weeds/m^2	% ground cover (28/5/93)	Linseed yield (t/ha)	% yield reduction
0	10	7	1.08	0
100	40	7	1.18	+ 9
400	80	30	0.97	- 10
800	40	25	0.84	- 22
1,600	130	35	0.91	- 16

LSD 0.30 t/ha

There was a tendancy for yield reductions to be caused by weed plant populations greater than 40/m^2, but above this figure yield effects were not consistent with plant population. Generally, however, yield effects were small and none were significantly difference to the weed free. The natural weeds present in the zero plots were removed after the initial asessment.

ARC (Cirencester)

Sown 20th April

Weed seeds/m^2	weeds/m^2	% ground cover (14/5/93)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.67	0
100	10	4	0.49	- 27
400	30	11	0.49	- 27
800	59	32	0.57	- 15
1,600	100	37	0.50	- 25

LSD 0.23 t/ha

Increasing seed rates of the weed produced increasing ground cover scores up to a maximum of 37%. Small statistically insignificant yield reductions were seen owing to the presence of the weed, but the degree of yield loss did not correlate with seed rate or ground cover of the fat-hen.

Morley

Sown 31st March

Weed seeds/m^2	weeds/m^2	% ground cover (30/6/93)	Linseed yield (t/ha)	% yield reduction
0	1	0	1.68	0
100	11	1	1.55	- 8
400	24	1	1.74	+ 4
800	45	4	1.51	- 10
1,600	69	9	1.50	- 11

LSD 0.44 t/ha

Weed populations up to 69/m^2 only produced ground cover of 9% maximum.Again yield effects were small and none were statistically significant.

Rothamsted

Sown 29th April

Weed seeds/m^2	weeds/m^2	% ground cover (9/6/93)	Linseed yield (t/ha)	% yield reduction
0	0	0	2.36	0
100	2.5	5	2.06	- 13
400	9.4	9	2.11	- 11
800	17.7	10	1.91	- 19
1,600	32.2	23	1.75	- 26

LSD 0.21 t/ha

In this trial there was a good relationship between weed seed rate, weed plants/m^2, ground cover by the weed and corresponding linseed yields which declined progressively as the weed population increased. There were significant yield reductions at all the weed populations.

1994

Fat-hen was included in trials at ARC (Wimborne) ARC (Cirencester) MRC (Morley) and Rothamsted

ARC (Wimborne)

Sown 5th April

Weed seeds/m^2	**weeds/m^2**	**Linseed yield (t/ha)**	**% yield reduction**
0	0	2.0	0
100	5	2.2	+ 10
400	10	2.1	+ 5
800	52	1.9	-5
1,600	83	1.5	- 25

LSD 0.52 t/ha

No assessment of ground cover was made at this site.

As with other trials, yield reductions were only seen with the highest population of fat hen, up to 25% yield loss from 83 weed plants/m^2.However this difference was not significantly different to the weed free linseed.

ARC (Cirencester)

Sown 21st April

Weed seeds/m^2	weeds/m^2	% ground cover (5/7/94)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.61	0
100	21	5	0.70	+ 14
400	61	10	0.74	+21
800	55	10	0.59	- 3
1,600	81	12	0.54	- 11

LSD 0.20 t/ha

Again high plant populations did not produce high ground cover scores (12% maximum). Only the highest seed rates produced yield reductions, though they were not statistically significantly different from the weed free linseed.

Morley

Sown 19th April

Weed seeds/m^2	weeds/m^2	% ground cover		Linseed yield (t/ha)	% yield reduction
		(26/7/94)	(3/8/94)		
0	1.8	2	0	4.06	0
100	0	2	1	3.82	6
400	0.9	10	7	4.16	+ 2
800	0.9	5	4	3.04	- 25
1,600	7	13	10	4.39	+ 8

LSD 1.67 t/ha

This was a high yielding linseed trial that had very low levels of weed establishment. The trial did not produce any significant yield reductions from any weed populations up to 7/m^2.

Rothamsted

Sown 26th April

Weed seeds/m^2	weeds/m^2	% ground cover (14/6/94)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.93	0
100	6	7	1.07	+ 15
400	31	17	0.84	- 10
800	24	19	0.88	- 5
1,600	55	35	0.69	- 26
			LSD 0.20 t/ha	

The highest weed seed rate, giving 55 plants/m^2 and 35% ground cover, produced a significant 26% yield loss. All other seed rates caused no significant yield reductions.

1995

Fat-hen was included in trials at ARC (Andover) ARC (Cirencester) MRC (Morley) and Rothamsted

ARC (Andover)

Sown 11th April

Weed seeds/m^2	Plants/m^2	Linseed yield (t/ha)	% yield reduction
0	0	0.67	0
100	2	0.64	- 4
400	17	0.65	- 3
800	26	0.72	+ 7
1,600	91	0.68	+ 1
		LSD 0.30 t/ha	

No ground cover assessment was taken at this site. Despite a relatively high population of fat-hen, the dry spring and summer of 1995 prevented any vigourous growth of the weed and no significant yield reductions were recorded from any of the weed seed rates.

ARC (Cirencester)

Sown May 15th

Weed seeds/m^2.	weeds/m^2.	% ground cover (19/6/95)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.23	0
100	25	10	0.29	+ 26
400	70	15	0.29	+ 26
800	118	50	0.29	+ 26
1,600	150	62	0.36	+ 56

LSD 0.23 t/ha

Good ground cover was achieved from the higher seed rates, but still no reductions in yield were recorded, despite the fact that the linseed was sown late and was low yielding.

Morley

Sown 14th April

Weed seeds/m^2.	weeds/m^2.	% ground cover (7/8/95)	Linseed yield (t/ha)	% yield reduction
0	0	3	0.43	0
100	10	8	0.60	+ 40
400	40	13	0.39	- 9
800	73	13	0.51	+ 19
1,600	124	17	0.52	+ 21

LSD 0.31 t/ha

At this site drought and flea beetle problems were more influential than weed competition. Despite good initial establishment from the fat hen, ground cover was never very extensive and no significant yield reductions were recorded.

Rothamsted

Sown 20th April

At this site fat-hen failed to establish except at the highest seed rate :

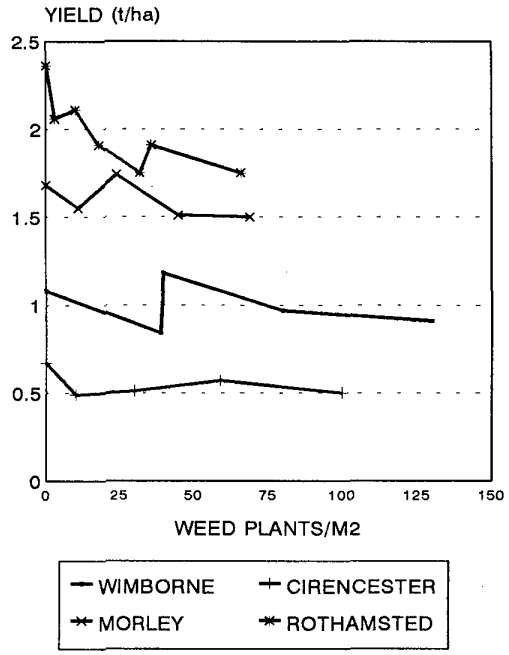
Weed seeds/m^2	**weeds/m^2**	**% ground cover (13/6/95)**	**Linseed yield (t/ha)**	**% yield reduction**
0	0	0	1.11	0
1,600	23	13	0.98	- 12

LSD 0.20 t/ha

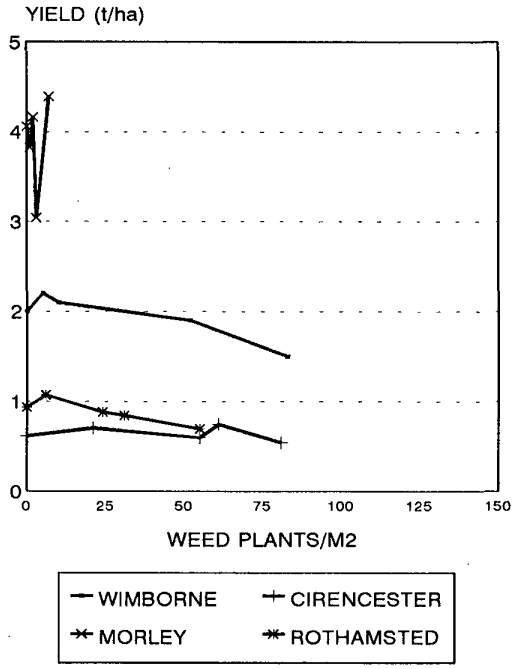
Even with the high seed rate, establishment of the weed was poor. Nevertheless a reasonable degree of ground cover was achieved, but the corresponding reduction in yield was small and not significant.

THE INFLUENCE OF FAT HEN ON THE YIELD OF LINSEED

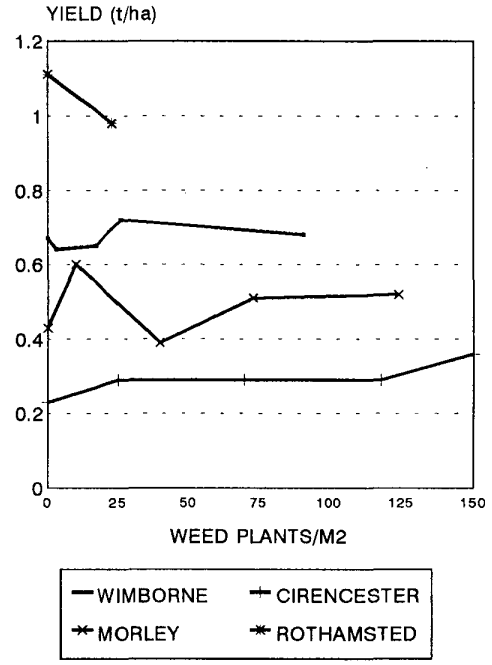
FAT HEN (Chenopodium album)
1993



FAT HEN (Chenopodium album)
1994



FAT HEN (Chenopodium album)
1995



SUMMARY

Fat-hen is by nature a weed of open ground, and is particularly common in crops such as sugar beet and linseed owing to the space available within these crops. As linseed itself is a small plant with little competitive powers, one would expect fat hen to be competitive with linseed and cause yield reductions. The results of these trials would not support this view with only two of the twelve trials producing a significant yield loss (Rothamsted 1993, 1994). The maximum yield losses achieved were fairly consistently 25 - 27%, usually from the highest seed rates used, i.e. 1,600 seeds/m^2, producing between 60 and 150 plants/m^2. Populations below this level rarely produced a significant yield reduction. In fact, out of total of 48 treatment/site combinations, 18 apparently gave a yield increase from the presence of fat-hen, though these effects were not statistically significant. Fat-hen was not as competitive as expected.

The responses to fat-hen infestation were very variable in terms of linseed yield. It is very difficult therefore to draw conclusions about the number of fat-hen plants required in a crop to consistently cause yield losses in linseed.

It does not appear to be a very vigorous weed when competing with linseed, particularly when it does not establish until April/May when the linseed is drilled and emerging.

3.1.4 Cultivated oats (*Avena sativa*)

This weed programme proved to be the most successful of all the target weed species, and over the three seasons 12 individual trials were conducted.

The maximum oat population that was targeted was 180 plants/m^2, and whilst this was never reached (174/m^2 being the highest) a valuable spread of plant populations was obtained at every location in every season.

1993

Four trials were successfully completed at ARC (Cirencester) ARC (Caythorpe) MRC (Morley) and IACR Rothamsted.

ARC (Cirencester)

Sown 20th April

This trial was drilled using the oat variety Rollo. Although the target weed population of 120 plants/m^2 was not reached, the range of established plants/m^2 from the four weed seeding rates was excellent, with a highest value of 58 plants/m^2.

The % ground cover given by this more erect species was lower than for other weed species, the 58 plants/m^2 giving a % ground cover of 20%.

The effect of the oat population on the yield of the linseed crop was extremely marked at this location, the highest weed population reducing yield by 75%.

Weed seeds/m^2	**weeds/m^2**	**% ground cover**	**Linseed yield (t/ha)**	**% yield reduction**
		14/5/93		
0	0	0	0.67	0
12.5	6	5	0.48	- 28.4
50	15	11	0.45	- 32.8
100	35	15	0.36	- 46.3
200	58	20	0.17	- 74.6

LSD 0.23 t/ha

The yield reductions resulting from the two highest populations of oats were significant. It is noticeable that a 9 fold increase in plants/m^2 only produced a four fold increase in ground cover, illustrating that this is a very erect weed.

ARC (Caythorpe)

This trial experienced an exceptionally high background weed infestation of chickweed and knotgrass, even though prior to drilling two herbicide applications had been made to the seedbed.

This weed population was removed with a further selective broad leaved herbicide application in early June, leaving the cultivated oat weeds, plus a low background population of wild oats.

Weed seeds/m^2	**weeds/m^2**	**Linseed yield (t/ha)**	**% yield reduction**
0	0	1.33	0
12.5	3	1.58	+18.8
50	46	0.99	- 25.6
100	83	0.80	- 39.5
200	120	0.89	- 33.1

LSD 0.31 t/ha

The three highest weed populations of oats significantly depressed the yield of the linseed. The low level of infestation in this trial, resulted in a small increase in the yield of linseed, but the improvement was not significant.

Morley

The weed populations of the oat variety Rollo were the highest at this location compared to any of the other 11 trials.The trial was drilled on March 31st, and although there was a prolonged period of dry weather after sowing which resulted in the other two weed species at this location giving quite similar plant populations over the range of seeding levels, the oats gave a good range of plant populations.

Weed seeds/m^2	**weeds/m^2**		**% ground cover**	**Linseed yield (t/ha)**	**% yield reduction**
	(24/5/93)	**(3/8/93)**			
0	0	0	0	1.55	0
12.5	4.8	17.3	1	1.50	- 3.2
50	21.5	49.0	6.3	1.52	- 1.9
100	45.5	65.7	9.0	1.15	- 25.8
200	86.7	173.7	18.3	0.64	- 58.7

LSD 0.44 t/ha

The two highest oat weed populations reduced the yield of the linseed, the highest population of 174 plants/m^2 causing a significant yield reduction.

Once again it was noticeable that the growth habit of this weed, resulted in a low % ground cover even from a high weed population.

Rothamsted

This trial was drilled on April 29th. The linseed emerged slightly earlier than the oats (3 days) and the maximum oat plants/m^2 achieved was 65.5. However they only gave an 18% ground cover.

Weed seeds/m^2	weeds/m^2	% ground cover (9/6/93)	Linseed yield (t/ha)	% yield reduction
0	0	0	2.36	0
12	5.8	5	2.37	+ 0.4
50	20.9	6	2.09	- 11.4
100	35.9	14	1.79	- 24.2
200	65.5	18	1.34	- 43.2

LSD 0.40 t/ha

The highest oat weed density reduced yield by 43%. This reduction and the one resulting from the second highest oat weed population were both significantly lower than the weed free linseed yield.

Samples taken to determine 1,000 seed weights showed no detectable effect from the weed population, all treatments resulting in seed weights of approximately 8.9 gms/1000 seeds for linseed.

1994

A further four trials were successfully completed in the season at ARC (Caythorpe) ARC (Cirencester), MRC (Morley) and IACR Rothamsted.

ARC (Caythorpe)

This trial was drilled on April 19th and the linseed and oats emerged on April 29th. A feature of this trial was the influence of the higher oat plant densities on the height of the linseed crop. In the weed free plots the linseed was 10 cm high (June 1st) and it was the same height in the plots with 12 and 18 oat plants/m^2. However at the two highest oat populations 48 and 74 plants/m^2 the linseed crop was 13 cms high. This was a response to the competition from the oat plants.

Weed seeds/m^2	**weeds/m^2**	**% ground cover (13-25/6/94)**	**Linseed yield (t/ha)**	**% yield reduction**
0	0	0	0.35	0
12.5	12	7	0.28	- 20
50	18	13	0.15	- 57.2
100	48	40	0.05	- 85.6
200	74	60	0.03	- 91.5

LSD 0.07 t/ha

The hot dry weather had a very major influence on the overall yields of linseed at this thin soiled location. Nevertheless the presence of different populations of oats did depress yield of the linseed even further. In the heavily infested oat plots, the linseed plants were noticeably more spindly, and their seed heads smaller, than in the weed free plots.

The maximum yield depression was 91.5% from 74 weeds/m^2. These plants were extremely thick, appearing to suit the dry conditions and they had a higher than usual % ground cover of 60%. The three highest oat weed populations all resulted in significantly lower linseed yields.

ARC (Cirencester)

The dry early spring on this Cotswold brash soil reduced establishment levels of the oats to only 63 plants/m^2 maximum from an April 21 sowing date. However a useful range of oat weed populations were established from the different seeding rates.

Weed seeds/m^2	**weeds/m^2**	**% ground cover**	**Linseed yield (t/ha)**	**% yield reduction**
		(5/7/94)		
0	0	0	0.61	0
12.5	10	5	0.59	- 3.3
50	25	13	0.51	- 16.4
100	43	21	0.53	- 13.1
200	63	25	0.40	- 34.4

LSD 0.20 t/ha

All four populations of oats appeared to reduce the yield of the linseed crop, but only the 63 plants/m^2, giving 25% ground cover, gave a significant linseed yield reduction.

Morley

This location produced the equal highest oat population of any of the four sites in 1994, with 150 plants/m^2.

The drilling date was April 19th, and irrigation on April 29th assisted establishment in a very dry seedbed.

Weed seeds/m^2	**weeds/m^2**	**% ground cover**	**Linseed yield (t/ha)**	**% yield reduction**
		(26/7/94)		
0	0	0	3.99	0
12.5	9	3	3.95	- 1.0
50	22.4	9	2.11	- 47.1
100	73.5	11.7	2.00	- 49.9
200	149.6	26.0	0.36	- 90.8

LSD 0.75 t/ha

Oat populations greater than 22/m^2 and ground cover in excess of 9% resulted in significant reductions in linseed yield. The effect of the 150 oat plants/m^2 was very significant, reducing the linseed yield by 90%.

Rothamsted

Again at this location in 1994 it was noted that oats appeared to suffer less from drought than other weed species in trial.

The plots were drilled on April 26th and produced the equal highest oat plant population of 150/m^2 from the highest seeding rate.

Weed seeds/m^2	weeds/m^2	% ground cover (14/6/94)	Linseed yield (t/ha)	% yield reduction
0	0	0	0.93	0
12.5	9	11.7	0.71	- 23.7
50	24.7	26.4	0.58	- 37.6
100	91.3	59.2	0.32	- 65.6
200	150	58.6	0.20	- 78.5

LSD 0.20 t/ha

All oat populations created significant reductions in the yield of the linseed crop with 78% yield reduction from 150 oat plant/m^2.

1995

In many respects the previous season could be considered unusually dry, but the 1995 season was exceptionally dry and this had a dramatic effect on the yields of the linseed crop at all four locations. The highest yield at any location, from weed free plots was only 1.47t/ha.

ARC (Cirencester)

This trial was drilled on March 20th but was actually harvested on August 31st, which is the earliest linseed harvest date ever recorded at this location, which again emphasises the dryness of the season.

Weed seeds/m^2	**weeds/m^2**	**% ground cover**	**Linseed yield (t/ha)**	**% yield reduction**
		(19/6/95)		
0	0	0	0.225	0
12.5	8.2	15	0.19	- 15.6
50	51.6	42	0.13	- 42.4
100	60	41	0.21	- 6.7
200	70	50	0.10	- 55.6

LSD 0.23 t/ha

This trial was severely influenced by the drought and no significant differences between treatments could be identified.

ARC (Caythorpe)

This proved to be highest yielding linseed location in 1995, resulting from an April 12th planting and a remarkably early harvest of August 17th. Three of the oat seed rates produced rather similar plant establishment levels, but the highest rate of 200 seeds/m^2 did produce 72 plants/m^2.

Weed seeds/m^2	**weeds/m^2**	**% ground cover**		**Linseed yield (t/ha)**	**% yield reduction**
		(29/6/95)	**(29/7/95)**		
0	0	0	0	1.47	0
12.5	17	8.3	8.3	1.35	- 8.2
50	16	28.3	36.7	1.11	- 24.5
100	27	51.7	53.3	0.92	- 37.4
200	72	66.7	76.7	0.77	- 47.6

LSD 0.17 t/ha

The competition from other weeds species in this trial at was much less marked than that of the oats, as they were dying off as a result of the drought. The oats however were managing to survive and gave a very large ground cover score of 77% by the end of July.

This resulted in a yield loss in the linseed of 48%. In fact the three highest % ground cover treatments all gave significant yield reductions in linseed.

Morley

This trial was drilled on April 14th and it was also noted at this location that oats were the only weed species that managed to establish well and maintain plant populations in the extremely dry season.

A wide range of oat populations were established 0 to 88/m^2, but the % ground cover scores only achieved a maximum of 18%.

Weed seeds/m^2	**weeds/m^2**	**% ground cover**	**Linseed yield (t/ha)**	**% yield reduction**
		(7/8/95)		
0	0	0	0.59	0
12.5	7.3	5.3	0.49	- 17
50	26.7	10.3	0.47	- 20.3
100	39	11	0.45	- 23.7
200	88.3	18.3	0.19	- 67.8

LSD 0.31 t/ha

All oat populations tended to reduce in linseed yield, but only the reduction from the highest oat population of 88 plants/m^2 with a ground cover of 18% was significant.

Rothamsted

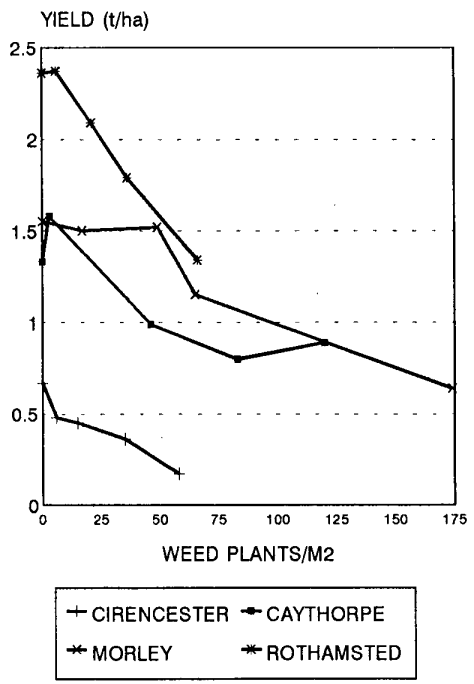
Although the actual yields of linseed at this location were rather low owing to the drought, the oat populations were the equal highest of the twelve trials over the three seasons. The four seeding rates of oats gave a wide range of plant populations from 11 to 174/m^2, with a maximum ground cover by mid July of 79%.

Weed seeds/m^2	**weeds/m^2**	**% ground cover**		**Linseed yield (t/ha)**	**% yield reduction**
		(6/9/95)	**(13/7/95)**		
0	0	0	0	1.11	0
12.5	10.7	17	19	0.91	- 18
50	30.7	25	47	0.59	- 46.8
100	86.1	48	61	0.29	- 73.9
200	174	60	79	0.18	- 83.8
				LSD 0.20 t/ha	

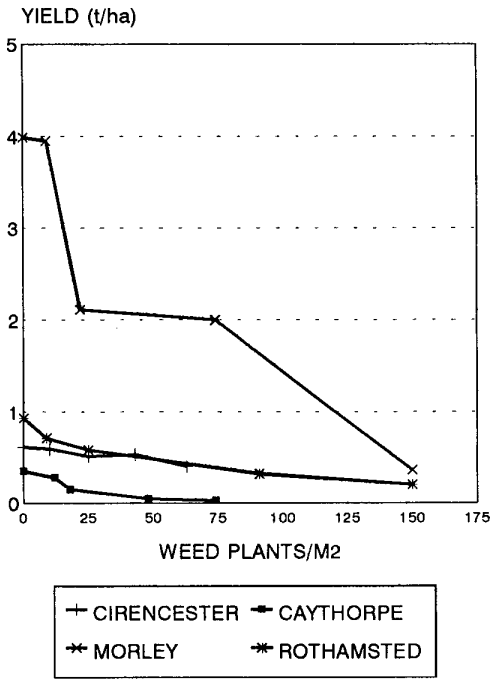
All oat populations caused linseed yield reduction, and the three highest populations gave significant responses.

THE INFLUENCE OF CULTIVATED OATS ON THE YIELD OF LINSEED

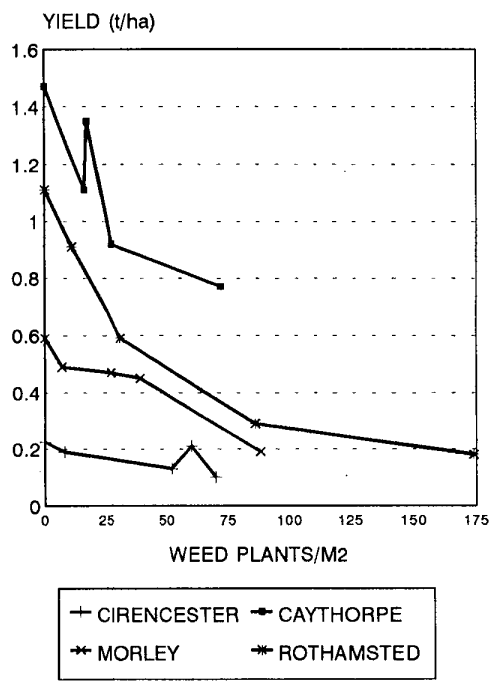
CULTIVATED OATS (AVENA sativa)
1993



CULTIVATED OATS (AVENA sativa)
1994



CULTIVATED OATS (AVENA sativa)
1995



SUMMARY

Although this weed was not associated with the higher % ground cover scores it was clearly the weed that influenced the yield of linseed more than any other of the candidate weeds.

The oats have a very erect habit, which although it produces a low ground cover score, does in fact conceal a significant amount of growth. The oat plants quickly established, grew taller than the linseed, and were clearly very competitive. A population of 58 plants/m^2 only produced a ground cover score of 20%, which was a 9 fold increase in plant numbers, over the 5 plants/m^2 but the increase in ground cover was only four fold.

In another trial, 174 plants/m^2 only gave a ground cover score of 18%. At the same location, as a comparison, 69 plants/m^2 of chickweed gave a ground cover of 52%.

Twenty six of the forty eight oat weed populations resulted in significant yield reductions in the linseed. The oat plant creates a thick plant structure which linseed appears to find very competitive. The oat was also quite tolerant of dry conditions, which were a marked feature of two of the three seasons of trials.

The first significant yield reduction in the linseed crop was recorded from an oat population of 9 plants/m^2. However it is very noticeable that this weed produced the majority of high yield reduction figures, the greatest being 91%.

These trials demonstrate that grass weeds such as oats are an important threat to the yields of linseed.

3.1.5 **Wild oats** (*Avena Fatua*)

Previous studies have indicated that cultivated oats can be used for trial purposes to mimic the effect of wild oats as a weed, as crop response patterns to those two weeds appear reasonably similar. On many farms it is unacceptable to introduce wild oats as an experimental tool, so the advantages of using cultivated oats are obvious.

Two trials were conducted one in 1993 and one in 1994 to verify that the cultivated oat data being generated in the project was applicable to the wild oat situation within a crop.

1993

Both cultivated oats and wild oats were sown on April 29th at either 50 or 200 seeds/m^2.

Wild oats				**Cultivated oats**			
Weed plants/m^2	% ground cover	Linseed yield (t/ha)	% yield reduction	Weed plants/m^2	% ground cover	Linseed yield (t/ha)	% yield reduction
10.5	5	2.30	- 2.5	20.9	6	2.09	- 11.4
38.1	9	2.04	- 13.6	65.5	18	1.34	- 43.2

(Linseed yield (weed free) 2.36t/ha - LSD 0.40t/ha)

Wild oats, because of their greater height can be slightly more competitive than cultivated oats. However in this trial, whilst the yield effects appear different, when checked using the regression analysis of the cultivated oats, it is possible to demonstrate that at equivalent plant densities wild oats and cultivated oats were approximately equal in their competitiveness.

1994

The trial was repeated the following year, and wild oats gave greater ground cover (plant for plant) than cultivated oats at the lower plant density.

Wild oats				Cultivated oats			
Weed plants/m^2	% ground cover	Linseed yield (t/ha)	% yield reduction	Weed plants/m^2	% ground cover	Linseed yield (t/ha)	% yield reduction
14.9	28.7	0.70	- 24.7	9	11.7	0.71	- 23.7
54.2	36.3	0.51	- 45.2	24.7	26.4	0.58	- 37.6

(Linseed yield (weed free) 0.93t/ha - LSD 0.20t/ha)

A comparison of the wild oat yield effects with those of the yield/density response curves for the cultivated oats indicated that the wild oats were marginally less competitive than the cultivated oats.

3.2 Visual and Photographic Assessment of Weed Populations

In order to achieve optimum weed management strategies the farmer needs to be able to balance costs of weed control with the potential yield loss from the untreated weeds. Traditionally, this has been done by relating weed plant numbers/m^2 to the yield. This is unsatisfactory as assessing weed numbers is time consuming and the correlation between weed numbers and crop yield is not very close. The presence of the linseed experiments at RES provided a resource that was used to evaluate alternative methods of assessing weed infestation levels to predict yield responses.

There are numerous ways of monitoring the quantity of weeds present in a crop at any particular time - leaf area, dry weight, % ground cover.

In 1993 at IACR Rothamsted the technique of % ground cover was evaluated using both visual and photographic methods of data collection.

Assessments were made on June 9th and the linseed crop at the time was 30 cms high.

Visual Assessments

Ground cover of linseed was estimated to be 45 - 48% in the absence of weeds. The presence of oats and the broad leaved weeds seemed not to reduce crop cover, but weed cover progressively increased with increasing density up to 18% for the cultivated oats, 23% for the fat hen but only 9% for the knotgrass.

Visual Assessment of % Ground Cover

(overall assessment of whole plots)

Weeds (plants/m^2)		**Mean % ground cover**				**% SW/**
		L*	**SW**	**O**	**S**	**(L+SW+O)**
Cultivated oats	0	48	0	<5	51	0.1
	5.8	48	<5	<5	50	3.8
	20.9	42	6	0	52	12.5
	35.9	47	14	<5	39	22.2
	65.5	47	18	0	35	27.7
Wild oat	10.5	48	<5	0	49	4.0
	38.1	50	9	<5	41	14.8
Fat-hen	0	45	0	0	55	0.0
	2.5	47	<5	<5	51	3.9
	9.4	43	9	<5	47	16.7
	17.7	47	10	0	43	17.5
	32.2	48	23	<5	8	31.5
Knot grass	0	45	0	<5	45	0.0
	2.2	45	<5	<5	52	4.1
	5.9	47	<5	<5	49	3.9
	10.8	49	8	0	42	14.0
	17.8	42	9	0	49	17.6

* L - % ground cover of linseed

SW - % ground cover of sown weed

0 - % ground cover of the other weeds

S - % ground cover of soil

Photographic Assessments

In general the visual and photographic assessments gave similar results. However there were some differences; in the photographic assessment linseed cover appeared to decline a little at the highest cultivated oat density from c55% to 36% and weed cover tended to be slightly greater than they had been with the visual assessments. The ground covers of the weeds at the highest oat and fat-hen densities were 26% and 20% respectively.With an exception (treatment D4 highest cultivated oat density) the two assessments of the proportion of sown weed in the total ground cover gave approximately similar results. Regression analysis showed the correlation (r^2) between the two assessments to be 0.85.

Photographic Assessment of % Ground Cover based on single 1m² quadrates

Weeds (plants/m²)			Mean % ground cover				% SW/
			L*	SW	O	S	(L+SW+O)
Cultivated oats	0	(DO)	55	0	<5	44	0
	5.8	(D1)	54	3	<5	42	5.1
	20.9	(D2)	43	6	<5	54	11.8
	35.9	(D3)	45	14	<5	40	22.9
	65.5	(D4)	36	26	<5	35	40.6
Wild oat	10.5	48 (D1)	5	<5	35	9.1	
	38.1	(D3)	47	12	<5	43	19.7
Fat-hen	0	(DO)	46	0	<5	52	0
	2.5	(D1)	41	2	<5	56	4.4
	9.4	(D2)	44	6	<5	48	11.5
	17.7	(D3)	44	9	<5	45	16.4
	32.2	(D4)	46	20	<	33	29.4
Knot grass	5.9	(D1)	48	<5	49	3.8	
	10.8	(D2)	47	7	<5	45	12.5
	17.8	(D3)	40	9	<5	49	17.6

* L - % ground cover of linseed
SW - % ground cover of sown weed
0 - % ground cover of the other weeds
S - % ground cover of soil

3.3 Weed Biomass Studies

These studies were conducted at IACR Rothamsted and involved the following weed species.

1993	1994	1995
Cultivated Oat	Cultivated Oat	Cultivated Oat
Wild Oat	Wild Oat	fat-hen
fat-hen	fat-hen	knotgrass
knotgrass	chickweed	

These samples were taken in order to obtain a better understanding of why crop yields were affected by the weeds. Such information is of value when attempting to use early assesments of weed growth to predict yield responses.

1993

Three destructive harvest samples were taken in this season.

June Sample

At this stage the linseed had few visible flower buds and was 35 - 40 cm high. Linseed plant numbers were estimated to be 368 plants/m^2, correlating well with the earlier plant counts. Linseed dry weight was 110 g/m^2 and weights were not detectably affected by the weed present. There were however, appreciable amounts of weed present on the plots with the higher weed densities. Despite hand weeding there was a small quantity of other weeds on the plots c 5g/m^2, mainly common field-speedwell.

Summary of sown weed data from 16 June Intermediate Harvest

(plant numbers/m^2 and dry weight g/m^2)

Density	Culti Oat		Wild Oat		fat-hen		knotgrass	
	nos	dry wgt	nos	dry wgt	nos	dry wgt	nos	dry wgt
D1	4.7	4.9	8.3	5.7	3.0	3.2	2.3	0.5
D2	22.3	12.9			15.0	16.4	4.7	2.9
D3	41.0	42.2	56.3	41.3	21.7	13.3	11.7	5.0
D4	91.3	7.3			59.3	42.4	26.0	9.5

SED weed numbers - 8.51; weed dry weights - 5.67

(these should be treated with caution as the data are not normally distributed)

July Sample

At the time of this assessment the linseed was nearing the end of its flowering period; young bols were present along with some flowers. Linseed plant numbers were not affected by the presence of weeds (data not shown) but there was some evidence that the highest densities of weeds were reducing crop weights. As expected, crop and weed weights especially the latter, had increased appreciably since the previous sample. 'Other' weeds had increased to 17g/m^2, still a relatively small proportion of the sown weeds and crop.

Summary of data collected from the 12 July Intermediate Harvest

			Weed densities			
Weed species	**DO**	**D1**	**D2**	**D3**	**D4**	**SED**
Linseed dry wgt (g/m^2)						
Cult oat	637.6	652.8	554.2	528.3	491.5	
fat-hen		670.6	584.9	548.4	559.9	
knotgrass		653.7	634.9	700.9	542.1	43.76
Wild oat	573.2		572.4			
Sown weed number/m^2						
Cult oat	0	5.7	27.0	31.7	96.3	
fat-hen	0	4.3	15.3	20.0	43.0	
knotgrass	0	1.7	6.7	21.3	24.3	6.86
Wild oat		14.0		37.3		
Sown weed dry wgt (g/m^2)						
Cult oat	0	25.4	67.3	146.7	362.9	
fat-hen	0	20.2	57.9	73.6	168.9	
knotgrass	0	3.9	10.7	31.9	38.1	31.75
Wild oat		30.3		128.0		

August Sample

The linseed was beginning to mature at the time of this intermediate harvest, bols were present but green.Clear reductions in linseed growth from the higher densities of oats and fat-hen were evident. Linseed and knotgrass had increased in weight since the July sample but apparently not the fat-hen and oats, which were now almost fully ripe. Despite the presence of a rabbit net the fat hen and oats were being grazed, which had an effect on the dry weights of the oat and to a lesser extent the fat-hen. The linseed and knotgrass were not affected. There was some suggestion that the highest oat and fat-hen densities had reduced the number of bols/stem.

Summary of data collected from the 5 August Intermediate harvest

Weed densities

Weed species	**DO**	**D1**	**D2**	**D3**	**D4**	**SED**
Linseed dry wgt (g/m^2)						
cult oat	727.8	750.6	662.5	588.3	431.8	
fat-hen		698.8	646.7	603.0	590.6	
knotgrass		705.6	737.5	660.9	706.0	49.85
wild oat		730.3		687.7		
Linseed bol numbers/plant						
cult oat	13.7	12.7	13.8	11.8	10.5	
fat-hen		12.4	12.9	12.1	11.5	
knotgrass		15.0	12.7	12.1	13.6	1.71
wild oat		12.3		10.4		
Sown weed number/m^2						
cult oat	0	5.7	16.7	34.0	59.7	
fat-hen		2.3	10.3	21.0	52.0	
knotgrass		2.7	10.0	16.3	31.7	5.70
wild oat		9.7		45.3		
Sown weed dry wgt (g/m^2)						
cult oat		24.7	28.5	142.4	261.1	
fat-hen		18.6	66.7	86.3	217.0	
knotgrass		6.6	19.2	68.8	82.3	36.60
wild oat		11.5		193.8		

1994

Two destructive samples were taken in this season.

June Sample

At this stage the linseed was rather variable in height (20 - 50 cm) and had no visible flower buds. Linseed dry weight was 72 g/m^2 and weights were not detectably affected by the weeds present. There were however, appreciable amounts of weed present on the plots with the higher densities of oats and adequate amounts on the chickweed plots. As had been noted earlier with this species large differences in original densities had a much less marked effect on dry weights. The fat-hen was not very vigorous. Except on the two thistle infested plots which had been abandoned, there were few other weeds on the experiment.

Summary of sown weed data from 20 June Intermediate Harvest

(plant numbers/m^2 and dry weight g/m^2)

Density	culti oat		wild oat		fat-hen		chickweed	
	nos	dry wgt	nos	dry wgt	nos	dry wgt	nos	dry wgt
D1	12.0	17.2	25.3	23.7	6.3	2.2	*	18.9
D2	28.7	54.1	56.7	54.8	39.3	9.2		21.8
D3	107	172			35.7	25.7		45.8
D4	187	243						

* It was not possible to count chickweed plant numbers at this assessment.

July Sample

At the time of this assessment the linseed was nearing the end of its flowering period; young capsules were present along with some flowers. However, because of the dry soil conditions it was only an average 43 cm high. Panicles were emerging from some of the oat plants. Linseed plant numbers were not affected by the presence of weeds but there was clear evidence that the two higher densities of cultivated oats were reducing crop weights. There were also indications of reductions in crop weight at the higher densities of chickweed and at the highest ones of wild oats and fat-hen. As expected, crop and weed weights, especially the latter, had increased appreciably since the previous sample. In general 'other' weeds were not a significant part of the biomass on the sampled plots.

Summary of data collected from the 13 July Intermediate Harvest

Weed densities

Weed species	DO	D1	D2	D3	D4	SED
Linseed dry wgt (g/m^2)						
cult oat	307.3	276.8	255.5	175.8	161.6	
fat-hen		343.1	367.3	333.2	254.3	
chickweed		310.7	297.2	226.5	285.1	42.1
wild oat		293.2	222.1	-	-	
Sown weed numbers/m^2						
cult oat	0	19.0	25.0	114	174	
fat-hen	0	5.7	37.0	29.7	43.3	
chickweed	-	-	-	-	-	
wild oat		10.0	73.0	-	-	
Sown weed dry wgt (g/m^2)						
cult oat	0	58.7	106.0	333.7	396.9	
fat-hen	0	7.9	33.6	38.3	49.8	
chickweed	0	24.9	145.3	106.5	118.4	30.6
wild oat	0	34.5	202.5	-	-	

1995

Two destructive harvest samples were taken in this season.

Intermediate destructive sample 28 June 95

Linseed growth was not particularly vigorous at the end of June, owing to the establishment difficulties resulting from the drought. Weed free linseed weighted about 88 g/m^2 . This weight was only significantly reduced by the two higher densities of oats (89 and 135 plants/m^2). These two densities of oats produced the greatest weight of weeds at this harvest. Potentially competitive amounts of weeds were also present on the higher density knotgrass plots and on the lower oat density ones. The vigour of the fat hen was very poor, as can be seen from the very low dry weight of only 13.1g/m^2.

Dry weights of linseed (g/m^2), and weed densities (plants/m^2) and dry weights (g/m^2) on 28 June

Weed Species	Weed density	Linseed dry wgt (g/m^2)	Weeds	
			Density	Dry wgt (g/m^2)
Weed free	0	88.4	0	0
Cultivated oats	1	96.7	8.0	41.5
	2	92.6	25.0	90.6
	3	**45.5**	88.7	241
	4	**38.6**	135	309
knotgrass	1	70.1	17.3	34.6
	2	88.9	54.3	61.5
	3	78.7	88.3	90.0
	4	76.2	199	131
fat-hen	4	62.3	37.0	13.1
SED weed free v weedy		14.9		
between weedy trts		18.2	27.8	35.6

NB Figures in bold are where linseed was significantly less vigorous than the weed free control

Intermediate destructive sample 2 August 95

The weeds and linseed increased in weight during the summer. In the absence of weeds the linseed weighed 283g/m^2 . All the oat and knotgrass infestations, even the lowest, significantly reduced linseed weights. The higher knotgrass densities appeared not to be greatly more damaging than the lower ones, which is confirmed by the relatively small differences in weight of the weed between the highest and lowest densities. In contrast, the higher oat densities were much more competitive than the lower ones. The fat-hen remained uncompetitive as the plants were small and weak and never exceeded 80 cm in height.

Dry weights of linseed (g/m^2), weed densities ($plants/m^2$) and dry weights (g/m^2) on 2 August

Weed Species	Weed density	Linseed dry wgt (g/m^2)	Weeds	
			Density	Dry wgt (g/m^2)
Weed free	0	283	0	0
Cultivated oats	1	216	14.0	123
	2	161	29.3	255
	3	90.0	73.0	459
	4	31.2	124	309
knotgrass	1	208	20.3	189
	2	213	37.7	196
	3	162	90.3	334
	4	135	157	310
fat-hen	4	237	20.7	29.7
SED weed free v weedy		23.2		
between weedy trts		28.4	12.2	48.1

DISCUSSION

The 43 trials that are reported in the previous section

cultivated oat	12
fat-hen	12
chickweed	12
knotgrass	7

all produced a range of different weed plant populations in crops of linseed and have enabled both the competitive effect of individual weed species to be evaluated, and also comparisons between the different weed species.

It is important however to establish if weed competition in linseed is an economic threat to the crop. This section will therefore review the 43 trials and relate linseed yield responses to the costs of weed control in the crop. The discussion will address three areas

- a comparison of the competitiveness of the four weed species
- the numbers of individual weeds that must be present in the linseed crop to cause yield loss
- the economics of weed control in the linseed crop, in relation to the evidence produced in these trials.

The comparative competitiveness of the four weeds chickweed, fat-hen, knotgrass and oats

The four species were chosen because they all have slightly different growth habits, which theoretically should influence the linseed crop in different ways

Oats

a tall growing aggressive weed, that has a high biomass potential, and can shade the linseed crop.

Chickweed

has the totally opposite growth habit to oats, being very prostrate, and forming 'plates' on the ground so that the plants soon begin to compete with each other.

Knotgrass

is a weed which can grow fairly tall, if given the support of a thick crop, but has not a high biomass.

Fat-hen

produces less ground cover usually than chickweed, and is an erect weed, but not as tall as oats. It has the potential to produce very large and vigorous plants.

All four weeds,by their presence in linseed crops have the ability to influence the growth and seed yield of the crop. Competition may occur early in the life of the crop, for example chickweed plants developing rapidly, covering a large ground area with their prostrate habit and interfering with the establishment and early growth of the linseed. In contrast oats, whilst not occupying a large ground area, will rapidly grow taller than the linseed crop, and tillering will create a large biomass which shades the linseed as well as competing for nutrients and water from the soil.

The comprehensive trials information can be interpreted to answer questions such as

- what weed population could be tolerated by the linseed crop without any significant yield reduction being recorded?

- what weed population always gave a significant yield reduction in the linseed crop?

These questions have been addressed in the following tables, for each of the four weed species. The number of weed plant/m^2 has been tabulated against the subsequent yield effect (significant or non significant reduction in yield of the linseed crop).

A number of trials have been omitted from this overall analysis.Their exclusion has been based upon biological decisions of inconsistency of response or inadequate weed populations. The trials that have been omitted are

1993	ARC	Wimborne - chickweed
1994	ARC	Wimborne - fat-hen
	Morley	fat hen
1995	ARC	Caythorpe - knotgrass
	Morley	chickweed
	Rothamsted	fat-hen

This is not a reflection of poor trial technique, but an acknowledgement that weed threshold trials present special difficulties in producing useful ranges of targeted weed populations.

The influence of knotgrass plants/m^2 and % ground cover on the yield of linseed

knotgrass plants/m^2	Yield reductions (linseed)	% knotgrass cover	Yield reduction (Linseed)
1	NS, NS	2	NS
2	NS, NS		
3.5	NS		
3	NS	5	NS, NS, NS
4	NS	7	NS, NS
5	NS	8	NS, NS
6	NS	9	significant
7	NS	10	NS, NS
9	NS	20	significant
10	NS, NS, NS, NS	39	significant
11	NS	43	signficant
14	NS	63	significant
17	NS		
18	significant		
20	NS, significant		
47	significant		
74	significant		
80	NS		
145	significant		

The influence of chickweed plants/m² and % ground cover on the yield of Linseed

chickweed plants/m²	Yield reduction Linseed	% chickweed ground cover	Yield reduction Linseed
6	NS	5	significant
		6	NS
11	NS	8	NS
13	NS	10	significant
		14	NS
18	significant	17	NS
22	significant	19	NS, NS
26	NS,	20	significant, NS
		27	NS
34	NS	30	NS
36	NS	43	NS
37	NS	45	NS
38	NS	48	NS
40	NS	52	significant
		53	significant
45	NS		
46	NS, NS	63	significant
		65	NS, NS
52	NS	67	significant
57	NS, NS	70	NS
64	NS, NS	80	NS
65	NS	82	NS
69	significant	88	significant
70	significant		
78	NS		
83	NS	95	NS, NS
87	significant		
103	NS		
109	NS		
128	NS		
142	NS		
215	NS		
230	NS		
232	significant, NS		
241	significant		
252	significant		
261	significant		
395	significant		
397	NS		
528	significant		
529	NS		

The influence of fat-hen plants/m^2 and % ground cover on the yield of linseed

fat-hen Plants/m^2	Yield Reduction Linseed	% fat-hen Ground Cover	Yield Reduction Linseed
		1	NS, NS, NS
2	NS,NS	3	NS
5	NS	4	NS, NS,
		5	Significant, NS
9	NS	7	NS
10	NS, NS,NS	8	NS
11	NS	9	NS, Significant
17	NS	10	Significant, NS, NS, NS
18	Significant	11	NS
21	NS	12	NS
23	Significant	13	Significant, NS, NS
24	NS, NS	15	NS
25	NS	17	NS, NS
26	NS	19	NS
30	NS	23	Significant
31	NS	25	NS
32	Significant	30	NS
40	NS, NS, NS	32	NS
45	NS	35	NS, Significant
52	NS	37	NS
55	NS, Significant	50	NS
59	NS	62	NS
61	NS		
69	NS		
70	NS		
73	NS		
80	NS		
81	NS		
83	NS		
91	NS		
100	NS		
118	NS		
124	NS		
130	NS		
150	NS		

The influence of oat plants/m^2 and % ground cover on the yield of linseed

Oat Plants/m^2	Yield Reduction Linseed	% Oat Ground Cover	Yield Reduction Linseed
3	NS	1	NS
6	NS, NS	3	NS
7	NS	5	NS, NS, NS, NS
9	NS, Significant	6	NS, NS
10	NS	7	NS
11	NS	8	NS
12	NS	9	NS, Significant
15	NS	10	NS
16	Significant	11	NS, NS
17	NS, NS	12	Significant, Significant
18	Significant	13	NS, Significant
21	NS	14	Significant
22	Significant	15	Significant
25	NS, Significant	18	Significant, Significant, Significant
26	NS	19	NS
27	Significant	20	Significant
31	Significant	21	NS
35	Significant	25	Significant
36	Significant	26	Significant, Significant
39	NS	28	Significant
43	NS	40	Significant
46	Significant	47	Significant
48	Significant	52	Significant
49	NS	59	Significant, Significant
58	Significant	60	Significant
63	Significant	61	Significant
66	NS, Significant	67	Significant
72	Significant	79	Significant
74	Significant, Significant		
83	Significant		
86	Significant		
88	Significant		
91	Significant		
120	Significant		
150	Significant		
174	Significant, Significant		

No clear picture developed for any of the four weed species as the range of yield responses sometimes produced significant or non significant yield changes from the same weed population, in different locations or different seasons. However, some patterns do emerge from the data.

The influence of weed populations (plants/m^2) on the yield of linseed

Weed	Weed population that gave no significant yield reduction	Range of weed population that gave both significant and non significant yield responses	Weed population that consistently produced yield reduction
oat	8 or less	9 - 66	> 66
chickweed	17 or less	18 - 529	-
knotgrass	11 or less	18 - 80	> 145
fat-hen	17 or less	18 - 150	-

The oats appear from this analysis to be the most aggressive weed, with a significant yield reduction in linseed resulting from only 8 oat plants/m^2. This compares with fat-hen and the other 2 weeds that required 18 plants/m^2 before a significant reduction in linseed yield was recorded.

This is also supported by the analysis of the number of weed plants/m^2 required to always produce a significant yield reduction. For oats the number is 66 and knotgrass 145, but for chickweed and fat-hen it was not possible to demonstrate a weed population level that always resulted in a significant reduction in linseed yield.

This would suggest therefore that oats and knotgrass are the most competitive of the four weed species when present in linseed crops, with oats the most important weed. Chickweed and fat-hen weed populations do create significant reductions in linseed yield but they are not as consistently achieved as with oats and knotgrass.

The competitive nature of oat is well documented from other weed studies. It appears to be able to compete aggressively with a wide range of crop species, even with cereals that have very similar growth habits to oats.

Whilst oats and linseed are both erect in their growth habits, oats create a larger biomass than linseed, and are also more vigorous earlier in the season. The two species also have rooting systems that differ, oats having a larger rooting system than linseed.

The importance of knotgrass infestation on the yield of linseed is in some ways more interesting, as it was less expected. Knotgrass is an annual weed which is described as prostrate and spreading. In the absence of cultivation it can spread rapidly, but it is generally claimed as only moderately competitive to crop species. In this series of trials it actually proved to be the most difficult weed species to establish in the trial plots, but relatively low plant numbers, and low ground cover scores were associated with significant linseed yield reduction.

Chickweed is one of the more obvious weed problems, particularly in an open crop like linseed, where it can very rapidly form 'plates' that cover large soil areas. However chickweed appears to reach the stage where it competes with itself (other chickweed plants) rather than the more erect crop, and its yield effect on the linseed crop was often less then the visual observation would suggest.

The intraspecific weed competition may in some circumstances actually make lower weed populations more competitive than higher weed popultions. It is possible to speculate that a partially effective herbicide application, that may reduce but not eliminate a chickweed population, may ultimately result in fewer, larger plants competing with linseed plants.

The influence of chickweed on linseed yield may be underestimated in this trial series. It was noticeable that chickweed did suffer from the dry conditions encountered in all three seasons of trials. This delayed the emergence of the chickweed reduced its vigour, and therefore reduced its early competitiveness with linseed.

Fat-hen can be a very damaging weed in some crops like sugarbeet, but in linseed its effect on the crop is much less marked. It was not possible to determine an infestation level that would always result in a significant yield loss in linseed. Like chickweed it became less competitive as the season progressed, probably due to its inability to withstand dry conditions in comparison to other species, so some high initial plant populations did not result in major linseed yield loss.

Fat-hen reduces sugar beet yield by decreasing interception of radiation. This is likely to be a lesser factor in linseed.

The number of weed plants necessary to cause yield reduction in linseed.

The previous section has indicated that it is possible to determine a plant population of two weed species that has always been associated with significant yield loss in linseed

- oats 66 plants/m^2
- knotgrass 145 plants/m^2

However, for the two other weed species it can be demonstrated that populations of 150/m^2 (fat-hen) and 529/m^2 (chickweed) have not significantly reduced the yield of linseed.

A useful method of comparing the competitiveness of weed species is to adopt the concept of thresholds. Popularly this is interpreted as 'the number of weed plants/m^2 required to reduce the yield of the crop by 5%'.

Regression analysis techniques allow this data to be derived from the results of the 34 trials that have been used in the full analysis.

The table below indicates the average number of weeds /m^2 that is associated with a yield reduction of 5% in the linseed crop, plus the range of '5% threshold values' that were recorded in the trials on the individual weed species.

	The number of weeds/m^2 required to reduce the yield of linseed by 5%	**The range of 5% threshold values (weeds/m^2)**
knotgrass (4)	4.6	2.1 to 7.1
oats (12)	7.3	2.3 to 14.9
fat-hen (8)	15.8	12.8 to 19.6
chickweed (10)	59.8	10.6 to 112.7

( ) number of trials.

This method of analysis again clearly places knotgrass and oats as more damaging weeds in a linseed crop than fat hen or chickweed. It appears that knotgrass is marginally more damaging than oats, but the number of trials that were successfully completed is different, and this must be considered when interpreting the result.

In the previous analysis technique, chickweed appeared to be potentially the least competitive of the four weed species, the linseed crop being able to tolerate over 500 plants/m^2.Using the threshold value approach, chickweed also appears to be the least competitive weed, requiring an average of 60 plants/m^2 to record a 5% yield loss in linseed.

The economics of weed control in linseed

The initial aim of weed control in any crop is to eliminate the competition by the weed which if left unchecked will reduce the yield of the crop. However, total removal may not be necessary as very low levels of weeds can be tolerated in some crops without causing yield loss.

In addition to avoiding crop yield loss, the removal of weeds from crops can ease harvesting and storage of seed from the crop, and reduce the amount of seed passing into the following season's crop. All of these benefits of weed control have financial implications, but it is only possible to accurately describe one of these benefits in financial terms - the avoidance of yield loss in the crop. This value can be compared with the cost of weed control measures, and the cost/benefit calculated.

Weed control in linseed using herbicides can currently cost between £16 and £47 per hectare if full rates of products approved for specific weed situations are used. The equivalent yield response (in terms of t/ha of linseed) can be calculated in comparison with these herbicide costs.

The cost/ha in linseed yield equivalent of a range of linseed herbicides

Active ingredient	Weeds controlled	Cost/ha	Yield response (t/ha) needed to cover Cost **
Metsulfuron-methyl	Ch FH KG	£18	0.15
Bentazone	Ch (FH)	£54	0.45
Clopyralid + bromoxynil	FH	£16	0.13
Bentazone + clopyralid + bromoxynil	Ch FH (KG)	£47 *	0.39
Trifluralin	Ch FH KG	£24	0.20
Cycloxydim	WO	£20	0.16
Diclofop-methyl	WO	£24	0.20
Propaquizafop	WO	£37	0.31
Sethoxydim	WO	£29	0.24
Tri-allate	WO	£30	0.25

* assumes lower rates of application when mixed

** assumes linseed at £120/tonne

( ) controlled at early growth stages only

Using Ally (metsulfuron-methyl), a popular linseed herbicide for broad leaved weed control, as a guide, at £18/ha this currently required a linseed yield of 0.15 t/ha to cover the cost of the herbicide.

Linseed can range in yields very considerably from less than 1t/ha to over 3.5t/ha. This value of 0.15t/ha must therefore be reinterpreted as a % yield response, dependent upon the yield potential of the crop - the higher the yield potential the lower % response is represented by 0.15 t/ha.

%Yield Response Represented by 0.15t/ha in Linseed Crops of Different Yield Potential

Linseed Yield t/ha	% Yield Response Represented by 0.15t/ha
1	15
1.5	10
2	7.5
2.5	6.0
3	5.0
3.5	4.3

A 3t/ha crop of linseed (24 cwt/acre) therefore requires a 5% yield response (0.15t/ha) to cover the cost of a popular herbicide to control broad leaved weeds.

Using the data generated from the threshold value analysis this would suggest that the levels of weed infestation of the broad leaved weeds under investigation, that are required to be present just to cover the cost of the chemical are

knotgrass	$4.6/m^2$
fat-hen	$15.8/m^2$
chickweed	$39.8/m^2$

Whilst the other disadvantage of weed infestation of a crop (harvesting and drying difficulties, increase in the weed seed bank in the soil if left uncontrolled) cannot be addressed in this calculation, it is clear that the differences in competitiveness between those three broad leaved weed species are considerable.

One knotgrass plant is as competitive in a linseed crop as 3.4 fat-hen plants or 8.7 chickweed plants.

The range of costs/ha (at full rates of application) are £20 - £37/ha. for the control of grass

weeds in linseed, giving a typical yield response of 0.25 t/ha required to cover the cost of the product.

Reinterpreting this 0.25t/ha as a % yield response gives the following value.

% yield represented by 0.25t/ha in linseed crop of different yield potential

Linseed field t/ha	**% yield response represented by 0.25t/ha**
1.0	25
1.5	16.7
2.0	12.5
2.5	10
3.0	8.3
3.5	7.1

A 3t/ha crop of linseed therefore requires an 8.3% (0.25t/ha) yield response to cover the cost of a typical herbicide to control grass weeds.

From the threshold analysis data, the level of oat infestation that is required to produce a yield response through control, to cover the cost of the herbicide is 14.1 plants/m^2.

This analysis would therefore rank knotgrass as the most damaging weed to linseed, with oats and fat-hen almost equal, but less damaging than knotgrass. Chickweed would appear to be the least damaging weed species.

APPENDIX

Details of the dates of activities at the different locations over the three seasons of trials.

	Wimborne ARC (Dorset)	Cirencester ARC (Gloucs)	Caythorpe ARC (Lincs)	Morley	IACR (Rothamsted)
1993 Drilled	20 April	20 April	20 April	31 March 2 April	29 April
Weed score	29 July	7 May	9th June	24 May 3 August	2 June
% Ground Cover	28 May	14 May	n/a	30 June	9 June
Harvested	21 October	18 September	18 October	2 September	12-13 September
1994 Drilled	5 April	21 April	19 April	19 April	26 April
Weed score	19 May	5 July	3 May	1 July 26 July	25 May 9 June
% ground cover	n/a	5 July	13 June - 25 June	26 July 3 August	14 June
Harvested	9 September	23 September	5 October	26 August	2 September
1995 Drilled	(Andover) 11 April	15 May	12 April	14 April	20 April
Weed score	12 June	26 June	11 May	27 June	25 May 9 - 14 June
% ground cover	n/a	19 June	29 June 29 July	7 August	6 June 13 June
Harvested	31 August	31 August	17 August	22 September	22 August