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WINTER LINSEED WEED CONTROL: STRATEGIES FOR GRASS AND BROAD-LEAVED WEED CONTROL

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WINTER LINSEED WEED CONTROL – STRATEGIES FOR GRASS AND BROAD-LEAVED WEED CONTROL

by

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ABSTRACT

The aim of the study, through four related field studies, was to investigate the efficacy and crop safety of herbicide strategies for winter linseed. The study used a range of sites (from North Yorkshire to Hampshire), soil types (clay loams to heavy clay soils), weed burdens and weed species, to study the effects on efficacy of weed control and linseed yields. The aims of the four studies were to evaluate a) the effect of grass-weed competition and timing of weed removal on winter linseed yields, b) the effect of pre-emergence herbicide on sensitivity of grass-weeds to post-emergence graminicide application, c) the effect of pre-emergence herbicides on sensitivity of broad-leaved weeds to post-emergence herbicide application and d) the effect of incorporation of Treflan (480 g/l trifluralin) on weed control and overwinter survival of winter linseed.

The critical period for grass-weed removal was found to be linked to the balance between crop and weed biomass. Yield potential was reduced, compared to herbicide-treated crops, where grass-weed biomass was allowed to develop to a level which equalled that of the linseed crop before removal. In practical terms this meant that in most cases, removal of grass-weeds could be delayed until March without compromising the yield potential of the crop. Treflan did provide a useful reduction in autumn grass-weed populations. Where effects were significant, grass weed populations were reduced by 26 to 74%. However, effects did not persist until spring. Relatively high doses of Laser (200 g/l cycloxydim) were required to control competitive brome (0.75 to 1.0 l/ha) and volunteer wheat (0.75+ l/ha) where herbicide application was delayed until tillering had started. There were few significant yield responses to grass-weed control, except at very high grass-weed populations (>75 black-grass plants/m^2). The only occasion where Treflan appeared to complement Laser application was in suppression of black-grass heads.

In around 60% of cases, Treflan reduced the total broad-leaved weed flora present prior to spring herbicide application, with the greatest effects where sensitive weed species dominated the weed flora. Where herbicides had a good broad spectrum of weed control, there were interactions between autumn and spring-applied products to give additional benefits to use individually. A yield response of only 0.2 t/ha was required to cover the cost of application of a full dose of Ally (20% w/w metsulfuron-methyl), and 0.3 t/ha the costs of a sequence of Treflan and Ally at full label dose rates. In contrast, Basagran (480 g/l bentazone) required a yield response of at least 0.5 t/ha to cover costs and it was difficult to achieve such yield responses in winter linseed crops. Application of Ally in spring caused visible stunting and damage to winter linseed crops on a number of occasions. However effects were quickly out-grown by the start of flowering and yields were unaffected.

Where Treflan was incorporated into soil (the traditional method of application), winter linseed plant populations were always reduced and significant reductions were recorded three out of six site years. Where Treflan was applied as a surface treatment, plant populations were similar to, or higher than, those in untreated plots. However, weed control by Treflan was not significantly compromised by post-drilling application.

SUMMARY REPORT

Introduction

Linseed has an open canopy and weed control is considered to be the most important input in maintaining yield potential. However, little work has been done to date in the in the UK to evaluate the effects of weed control in the crop. The number of fully approved herbicides for use on linseed is limited and many herbicides have been used under specific off-label arrangements, or under approvals for minor crop use. This approach on both the spring and winter crop has demonstrated that there can be phytotoxic effects from certain herbicides, even though some of the effects may be only transitory. In the case of winter linseed, there is an increased risk of phyotoxicity when herbicides are applied in the autumn or early spring as the crop may already be stressed from frost damage and overwinter kill.

At the start of the project in 1997, the only active approved for pre-emergence use on spring linseed was trifluralin. At the time, it was noted that this herbicide could have a detrimental effect on winter linseed when incorporated prior to drilling. It is necessary to evaluate the role of autumn herbicides for weed control because of the potential difficulties in controlling weeds with the limited range of spring-applied herbicides then available. Effective use of cheap autumn-applied herbicides could also reduce the need for herbicide in the spring by reducing the total weed burden present, by suppressing weed growth or by sensitising weeds to subsequent herbicide application.

The aim of this study, through four related field studies, was to investigate the efficacy and crop safety of herbicide strategies in winter linseed. The specific aims of these studies were to evaluate:

1) The effect of grass-weed competition and timing of weed removal on winter linseed yields.

2) The effect of pre-emergence herbicide on sensitivity of grass-weeds and volunteer cereals to post-emergence graminicide application.

3) The effect of pre-emergence herbicides on sensitivity of broad-leaved weeds to post-emergence herbicide application.

4) The effect of incorporation of trifluralin on weed control and overwinter survival of winter linseed, and the efficacy of post-drilling applications of trifluralin.

1) The effect of grass-weed competition and timing of weed removal on winter linseed yields.

Method

This study ran for 2 years (harvest years 1998 and 1999) at ADAS Boxworth on a clay soil of the Hanslope series. The site was sown with wheat volunteers (prior to linseed drilling), at a range of densities (target of 10, 30 and 90 wheat plants/m^2), in an attempt to increase the natural level of grass-weed competition. Falcon (a.i. 100 g/l propaquizafop), was applied at the following timings:

1) No Falcon applied
2) 1.0 l/ha Falcon applied end October/early November
3) 1.0 l/ha Falcon applied end November/early December
4) 1.0 l/ha Falcon applied end February/early March
5) 1.0 l/ha Falcon applied end March/early April

Treatments were arranged in a fully-randomised block design with 3 replicates of each graminicide x weed density treatment combination, and 6 replicates of each untreated control treatment (2 per block per volunteer density treatment). Crop populations, weed populations and weed biomass were recorded prior to each graminicide application and when the sown wheat volunteers reached grain-fill stage, in the 'untreated' control plots. Treatments were examined for any sign of herbicide related damage during the season. Yield was recorded using plot combines.

Key results and discussion

Black-grass dominated the grass-weed flora in both seasons of study (>100 blackgrass plants/m^2). At harvest in 1998, leaving weeds uncontrolled significantly reduced yields, and yield increased (though not significantly) the later herbicides were applied, up until the end of March, resulting in yield responses to weed and lodging control ranging from 0.29 to 0.39 t/ha. In 1999, there was a yield response to all herbicide applications. These responses were statistically significant, with the exception of the final herbicide application in April where the response was limited to 0.34 t/ha. In all other cases, the yield response to weed control ranged from 0.58 to 0.74 t/ha.

The critical period for weed removal was linked to the balance between crop and weed biomass. Yield potential was reduced where grass-weed biomass was allowed to develop to a level which equalled that of the linseed crop before removal. However, this balance will be influenced by any factors affecting crop vigour. In 1998/99, in early spring, the crop did not appear to be developing as well as in previous seasons which may have increased sensitivity to weed competition. Where crop growth outpaced weed growth then weed control could be delayed until March without penalty. This would minimise potential risks associated with herbicide application when there is a significant risks of frost damage to the crop which could exacerbate sensitivity to herbicide, though ideally, grass-weed competition should be removed as soon as possible in the season. There was no evidence of any risk to the crop from graminicide application in the autumn or winter period.

2) The effect of pre-emergence herbicide on sensitivity of grass-weeds and volunteer cereals to post-emergence graminicide application.

Method

This experiment was located at ADAS Boxworth and ADAS Bridgets (silt clay loam, overlying chalk). Sites were selected on the basis of presence of natural grass-weed seedbanks, to which grass-weed seed was broadcast at Bridgets to boost populations. The study was run for 3 years at Boxworth and 2 years at Bridgets and evaluated the interaction of Treflan (480 g/l (46% w/w) trifluralin), and Laser (200 g/l cycloxydim) treatments on grass-weed populations. Post-drilling Treflan treatments were applied as soon as possible after drilling of linseed plots, as a surface application without incorporation. Post-emergence Laser treatments were applied when the black-grass plants had at least 2 leaves unfolded. Rates of herbicide applied were as shown below;

Treatment	Post-drilling herbicide	Post-emergence herbicide
1.	Nil	Nil
2.	Nil	1.0 l/ha Laser
3.	Nil	0.75 l/ha Laser
4.	Nil	0.5 l/ha Laser
5.	Nil	0.25 l/ha Laser
6.	1.75 l/ha Treflan	Nil
7.	1.75 l/ha Treflan	1.0 l/ha Laser
8.	1.75 l/ha Treflan	0.75 l/ha Laser
9.	1.75 l/ha Treflan	0.5 l/ha Laser
10.	1.75 l/ha Treflan	0.25 l/ha Laser

Treatments were fully randomised 3 replicates of each treatment, except for the untreated controls where there were 3 replicates per block.

Linseed and weed populations were assessed in November/December, prior to, or just after, graminicide application and again in February/March to assess any overwinter effects. Weed populations were re-assessed in late March early April. At Bridgets, black-grass heads were counted in June or July. During the season the linseed crop was examined for occurrence of any damage due to herbicide application. Yields were measured using plot combines.

Key results and discussion

Laser application had no effect on linseed plant populations, and no symptoms of herbicide damage were observed (i.e. chlorosis, scorch or stunting etc.) following Laser application. No detrimental effects on crop growth and development were observed later in the season. Post-drilling applications of Treflan had little consequential effect on linseed plant stands.

Application of Treflan significantly reduced the autumn grass-weed burden in three out of the five cases studied (Boxworth in autumn 1997 and 1999, and Bridgets in autumn 1999). Effects were observed at a range of weed densities, but effects were not consistent across the range of weed densities encountered. Effects of Treflan were also inconsistent within individual weed species. Significant reductions in total grass-weed burden were mainly due to effects of Treflan on black-grass and barren brome components of the weed flora. In two out of four cases encountered, Treflan application significantly reduced black-grass populations by between 45% (Boxworth, autumn ’97) and 73% (Bridgets, autumn ’99). In only one out of three cases encountered did Treflan significantly reduce barren brome populations (by 45% at Boxworth in autumn '99).

Application of Treflan in the majority of cases studied, had little impact on spring grass-weed populations as a whole, or for individual grass-weed species. At Bridgets, although there was no significant effect of Treflan on black-grass plant populations, there were significant effects observed on later black-grass head populations. In these cases, application of Treflan reduced black-grass head populations and exhibited an interaction with Laser application to increase the efficacy of control (Fig 1). Application of 1.75 l/ha of Treflan allowed dose rates as low as 0.5 l/ha of Laser to prevent black grass head production. The greater effect of Treflan at the Bridgets site may be due to the fact that much of the backgrass probably arose from seed broadcast to boost grass-weed populations. Broadcast and shallow incorporated seed may have emerged in a single flush at the time of treatment or may not have been well buried in soil, resulting in Treflan uptake by germinating and emerging plants.

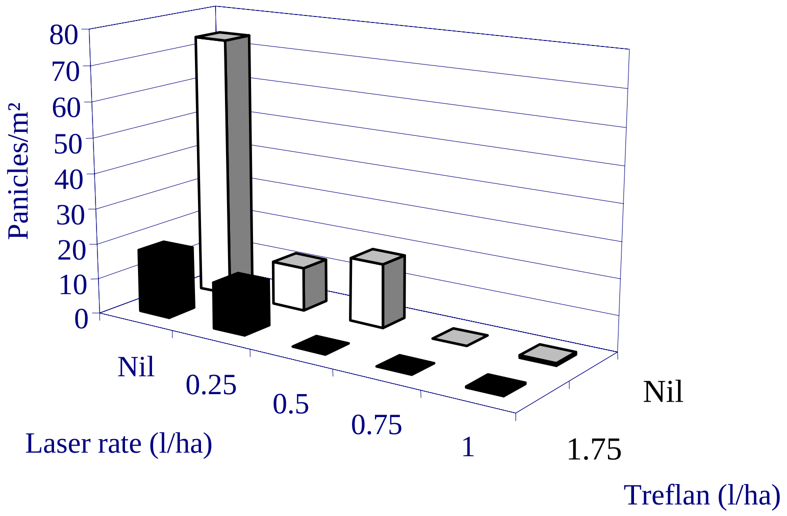


Fig 1. An example of the effect of post-drilling Treflan application and post-emergence Laser application on black-grass head populations – Bridgets, June 1999

Laser was very effective in reducing populations of all grass-weeds present, and efficacy was closely related to dose rates. Linseed is not a competitive crop to grass-weeds and relatively high dose rates of 0.5 to 1.0 l/ha of Laser were required to effectively control barren brome and volunteer wheat populations. Black-grass was effectively controlled by dose rates of 0.5 – 0.75 l/ha, even at very high populations (Table 1).

Table 1. Dose of Laser required to give 50, 75 and 90% or more control of grass-weeds in winter linseed (based on data in tables 3.6, 3.8, 3.10, 3.12 and 3.14).

Grass Species	Population In untreated control (plants/m²)	Site & year	Dose of Laser required (l/ha)		
			50% Control	75% Control	90%+ control
Black-grass	(643)	Boxworth 1999	<0.25	0.25	0.5 +
	(77)	Boxworth 1998	<0.25	0.25	0.5+
	(17)	Bridgets 2000	<0.25	0.5	0.75+
Barren Brome	(176)	Boxworth 1999	0.5	0.75	1.0
	(9)	Boxworth 1998	0.5	0.5	0.75+
Wheat	(17)	Boxworth 2000	0.25	0.75	0.75+
	(10)	Boxworth 1999	0.5	0.75	0.75+

3) The effect of pre-emergence herbicides on sensitivity of broad-leaved weeds to post-emergence herbicide application.

The experiment was sited at ADAS Bridgets and ADAS High Mowthorpe (shallow silty clay loam overlying chalk) with naturally-occurring high densities of broad-leaved weeds and a diversity of weed species. The experiment ran from harvest years 1998 to 2000.

The experiment was run as three separate self-contained studies for three years. Herbicides currently approved for use in spring linseed crops were studied including Ally (20% w/w mestsulfuron methyl), Basagran (480 g/l bentazone) and Vindex (240 g/l bromoxynil plus 50 g/l clopyralid). Within each individual study, Treflan was either not applied at all, or applied at 0.875 and 1.75 l/ha. Within each of these Treflan treatments, Ally, Basagran or Basagran plus Vindex were applied at a range of dose rates (nil, 33%, 66% and 100% of full label rate for Ally, and Nil, 25, 50 and 100% of full label rate for Basagran, and Vindex plus Basagran treatments). Treatments were grouped by spring herbicide treatment into three separate studies.

Treflan treatments were applied on the day of drilling as a post-drilling surface treatment. The post-emergence treatments were applied as soon as possible in spring when the crop was at least 5cm tall. A fully randomised field plot design was used for each study, with 3 replicates of each treatment.

Linseed populations were assessed prior to any follow up herbicide application and again in April. At fixed points, weed populations were assessed in the autumn after Treflan treatment, at the time of spring herbicide application and 30 days after spring herbicide application. During the season crops were examined for signs of herbicide damage.

Key results and discussion

In 27% of cases studied, Treflan gave a significant reduction in the total weed population present in the autumn. At the spring assessment, this increased to 61% of cases studied. The scale of the reductions achieved by the 1.75 l/ha rate ranged from 27 to 71% in the autumn and 27 to 84% in the spring, depending on the balance of weed species present. Where Treflan had a significant effects on weed populations, the weed flora was dominated by sensitive weeds, such as field speedwell, annual meadow grass, poppy, chickweed, field speedwell or forget-me-not.

There are weaknesses in the spectrum of control provided by individual herbicides approved for use in linseed. Within the cases studied, there were a number of instances where interactions were observed between autumn and spring-applied herbicides, where either a significant proportion of the weed flora was sensitive to the herbicides applied in both the autumn or spring, or, the spring-applied herbicide covered a weakness in the control provided by autumn application of Treflan. In both cases, the effectiveness of the herbicide was a key factor and interactions were more prevalent where Ally was used in the sequence rather than Basagran or Basagran plus Vindex. An example of the interaction between Treflan and Ally on the control of a field speedwell dominated flora is presented in Table 2.

Table 2. Percent reduction in total weed flora (compared to untreated control) achieved by interaction of autumn applied Treflan and spring-applied Ally herbicide sequences (Bridgets 1998).

Treflan rate	Ally rate			
	None	10 g/ha	20 g/ha	30 g/ha
None	-	+24%	0%	-15%
0.875 l/ha	-13%	-37%	-19%	-36%
1.75 l/ha	-11%	-32%	-60%	-53%

In three out of six cases there were good examples of weed control interactions between Treflan and Ally. There were no clear interactions of Treflan with Basagran alone or Vindex plus Basagran at the Bridgets site, due to very high populations of field pansy in the weed flora, which were unaffected by treatment. At High Mowthorpe, in weed situations dominated by poppy and oilseed rape (1998) or field speedwell (2000), there were additional benefits gained from using sequences of Treflan followed by Basagran or Vindex plus

Basagran, which gave good control from rates as low as half the recommended label dose of the spring-applied herbicides, though levels of control were inconsistent across dose rates.

In 1998 at High Mowthorpe, Ally caused severe stunting and a reduction in crop vigour, observed after treatment, when the crop was approximately 10-15cm tall. Observed effects were clearly related to dose rate applied. In 1999, on both sites, a widespread crop yellowing was observed during stem extension of the crop, though in this case crop vigour was unaffected. Both crop yellowing and the extent of the damage were related to dose rate applied. Previous application of Treflan had no influence on the effect. Effects were transient and in both years and within 2-3 weeks of first appearance had disappeared.

In 1998 at Bridgets and 1998 and 1999 at High Mowthorpe, all herbicide treatments in the Treflan/Ally sequence gave yield responses that more than covered the costs of treatment. These were sites where weed populations ranged from 60-90 weed/m² in untreated plots, and yield responses to treatment were typically of the order of 0.5 t/ha or more. The yield response at High Mowthorpe in 1999 was also partly due to control of crop lodging, with high weed populations causing extensive lodging. Where there was little yield response to herbicide application, weeds were either poorly controlled and yield potential was low, or weed populations were low (i.e. < 11 field speedwell plants/m²). There was one example which demonstrated a complementary benefit from autumn and spring weed control. At Bridgets in 1998, failure to apply autumn weed control resulted in an unrecoverable loss in yield potential of 0.35 t/ha when using Ally alone, and 0.45 t/ha when using Basagran alone in spring.

At £35/litre Basagran is an expensive herbicide, requiring a linseed yield response of 0.7 t/ha to cover costs of application of a full label rate. In all cases studied, there was only one instance in which costs of Basagran application were covered by yield response to treatment. Adding Vindex to the sequence adds to costs increasing the return required. In the one case where exceptional yield responses were achieved, linseed plant populations in spring were lower than the target population which may have reduced interplant competition with the weeds present.

4) The effect of incorporation of trifluralin on weed control and overwinter survival of winter linseed, and the efficacy of post-drilling applications of trifluralin.

The experiment was located on three sites ADAS Boxworth, Bridgets and High Mowthorpe. The experiment was run for 2 years on each site (harvest years 1998 and 1999). Treatments were as follows:

1. No Treflan applied, no incorporation cultivation
2. Incorporation cultivation only prior to drilling
3. 1.75 l ha^{-1} Treflan incorporated into soil prior to drilling
4. 1.75 l ha^{-1} Treflan applied to soil surface (within 48 hours of drilling)

Treflan was applied at the label approved rate of 1.75 l/ha for use in linseed (medium to heavy soils) in a water volume of 200 l/ha. Incorporation was carried out at each site using rotovators (Boxworth and High

Mowthorpe) or a power harrow (Bridgets). Treatments were arranged in a fully randomised block design , with three replicates at Bridgets and High Mowthorpe and four at Boxworth.

In the spring, plots were oversprayed with 30 g/ha of Ally (metsulfuron-methyl) to control any remaining broad-leaved weeds. Where cleavers were also a significant problem, Eagle (75% w/w amidosulfuron) was applied at 40 g/ha as an overspray in 1999. Graminicides were also applied as an overspray where cereal volunteers were a significant problem.

Linseed and weed populations were assessed at full establishment and again at the end of March/early April. Yields were assessed using plot combines.

Key results and discussion

Effects of Treflan on winter linseed plant populations were greatest in the autumn. At all sites, both in the autumn and spring, plant populations were lowest where Treflan had been incorporated into soil. Significant reductions, compared to the untreated control, were recorded in three out of six site years. A large (67%) reduction in plant population due to incorporation was observed at High Mowthorpe in 19988/99, with vigour of the crop also reduced. The effect in this case was sufficient to cause a 50% yield loss. The average reduction in plant population due to Treflan incorporation, in both spring and autumn, across all sites and years was 24%. The effects could be clearly attributed to the impact of Treflan, as cultivation alone did not reduce plant populations compared to the untreated control. Where Treflan was applied as a surface treatment post-drilling, plant populations were similar to or higher than those in the untreated plots.

The overall effectiveness of weed control by post-drilling applications of Treflan was generally either similar to, or (more often) was less effective than, the traditional incorporation treatment. Although in real terms differences between the two methods of Treflan use were small. In many cases the post-drilling treatment resulted in significant reductions in the total weed burden present. The difference between the two application methods tended to be greatest when Treflan was most effective, i.e. when there were large populations of susceptible broad-leaved weeds present in the weed flora, but such differences were not statistically significant.

Despite the effects on crop establishment, with few exceptions these were compensated for later in the season and yields were not reduced by Treflan application where plant populations remained above 300 plants/m^2.

Discussions and Conclusions

The advent of winter-sown linseed has caused weed control problems for agronomists and growers, because of lack of information on safe active ingredients. Similarly the limited number of active ingredients approved for use on the crop limits the strategies available for weed control in the crop.

In a number of cases, Treflan was shown to be a significant aid in reducing the total overwinter weed burden, both in grass-weed and broad-leaved weed dominated situations. Its effects are only limited by particular weaknesses in its spectrum of weed control (i.e. cleaver, charlock, field pansy, common poppy, mayweed and shepherds purse) which means it will need to be used in sequence with spring-applied products in most field situations. Treflan is a cheap herbicide and there is no significant benefit to be gained from reducing application rates in the autumn.

Where herbicides have a good broad spectrum of weed control, there can be clear beneficial interactions between autumn and spring-applied products to give benefits over and above those obtained from use of products individually. These occur where Treflan and spring-applied herbicides interact on the same weed species, or complement weaknesses in the control spectrum of each product.

A linseed yield response of only 0.2 t/ha will cover the application costs for a full dose of Ally, and 0.3 t/ha the cost of a sequence of Treflan and Ally at full label dose rates for use in linseed. In this study, this scale of yield response to weed control was not difficult to achieve. In contrast, Basagran requires a yield response of at least 0.5 t/ha to cover costs. Products like Basagran and Vindex are less effective in controlling large, well-established weds which are often encountered in winter-sown linseed at the time of spring-herbicide application. In these circumstances, it is difficult to achieve such yield responses in winter linseed crops, except in exceptional circumstances and reducing dose rates of such products further reduces their effectiveness.

Where weed populations are high (>40 weeds/m²), Ally will continue to be the most cost-effective broad-leaved herbicide treatment used in winter linseed. Where Treflan-sensitive weeds dominate the weed flora, dose rates of spring herbicides can be greatly reduced with some confidence when Ally is used in conjunction with Treflan. In very low weed populations (10 weeds/m² or less), Treflan alone may be sufficient where sensitive weed species predominate (e.g. field speedwell and chickeweed).

One of the factors that limits the usefulness of Treflan in linseed is the restriction on maximum dose rate to 1.75 l/ha, compared to up to 2.3 l/ha in other crops such as cereals and oilseed rape. Weed control could be increased if the linseed crop could tolerate higher dose rates. As a safer application method, post-drilling application may allow rates of application to be increased in linseed, and this warrants further study.

Though Ally did cause some transient crop damage after application, this did not appear to cause any long-term problems. However, it serves as a warning that extrapolation of use from spring-sown to winter crops is not without potential risk. One of the problems that besets development of minor crops such as linseed is that the initial reliance on off-label or minor crop approvals, that are not always tried and tested, can lead to problems and lack of confidence in a crop before its well established.

Black-grass, brome and volunteer cereals are very competitive in linseed crops. Yield responses to control ranged from 0.29 to 0.74 t/ha in the grass-weed competition study. Relatively high rates of graminicide were required to control barren brome and volunteer cereals in winter linseed if control was delayed until December or later in the season, when these weeds had started to tiller. Black-grass was easier to control and doses of 0.5 l/ha of Laser were very effective in most cases studied. Costs of graminicide application were only recovered where weed populations were very high (i.e. > 70 black-grass plants/m²). Despite this, costs of control should not be considered in the context of linseed alone, but in the context of rotational control, as grass-weed control is much more cost-effective in break crops than in cereals.

Graminicides were much more effective at controlling grass-weeds than Treflan, which limits the opportunity for any interaction between autumn and spring-applied herbicides, but the effect observed on black-grass head populations by sequences of Treflan and Laser warrants further study. With the advent of widespread herbicide resistance in black-grass, such sequences (from different herbicide groups) could help reduce the build-up of herbicide resistance, though the low rate of Treflan permitted in linseed restricts the usefulness of this technique. Treflan and related products are currently used in wheat in herbicide-resistant situations as a strategic resistance management tool.

It was demonstrated in the study that linseed could tolerate a high level of grass weed competition over the winter period without affecting yield potential. The optimum time for removal of grass-weed competition was when weed biomass had increased to match that of the crop, in practical terms this meant that in most situations grass-weed control could be delayed until March without compromising yield potential. Although it is advisable to remove grass-weed competition as soon as possible in the season, if weather conditions early in the season were likely to affect the crops susceptibility to herbicide damage (i.e. if a period of frosty weather was predicted), then it should be possible to delay weed control until the following spring without any detrimental effects on yield, provided that the linseed crop is healthy and actively growing. However, later application of graminicides reduces the opportunity to use reduced rates. A further difficulty in trying to target application of graminicides early in the season is the slow growth of winter linseed, which consequently delays attainment of the target growth stage for application (typically when the crop is a minimum of 2.5cm tall).

Guidelines on weed control for winter linseed growers

- Grass-weeds are particularly competitive in winter linseed, and control leads to significant yield responses. Economic response to control depends on high grass-weed populations.
- In most cases, removal of grass-weeds can be delayed until March without compromising the yield potential of the crop. Herbicide application timings can therefore be selected with safety of the crop in mind, avoiding periods of frosty weather. However, earlier spraying allows the opportunity to use reduced rates effectively.

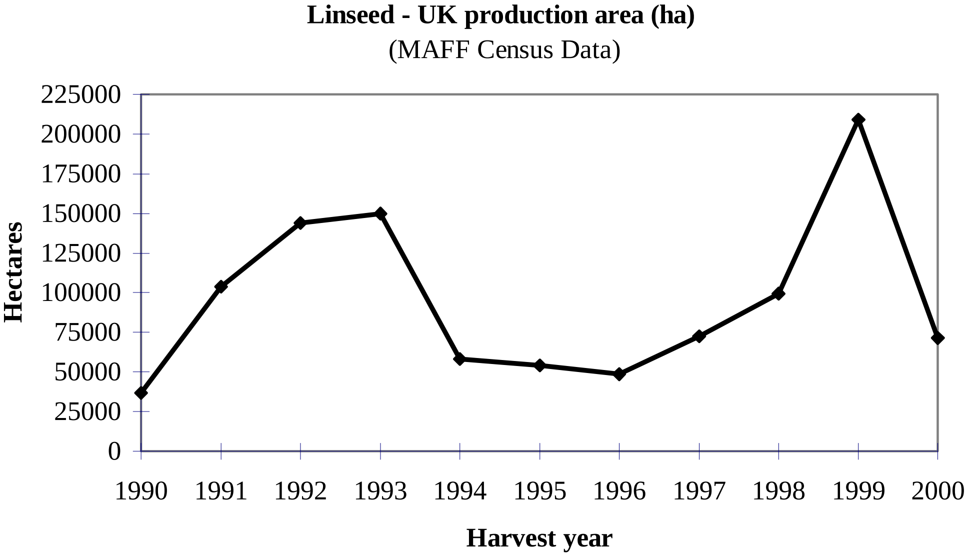
- Treflan should not be incorporated into soil prior to drilling winter linseed, but applied as a post-drilling spray.
- Typically, on medium and light textured soils, where the weed flora is dominated by species such as chickweed, field speedwell and even common poppy, application of Treflan should provide a useful reduction in the autumn weed flora.
- There is no benefit in reducing dose rates of Treflan applied in the autumn.
- For control of broad-leaved weeds, of the limited spring herbicide options available, spring application of Ally is most likely to provide an economic return.
- Where Treflan has been applied in the autumn, and sensitive weeds dominate the flora, Ally rates can be reduced by up to 60% (to 10 g/ha) without compromising weed control.
- There is evidence of some complementary activity between autumn Treflan and spring herbicide applications (particularly with Ally) which can lead to better control of the total weed flora than that achieved by each product alone.
- Use of Ally in winter linseed can cause temporary stunting and/or yellowing of the crop. Such effects are transient and do not appear to influence the crop yield potential.
- Relatively high dose rates of graminicide are required to control grass-weeds in winter linseed, particularly where application is delayed until late winter and grass weeds, such as brome and volunteer wheat have started to tiller.
- There was no evidence that autumn application of graminicides caused any damage to winter linseed.
- There is evidence of some interaction between Treflan application and post-emergence graminicide treatments to reduce black-grass head populations.

TECHNICAL REPORT

1.0. INTRODUCTION

Linseed (*Linum usitatissimum)* is an important industrial oilseed crop within the EU. The EU is a major importer of linseed. During the last peak in linseed production in the UK during the early 1990's, approximately 50% of EU demand for use in the oils, paint, printing and linoleum industry was still being imported, primarily from Canada and Argentina. Within the EU, the UK is a major producer of linseed, with the crop being grown primarily for its oil, and to a more limited extent (with specific cultivars) for its low-grade fibre. For a number of agronomic and economic reasons, the area of linseed grown in the UK has fluctuated over the last 10 years (Figure 1). During this period UK linseed production first peaked in 1993 at 150,000 hectares, as a result of favourable subsidy payments, before declining due to a number of economic (linseed crop support payments included within the EC Arable Area Payments Scheme) and agronomic factors (late harvests and flax flea beetle (*Aphthona euphorbiae* and *Longitarsus parvulus*) damage (Oakley, Corbett, Parker & Young, 1996) associated with spring-sown linseed crops. A second peak in production occurred in 1999 at 209,000 hectares, predominantly due to sowing of spring cultivars, following the wet autumn of 1998 which limited the sowing of winter-sown crops.

Figure 1.1 Changes in the linseed area grown in the UK from 1990 to 2000



Linseed varieties, from material native to Eastern Europe selected for cold-tolerance, were developed by INRA in France (Davies, 1997). The developed lines had good winter hardiness and a tendency to produce side branches. In the late 1970's this material was crossed with other lines to improve agronomic performance, and from these crosses, winter hardy varieties were selected in the mid-1980's for development. Frost-tolerant varieties of linseed became commercially available in the UK in 1994. By 1997, 30,000 hectares of winter tolerant cultivars were being sown, according to Semundo. These cultivars had the potential to alleviate the problems of flax flea beetle attack and late harvesting which afflict the spring-sown crop. In addition, winter linseed cultivars have the potential to out-yield traditional spring-sown cultivars, as shown in previous HGCA projects (Kightly *et al*. 1997; and other studies (Turley *et al*., 1999) and advertised by the seed industry.

Linseed is heavily reliant on EC area-aid subsidy payments to maintain the crops. For linseed to retain a place in UK cropping there is a need to increase output, by increasing yield or lowering the costs of production. There is also a need to increase the reliability of the winter-sown crop by a getting a better understanding the factors affecting crop productivity. Uptake of the winter-sown crop has run ahead of agronomic research and experience. As a result, a number of problems have been encountered which have contributed to the variation in year to year performance of crops. In addition, the limited number of agrochemical products approved and available for use on the crop has also caused difficulties. One of the areas of winter crop management which could be improved is weed control and the safety of herbicide applications (Froment and Turley, 1998a, 1998b).

Linseed has an open canopy and weed control is thought to be the most important input in maintaining yield potential (Lutman 1991). However, with the exception of some HGCA-funded work on spring linseed (Carver *et al*. 1997), and studies on winter barley competition in flax cultivars (Hack *et al.* 1991), little research has been done in the UK to evaluate the effects of weed control.

The number of fully approved herbicides for use on linseed is also limited. Many herbicide active ingredients trialled on the crop have initially been selected on the basis of their use under specific off-label arrangements, or approval for minor crop use, where the herbicide is already approved for use on oilseed rape, and where subsequent approval could be readily sought for promising actives. However, this approach on both the spring (Lutman, 1991; Freer, 1991) and winter crop (Froment and Turley 1998b) has demonstrated that there can be phytotoxic effects from such approaches to weed control, even though some of the effects may be only transitory. In the case of winter linseed, there is an increased risk of phyotoxicity when herbicides are applied in the autumn or early spring, as the crop may already be stressed from frost damage and overwinter kill (Turley *et al.*,1999).

At the start of this project in 1997, the only herbicide approved for pre-emergence use on spring linseed was trifluralin. At the time, it was noted that this herbicide could have a detrimental effect on winter linseed when incorporated prior to drilling, as noted in previous research (HGCA project OS10/01/95; Froment and Turley, 1998a). It is necessary to evaluate the role of autumn herbicides for weed control because of the potential difficulties in controlling weeds with the limited range of spring-applied herbicides available. Effective use of cheap autumn-applied herbicides, such as trifluralin, could also reduce the need for herbicide in the spring by reducing the total weed burden present, by suppressing weed growth or by sensitising weeds to subsequent herbicide treatment.

With regard to tolerance of weed competition, recently completed HGCA-funded work examining weed competition in spring linseed (Carver *et al*. 1997; Lutman, 1997), demonstrated a surprising tolerance by the linseed crop to high populations of chickweed and fat-hen. The situation may not be the same for winter linseed, where the crop is slow growing in both the autumn and early spring, and large frost hardened weeds are left post winter. In addition, production of linseed has been moving onto heavier textured soils where competitive grass-weed species assume great importance. There has been no work done to date to evaluate the tolerance of winter-sown linseed to grass-weed infestation.

The key information growers require on weed control in winter linseed is:-

- What is the most economic strategy for weed control in range of different weed situations.
- Given that some products are being applied at growers own risk, what are the safest products and sequences.

The aim of this current study, through four related field experiments, was to investigate the efficacy and crop safety of herbicide strategies, based on products approved for grass and broad-leaved weed control in linseed. This study utilises a range of sites, in terms of geographical spread, soil type, weed burden and weed species, to investigate the effects of weed competition on winter linseed growth and yield. The focus for each of the four field studies is detailed below. The aims and objectives of these studies are detailed in the following sections.

1) Effect of grass-weed competition and timing of weed removal on winter linseed yields.

2) Effect of pre-emergence herbicide on sensitivity of grass-weeds and volunteer cereals to post-emergence graminicide application.

3) Effect of pre-emergence herbicides on sensitivity of broad-leaved weeds to post-emergence herbicide application.

4) Effect of incorporation of trifluralin on weed control and overwinter survival of winter linseed.

2.0. EFFECT OF WEED COMPETITION AND TIMING OF WEED REMOVAL ON WINTER LINSEED YIELDS

2.0.1 OBJECTIVE

To evaluate the effect of grass-weed competition and the time of weed removal (i.e. duration of competition) on yield of winter linseed.

2.1 MATERIALS AND METHODS

2.1.1 Site and soil type

The experiment was run for 2 years (harvest years 1998 and 1999) at ADAS Boxworth on a clay soil of the Hanslope series. The site was sown with cereal volunteers, at a range of densities, to increase the natural level of grass-weed competition.

2.1.2. Experiment Treatments

Factor 1. *Target volunteer cereal (winter wheat) population*

1) 10 plants/m²
2) 30 plants/m²
3) 90 plants/m²

Factor 2. *Graminicide timing (time of removal of grass-weed competition*)

1) No Falcon applied
2) 1.0 l/ha Falcon applied end October/early November
3) 1.0 l/ha Falcon applied end November/early December
4) 1.0 l/ha Falcon applied end February/early March
5) 1.0 l/ha Falcon applied end March/early April

1.0 l/ha Falcon (a.i. 100 g/l propaquizafop) represents the maximum label-recommended dose. After the first treatment, where necessary, plots were kept free of subsequent weed growth by repeated use of graminicides, and by use of oversprays in spring to control broad-leaved weeds.

The weed growth stages at each date of herbicide application were as detailed in Table 2.0.

Table 2.0. Range of grass weed growth stages (Zodocks Cereal GS) at the time of herbicide application (Boxworth).

1997/98				1998/99			
Date of weed removal	Wheat	Black-grass	Barren brome	Date of weed removal	Wheat	Black-grass	Barren brome
30.10.97	_	21-24	11-14	09.11.98	11-22	10-22	12-22
26.11.97	12-23	11-24	11-22	31.11.98	11-22	10-22	12-22
27.02.98	23-30	13-25	12-28	23.02.99	22-2,10	12-2,31	13-28
01.04.98	13-31	12-2,16	12-2,23	21.03.99	14-30	11-30	-
30.06.98	75	Shedding	Shedding	05.07.99	21-69	69	-

2.1.3. Trial Design

A fully-randomised block design was used with 3 replicates of each graminicide x weed density treatment combination, and 6 replicates of each untreated control treatment (2 per block per volunteer density treatment). Individual plots measured 4 m wide by 24 m long.

2.1.4. Methodology.

The site was prepared by ploughing, and levelled with appropriate cultivation machinery to form a seedbed. Winter wheat seed was broadcast onto plots prior to drilling linseed at rates appropriate to achieve the target populations detailed above. Drilling of the linseed crop was used to incorporate the broadcast cereal seed. Pre and early post-emergence herbicides were not applied to the site, as a precaution against compromising establishment of the crop or broadcast cereal.

Linseed was sown at a rate calculated to achieve a target population of 450 plants/m². Linseed was drilled to a depth of 10 mm and all plots were rolled to conserve moisture and level the surface. Crops were monitored for pest and disease (e.g. slugs and flea beetles) and appropriate steps taken to minimise damage.

2.1.5. Assessments

Crop populations, weed populations and weed biomass were recorded in five 0.1 m² quadrats per plot prior to graminicide application.

At early flowering and prior to desiccation, treatments were examined for any sign of delay in flowering, and to assess any differences in maturity attributable to herbicide treatments.

When the sown cereal volunteers reached grain-fill stage, in the ‘untreated’ control plots, crop and weed biomass were assessed in five 0.1 m² quadrats per plot to measure the maximum level of competition experienced in the absence of grass-weed control.

Yield was recorded using plot combines.

2.2 RESULTS

2.2.1. Weed competition

In autumn 1997, a wide range of cereal populations were established, but the weed flora was dominated by black-grass populations (Table 2.1). The competition from non-cereal weed species was similar to that of the sown wheat until April, when non-cereal weed species started to dominate the weed flora. In autumn 1998, the sown wheat failed to germinate, but high populations of black-grass dominated the weed flora to the virtual exclusion of all other species. As a result, the focus of the second year of study concentrates on the effect of duration of weed competition.

In both years linseed established well and populations were above the minimum of 400 plants/m² recommended to optimise yield (Turley *et. al.*, 1999).

In the first year (1997/98), although increasing the wheat population increased the level of plant competition on a dry weight basis, effects were not statistically significant (Table 2.1). Throughout the growing season, the increase in weed competition due to sowing of wheat did not have a significant influence on linseed biomass. The weed flora quickly became dominated by black-grass and other weeds which accounted for around half of the weed biomass on a dry weight basis, with no significant difference between the sown treatments. Until the beginning of April, biomass of linseed was much greater than that of the competing weed flora (Figure 2.1). At this stage an average of 177 black-grass plants/m² were well established in the crop. Where weeds were left untreated, by the end of June, weed and crop biomass were very similar in each treatment. At this stage black-grass populations accounted for 86% of the non-sown weed flora.

In the second year of study, weed competition developed much earlier in the season (Table 2.1). Autumn crop and weed biomass were very similar to those for 1997. By the end of February, crop dry matter production was only around half of that recorded the previous season, with little difference between weed and crop biomass. By the end of March, linseed biomass was much reduced compared to the previous season and weed biomass was approximately twice that of the crop. Continuing up until the final assessment in July, weed biomass was greater than that of the linseed crop.

Table 2.1. Plant and weed populations, and plant dry weights prior to herbicide application in each season.

Assessment date	1997/98				1998/99	
	10 Wheat plants/m^2	30 Wheat plants/m^2	90 Wheat plants/m^2	SE		SE
30/10/97					**9/11/98**	
Population/m^2						
Linseed	587	703	605	51.9 ns	630	24.2
Wheat	8	21	43	7.3 ns	7	5.1
Other weed	89	220	129	53.1 ns	207	72.0
Dry weight (g/m^2)						
Linseed	8.8	6.4	5.3	2.50 ns	7.8	0.4
Wheat	0.1	0.4	0.7	0.12 ns	0.2	0.1
Other weed	0.3	0.6	0.4	0.11 ns	1.5	0.7
26/11/97						
Population/m^2					**30/11/98**	
Linseed	539	571	584	28.3 ns	608	40.3
Wheat	15	19	43	10.8 ns	7	2.8
Other weed	166	151	191	62.4 ns	286	92.4
Dry weight (g/m^2)						
Linseed	9.9	9.1	10.6	0.59 ns	10.1	0.79
Wheat	0.2	0.8	1.6	0.33 ns	0.4	0.20
Other weed	1.3	0.9	1.1	0.28 ns	4.1	1.69
27/2/98					**23/2/99**	
Population/m^2						
Linseed	581	603	575	23.1 ns	569	66.4
Wheat	43	19	50	19.9 ns	4	2.0
Other weed	75	140	165	27.5 ns	191	25.7
Dry weight (g/m^2)						
Linseed	56.4	55.4	63.0	2.56 ns	27.8	1.60
Wheat	4.5	3.1	11.2	2.35 ns	0.6	0.32
Other weed	5.5	16.1	12.5	2.74 ns	21.2	1.72
1/4/98					**30/3/99**	
Population/m^2						
Linseed	650	607	659	32.5 ns	519	89.6
Wheat	4	17	68	5.5 **	2	1.7
Other weed	179	123	230	40.9 ns	264	38.2
Dry weight (g/m^2)						
Linseed	171.3	136.2	136.6	20.66 ns	36.5	7.37
Wheat	4.1	10.2	32.5	4.06 *	0.6	0.49
Other weed	34.8	22.9	44.4	9.83 ns	75.0	5.90
30/6/98					**5/7/99**	
Population/m^2						
Wheat	12	32	119	16.4 *	1	0.5
Other weed	112	311	156	93.7 ns	104	19.0
Dry weight (g/m^2)						
Linseed	848.5	719.9	603.5	86.91 ns	362.0	66.71
Wheat	555.9	143.4	528.7	54.33 **	1.0	1.40
Other weed	181.9	409.2	212.6	110.76 ns	435.0	53.69

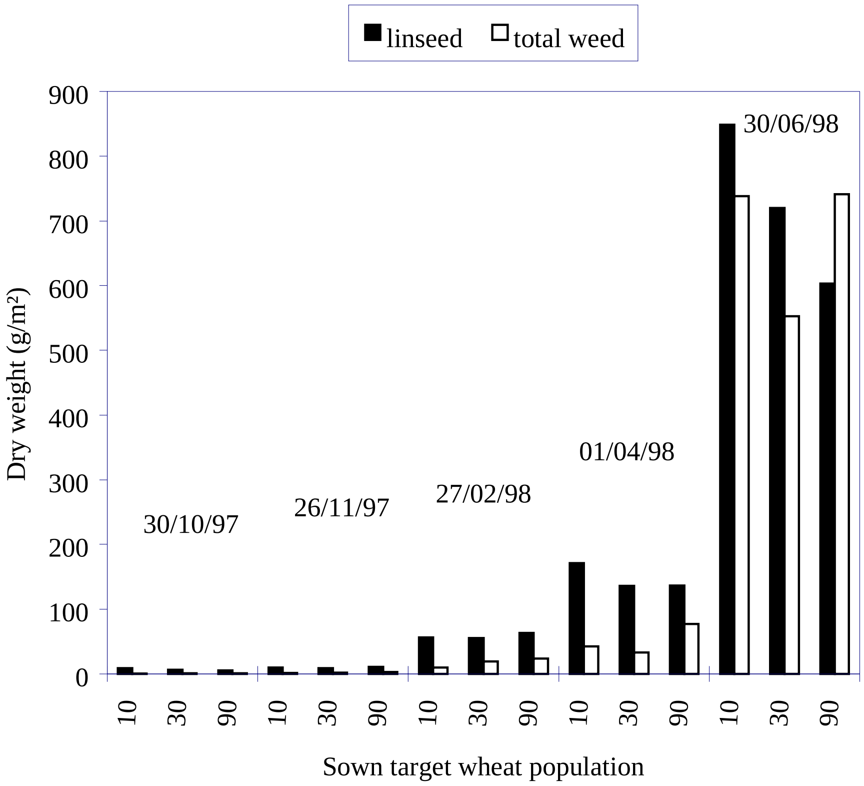


Figure 2.1. Linseed crop and total weed dry matter production (g/m²) prior to weed removal – 1997/98 (dates denote date of assessment and weed removal)

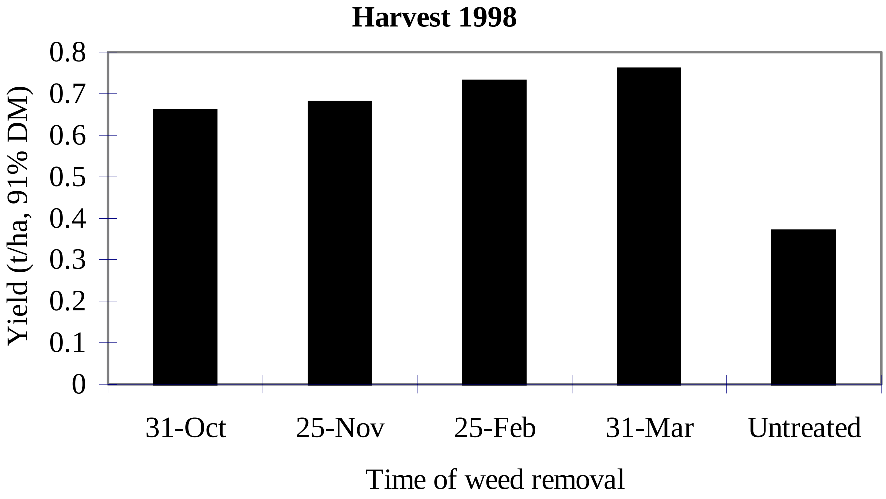


Figure 2.2. Effect of time of weed removal on yield – 1998 (Mean of all wheat seed rates) (SE treat v untreated = 0.029 t/ha, in all other cases = 0.041 t/ha)

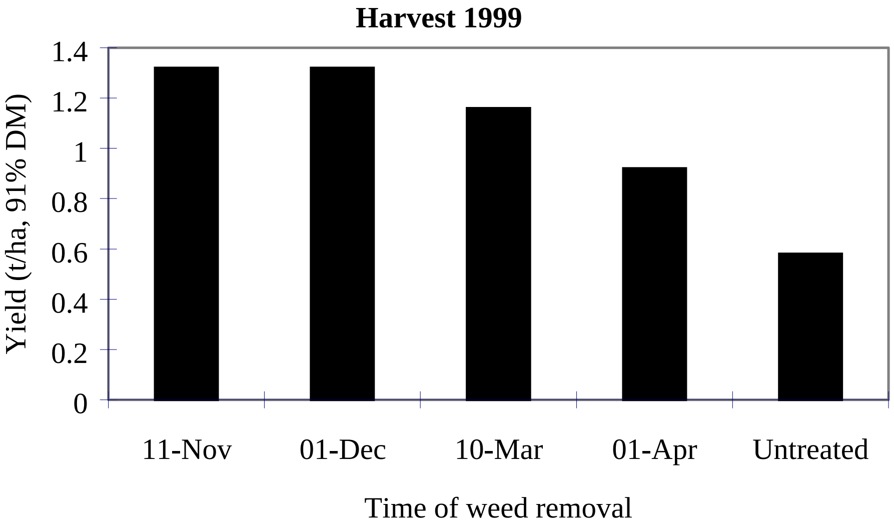


Figure 2.3. Effect of time of weed removal on yield - 1999
(SE treat v untreated = 0.055 t/ha, in all other cases = 0.079 t/ha)

2.2.2. Effects on yield

In 1998, the crop lodged in all treatments, though this was not significantly influenced by treatment, as a result yields were low. In 1999, only the untreated plots suffered from minor lodging (up to 30% of crop lodged), due to the weed burden present in these field plots.

The difference in the onset of weed competition each season was reflected in yield response to time of black-grass removal (Figures 2.2 and 2.3). Weed competition was much greater in 1999, reflected in a higher weed biomass (Table 2.1), though individual plants were less well developed than at similar dates in the previous year (Table 2.0).

In 1998, leaving weeds uncontrolled significantly reduced yields, and yield increased (though not significantly) the later the herbicide was applied, up until the end of March, resulting in yield responses to weed and lodging control ranging from 0.29 to 0.39 t/ha. In 1999, there was a yield response to all herbicide applications. These responses were statistically significant, with the exception of the final herbicide application in April where the response was limited to 0.34 t/ha. In all other cases, the yield response to weed control ranged from 0.58 to 0.74 t/ha.

2.3. DISCUSSION

The critical period for weed removal is linked to the balance between crop and weed biomass. In this study yield potential was reduced where grass-weed biomass was allowed to develop to a level which equalled that of the linseed crop before removal. However this will be influenced by any factors affecting crop vigour. In 1998/99, in early spring, the crop did not appear to be developing as well as in previous seasons which may have increased sensitivity to weed competition.

In other studies examining weed competition in greater detail in linseed, it has been possible to determine thresholds for control of cereal weed species. Based on models of field data, Hack, Marshall and Kirkwood (1991) were able to define an economic control threshold of 30 plants/m² for barley volunteers in spring-sown fibre flax crops (linseed cultivars grown for fibre). In more recent studies, economic thresholds for control of oats in spring linseed have been derived by Carver *et al.* (1997) and Lutman (1997) (12-14 plants/m²). In this study of black-grass dominated, mixed grass-weed populations, there was an economic advantage from grass-weed control in all cases, even where yield potential was reduced by crop lodging in 1998 (though the returns were reduced in this situation). The response to weed control depended on the interaction between crop and weed vigour. Where crop growth outpaced weed growth then weed control could be delayed until March without penalty. This would minimise potential risks associated with herbicide application when there is a significant risks of frost damage to the crop which could exacerbate sensitivity to herbicide.

Ideally, grass-weed competition should be removed as soon as possible in the season. Previous published work (Turley and Froment 1999) done as part of this study, highlighted that in winter linseed, efficacy of control declines the later graminicides are applied in the season (particularly where reduced dose rates are utilised). However, this work also indicated that yield could also be reduced by autumn graminicide application, with no outward signs of damage. Balancing the results of these studies, there is an economic advantage to be gained from control of high populations of grass-weeds which exceeds the risks associated with graminicide application.

3.0. EFFECT OF PRE-EMERGENCE HERBICIDE ON SENSITIVITY OF GRASS-WEEDS AND VOLUNTEER CEREALS TO POST-EMERGENCE GRAMINICIDE APPLICATION.

3.0.1. OBJECTIVES

To evaluate the safety of graminicide application to winter linseed and effects of pre-emergence herbicides on grass-weed sensitivity to graminicides.

3.1. MATERIALS AND METHODS

3.1.1. Sites and soil type

This experiment was located on two ADAS Sites (Table 3.1). Sites were selected on the basis of presence of natural grass-weed seedbanks which were likely to give rise to significant grass-weed populations. Where grass-weed populations were low, grass-weed seed was broadcast to boost populations. The study was run for 3 years at Boxworth (harvest years 1998-00) and 2 years at Bridgets (harvest years 1999-00).

Table 3.1. Sites and soil types

Site	Soil Type
ADAS Boxworth, Cambs.	Clay – Hanslope series
ADAS Bridgets, Hants.	Shallow silt clay loam overlying chalk – Andover series

3.1.2. Experiment treatments

The interaction of Treflan (480 g/l (46% w/w) trifluralin), with a range of Laser (a.i. 200 g/l cycloxydim) treatments was examined. Post-drilling Treflan (480 g/l (46% w/w) trifluralin) treatments were applied straight after drilling of linseed plots, as a surface application without incorporation. Post-emergence Laser (a.i. 200 g/l cycloxydim) treatments were applied when the black-grass plants had at least 2 leaves unfolded. Actual treatments and rates of herbicide applied (as commercial product) were as shown below, and in Table 3.2.

Treatment	Post-drilling herbicide	Post-emergence herbicide
1.	Nil	Nil
2.	Nil	1.0 l/ha Laser
3.	Nil	0.75 l/ha Laser
4.	Nil	0.5 l/ha Laser
5.	Nil	0.25 l/ha Laser
6.	1.75 l/ha Treflan	Nil
7.	1.75 l/ha Treflan	1.0 l/ha Laser
8.	1.75 l/ha Treflan	0.75 l/ha Laser
9.	1.75 l/ha Treflan	0.5 l/ha Laser
10.	1.75 l/ha Treflan	0.25 l/ha Laser

Table 3.2. Date of Laser application at each site and range of growth stage (Zadocks cereal GS) of grass weeds present at the time of treatment application.

Boxworth				Bridgets		
Date of Laser application	Wheat	Black-grass	Barren brome	Date of Laser application	Black-grass	Annual meadow-grass
1998						
25.02.98	13-23	12-29	11-29			
1999				**1999**		
01.12.98	12-21	10-18	11-22	05.10.98	12	12
2000				**2000**		
14.12.99	10-24	10-12	13-24	23.11.98	12	-

3.1.3. Trial Design

A fully randomised black design was used with 3 replicates of each treatment, except for the untreated controls where there were 3 replicates per block (i.e. 9 replicates in total). Plot sizes were 3 m wide by 12 m long at Bridgets and 4 m wide by 24 m long at Boxworth.

3.1.4. Methodology

Sites were prepared by ploughing, followed by levelling with appropriate cultivation.. The linseed crop (cv Oliver) was drilled in either the third or fourth week of September to avoid excessive winter loss of plants. To boost grass-weed populations at the Bridgets site, prior to drilling, black-grass was sown at the rate of 60 seeds/m^2 in 1998 and 30 seeds/ m^2 in 1999, and incorporated into the topsoil by following tines during drilling of the linseed crop. Linseed was sown at a rate calculated to achieve a target population of 450 plants/m^2. Linseed was drilled to a depth of 10 mm and all plots were rolled post drilling to conserve moisture and level the soil surface. After rolling, Treflan was applied in 200 l/ha water to appropriate treatments. Dates of graminicide application are detailed in Table 3.2. Laser was applied in 220 l/ha water, with 1.8 l/ha (0.8%) Actipron as an adjuvant. A broad-leaved weed herbicide (Ally (20% w/w metsulfuron–methyl)) was applied across all treatments in the spring. All other agronomic inputs were applied uniformly across all treatments using normal farm machinery.

3.1.5. Assessments

At fixed points in each plot, linseed and weed populations were assessed in November/December, prior to, or just after, graminicide application and again in February/March to assess any overwinter effects. Weed populations were re-assessed in late March early April. At Bridgets, black-grass heads were counted in June/July. At fixed points in each plot, linseed populations were assessed in 5 x 0.1 m^2 quadrats per plot and weed populations in 10 x 0.1 m^2 quadrats per plot.

At the time of any weed assessment, the linseed crop was examined for occurrence of any chlorosis or stunting. At early flowering, the crop was examined for any sign of delay in flowering, and prior to desiccation to assess any differences in maturity attributable to herbicide treatments.

Prior to harvest crops were examined for any lodging damage. Yields were measured using plot combines.

3.2 RESULTS

3.2.1. Effects of Treflan on linseed plant populations

There were considerable reductions in linseed plant populations over the winter period, particularly on the Boxworth site (Table 3.3), where spring populations were well below the target minimum of 400/m^2, which would have reduced yield potential on this site. However, applying Treflan as a post-drilling surface treatment in virtually all cases had few significant effects on autumn or spring populations (Table 3.3). Significant reductions due to herbicide treatment were only found at the Boxworth site in 1999 and 2000, but reductions were small, with only 6-8% of plants lost following Treflan application. Where significant effects were observed, these were often accompanied by significant interactions with graminicide treatments, demonstrating that there was no consistent effect of Treflan across treatments.

Laser application at a range of dose rates had no effect on linseed plant populations (Table 3.4). In addition, no symptoms of herbicide damage were observed (i.e. chlorosis, scorch or stunting etc.) following Laser application, and no detrimental effects on crop growth and development were observed later in the season.

Table 3.3. Effect of post-drilling application of Treflan on autumn and spring linseed populations

Site/harvest year	Date of assessment	Plants/m²		
		No Treflan	1.75 l/ha Treflan	SE (18 d.f.)
Boxworth - 1998	29/10/97	568	565	13.2 ns
Boxworth - 1998	22/04/98	274	268	16.1 ns
Boxworth - 1999	05/11/98	508	473	44.7 ns
Boxworth - 1999	22/04/99	246	226	13.5 *†
Boxworth - 2000	19/11//99	454	396	21.2 **†
Boxworth - 2000	24/03/00	279	260	12.5 *
Bridgets - 1999	03/11/98	555	559	42.3 ns
Bridgets - 1999	11/03/99	454	453	26.9 ns
Bridgets - 2000	08/11/99	575	570	26.9 ns
Bridgets - 2000	17/03/00	394	402	26.9 ns

† Denotes there is also a significant interaction between Treflan and Laser treatments.

Table 3.4. Effect of Laser application on winter linseed populations (plants/m²)
(mean of all Treflan treatments)

Site/harvest year	Date of assessment	Laser application rate					
		Nil	0.25 l/ha	0.5 l/ha	0.75 l/ha	1.0 l/ha	SE (18 d.f.)
Boxworth - 1998	22/04/98	272	262	284	279	259	25.5 ns
Boxworth - 1999	22/04/99	233	233	247	227	238	21.3 ns
Boxworth - 2000	24/03/00	256	251	279	277	284	19.8 ns
Bridgets - 1999	11/03/99	444	449	454	474	448	42.4 ns
Bridgets - 2000	17/03/00	437	378	412	401	362	42.4 ns

3.2.2. Effects on weed populations

Results from autumn and key spring and summer weed assessments on each site are presented in Tables 3.5 to 3.14.

At Boxworth, where present, broad-leaved weed populations were assessed in the autumn. Application of Treflan as a post-drilling spray had no significant effect on total broad-leaved weed populations. The only significant effect recorded was on populations of field speedwell in spring 1997, where Treflan reduced speedwell populations by 75% (Table 3.5).

Grass-weed populations were dominated by black-grass, barren brome and wheat volunteers at Boxworth and black-grass at Bridgets. Very high grass-weed populations were present at Boxworth in 1997/98 (Tables 3.5, 3.6) and 1998/99 (Tables 3.7, 3.8), but were relatively low in 1999/00 (Tables 3.9, 3.10). Grass-weed populations were lower at the Bridgets site (Tables 3.11 to 3.14), and very low in 1997/98 (Tables 3.11 and 3.12).

Application of Treflan after drilling significantly reduced the autumn grass-weed burden in three out of the five cases studied (Boxworth in autumn 1997 and 1999, and Bridgets in autumn 1999). Effects were observed at a range of weed densities, but effects were not consistent across the range of weed densities encountered. Effects of Treflan were also inconsistent within individual weed species. Significant reductions in total grass-weed burden were mainly due to effects of Treflan on black-grass and barren brome components of the weed flora. In two out of four cases encountered, Treflan application significantly reduced black-grass populations by between 45% (Boxworth, autumn ’97) (Table 3.5) and 73% (Bridgets, autumn ’99) (Table 3.13). In only one out of three cases encountered did Treflan significantly reduce barren brome populations (by 45% at Boxworth in autumn '99) (Table 3.9). Annual meadow grass populations were too low to provide reliable data where encountered at Bridgets in 1998 (Table 3.12).

Application of Treflan in the majority of cases studied, had little impact on grass-weed populations in the spring, as a whole, or for individual grass-weed species. The only exceptions to this were at Boxworth in 2000, where unexpectedly, Treflan significantly reduced volunteer wheat populations (Table 3.10). This is probably an anomaly, as Treflan is approved for use in cereals at much higher application rates than those used in this study. However, Treflan can case damage to cereals in some situations, for example where seed beds are cloddy. At Bridgets in 1999 the total grass-weed population was also significantly reduced by Treflan application (although effects on individual grass-weed species were not significant) (Table 3.12). At Bridgets, although there was no significant effect of Treflan on black-grass plant populations, there were significant effects on later head populations in both 1999 (Table 3.12, Fig 3.1) and 2000 (Table 3.14, Fig 3.2). In these cases, application of Treflan reduced black-grass head populations and exhibited additional interactions with Laser application to increase the efficacy of control. Application of 1.75 l/ha of Treflan allowed dose rates as low as 0.5 l/ha of Laser to prevent black-grass head production. Greater sensitivity to Treflan at the Bridgets site may be due to the fact that much of the black-grass probably arose from seed

Table 3.5. Effect of Treflan on autumn grass and total broad-leaved weed populations at Boxworth – 29/10/97

	Plants/m^2		
	No Treflan	1.75 l/ha Treflan	SE (18 d.f.)
Black-grass	119	74	22.2 **
Barren-brome	30	36	10.1 ns
Total grass-weeds	149	111	24.6 *
Total Broad-leaved weed ‡	25	20	6.7 ns
Field speedwell (2/2/98)	20	5	6.0 **

‡ Sow thistle, chickweed and field speedwell

Table 3.6. Effect of Treflan and Laser applications on spring grass-weed populations at Boxworth – 1998 (plants/m^2)

Weed	Treflan	Laser application rate					
		Nil	0.25 l/ha	0.5 l/ha	0.75 l/ha	1.0 l/ha	Mean
Black-grass	Nil	76.1	15.7	3.0	0.3	1.7	19
22/4/98	1.75 l/ha	83.7	25.0	1.7	0.3	1.3	22
	Mean	79.9	20.3	2.3	0.3	1.5	
	SE (Treflan) = 9.36 ns, SE (Laser) = 14.79 *** LSD 21.98, SE (Treflan x Laser) = 20.93 ns						
Barren brome	Nil	8.9	8.3	1.3	0.3	0	3.8
22/4/98	1.75 l/ha	7.0	10.7	2.3	0.3	0.3	4.1
	Mean	7.9	9.5	1.8	0.3	0.2	
	SE (Treflan) = 2.16ns, SE (Laser) = 3.42** , LSD 7.21, SE (Treflan x Laser) = 4.85 ns						
Total grass-weed	Nil	85.0	24.7	4.3	0.7	1.7	23.3
22/4/98	1.75 l/ha	90.7	36.3	4.0	0.7	1.7	26.7
	Mean	87.8	30.5	4.2	0.7	1.7	
	SE (Treflan) = 11.00 ns, SE (Laser) = 17.39***, LSD 25.84, SE (Treflan x Laser) = 24.61 ns						

Table 3.7. Effect of Treflan on autumn grass-weed populations at Boxworth – 15/11/98

	Plants/m²		
	No Treflan	1.75 l/ha Treflan	SE (18 d.f.)
Black-grass	426	433	26.6 ns
Barren brome	132	102	16.7 ns
Volunteer wheat	2.3	8.7	3.8 ns
Total grass-weeds	560	545	24.8 ns

Table 3.8. Effect of Treflan and Laser applications on spring grass-weed populations at Boxworth – 1999 (plants/m²)

Weed	Treflan	Laser application rate					
		Nil	0.25 l/ha	0.5 l/ha	0.75 l/ha	1.0 l/ha	Mean
Black-grass	Nil	684	216	57	35	13	201
22/3/99	1.75 l/ha	602	216	73	36	25	190
	Mean	643	216	65	36	19	
	SE (Treflan) = 56.9 ns, SE (Laser) = 46.4*** LSD 68.9, SE (Treflan x Laser) = 73.3 ns						
Barren Brome	Nil	175.4	159.6	70.8	46.7	5.4	91.6
22/3/99	1.75 l/ha	175.8	174.2	78.7	30.4	9.2	93.7
	Mean	175.6	166.9	74.8	38.5	7.3	
	SE (Treflan) = 22.5 ns, SE (Laser) = 35.6*** LSD 52.8, SE (Treflan x Laser) = 50.3 ns						
Volunteer wheat	Nil	9.2	8.8	5.8	0.4	0	4.8
22/3/99	1.75 l/ha	11.3	19.2	3.3	0	0	6.7
	Mean	10.2	14.0	4.6	0.2	0	
	SE (Treflan) = 3.69 ns, SE (Laser) = 4.13**, LSD 8.68, SE (Treflan x Laser) = 8.27 ns						
Total grass-weed	Nil	869	384	133	82	18	297
22/3/99	1.75 l/ha	790	409	155	67	34	291
	Mean	829	397	144	75	26	
	SE (Treflan) = 43.3 ns, SE (Laser) = 68.3*** LSD 101.4, SE (Treflan x Laser) = 96.6 ns						

Table 3.9. Effect of Treflan on autumn grass and total broad-leaved weed populations at Boxworth – 16/11/99

	Plants/m²		
	No Treflan	1.75 l/ha Treflan	SE (18 d.f.)
Barren brome	13.2	7.3	3.73*†
Volunteer wheat	22.2	17.3	3.54 ns
Total grass weeds	38.1	25.3	6.73 **
Total broad-leaved weed ‡	47.9	40.4	6.50 ns
‡ Chickweed, Ivy-leaved speedwell & shepherds purse			

† Denotes there is also a significant interaction between Treflan and Laser treatments.

Table 3.10. Effect of Treflan and Laser applications on spring grass-weed populations at Boxworth – 2000 (plants/m²)

Weed	Treflan	Laser application rate					
		Nil	0.25 l/ha	0.5 l/ha	0.75 l/ha	1.0 l/ha	Mean
Volunteer wheat	Nil	17.0	11.0	7.7	1.7	0.3	7.5
24/3/00	1.75 l/ha	9.3	5.3	5.0	1.3	0	4.2
	Mean	13.2	8.2	6.3	1.5	0.2	
	SE (Treflan) = 1.94*, LSD 2.88, SE (Laser) = SE 3.07***, LSD 4.56, SE (Treflan x Laser) = 4.33 ns						
Total grass-weed	Nil	20.7	13.3	9.7	2.3	0.7	9.3
24/3/00	1.75 l/ha	10.7	7.3	5.3	1.7	0.7	5.1
	Mean	15.7	10.3	7.5	2.0	0.7	
	SE (Treflan) = 3.31 ns, SE (Laser) = 3.44***, LSD 5.10, SE (Treflan x Laser) = 4.85 ns						

Table 3.11. Effect of Treflan on autumn grass and total broad-leaved weed populations at Bridgets - 3/11/98

	Plants/m^2		
	No Treflan	1.75 l/ha Treflan	SE (18 d.f.)
Black-grass	4.0	2.0	1.85 ns
Annual meadow-grass	1.0	0.7	1.03 ns

Table 3.12. Effect of Treflan and Laser applications on spring grass-weed populations at Bridgets – 1999 (plants/m^2)

Weed	Treflan	Laser application rate					
		Nil	0.25 l/ha	0.5 l/ha	0.75 l/ha	1.0 l/ha	Mean
Black grass	Nil	3.3	0.3	0.3	0.7	0	0.9
7/1/99	1.75 l/ha	0	0.3	0.7	0.3	0	0.3
	Mean	1.7	0.3	0.5	0.5	0	
	SE (Treflan) = 0.51 ns, SE (Laser) = 0.86 ns, SE (Treflan x Laser) = 1.23 * LSD = 1.28						
Annual meadow-	Nil	0.7	0	1.7	0.3	0	0.5
Grass	1.75 l/ha	0.3	0	0	0	0	0.1
7/1/99	Mean	0.5	0	0.8	0.2	0	
	SE (Treflan) = 0.52 ns, SE (Laser) = 0.82 ns, SE (Treflan x Laser) = 1.16 ns						
Volunteer wheat	Nil	4.0	0	0.3	0.3	0	0.9
7/1/99	1.75 l/ha	0	0	0	0.3	0	0.1
	Mean	2.0	0	0.2	0.3	0	
	SE (Treflan) = 0.72 ns, SE (Laser) = 1.61ns, SE (Treflan x Laser) = 2.29 ns						
Total grass-weed	Nil	8.0	0.3	2.3	1.3	0	2.4
7/1/99	1.75 l/ha	0.3	0.3	0.7	0.7	0	0.4
	Mean	4.2	0.3	1.5	1.0	0	
	SE (Treflan) = 0.71*** LSD = 1.05, SE (Laser) = 1.12*** LSD = 1.66, SE (Treflan x Laser) = 1.58*** LSD = 2.35						
				Heads/m^2			
Black-grass	Nil	26.3	3.0	4.3	0.3	0	6.8
11/6/99	1.75 l/ha	0.7	0.3	0	0	0	0.2
	Mean	13.5	1.7	2.2	0.2	0	
	SE (Treflan) = 0.86*** LSD = 1.28, SE (Laser) = 1.37*** LSD = 2.03, SE (Treflan x Laser) = 1.94*** LSD = 2.88						

Table 3.13. Effect of Treflan on autumn grass-weed populations at Bridgets – 8/11/99

	Plants/m^2		
	No Treflan	1.75 l/ha Treflan	SE (18 d.f.)
Black grass	19.3	5.3	6.41 **

Table 3.14. Effect of Treflan and Laser applications on spring grass-weed populations at Bridgets - 2000 (plants/m^2)

Weed	Treflan	Laser application rate					
		Nil	0.25 l/ha	0.5 l/ha	0.75 l/ha	1.0 l/ha	Mean
Black-grass	Nil	25.4	2.9	1.7	0	1.3	6.3
17/3/00	1.75 l/ha	7.5	4.2	7.9	0	0.4	4.0
	Mean	16.5	3.5	4.8	0	0.8	
	SE (Treflan) = 2.90 ns, SE (Laser) = 4.58*** LSD 6.80, SE (Treflan x Laser) =6.49** LSD 13.64						
Total grass-weeds	Nil	41.7	7.9	4.2	0	1.3	11.0
17/3/00	1.75 l/ha	8.8	5.0	7.9	0.4	1.3	4.7
	Mean	25.2	6.5	6.1	0.2	1.3	
	SE (Treflan) = 4.74 ns, SE (Laser) = 7.49*** LSD = 11.14, SE (Treflan x Laser) = 10.60** LSD = 15.76.						
				Heads/m^2			
Black-grass	Nil	74.0	12.3	18.0	0	0.7	21.0
6/7/00	1.75 l/ha	17.7	13.0	0	0	0.3	6.2
	Mean	45.8	12.7	9.0	0	0.5	
	SE (Treflan) = 6.19** LSD = 9.20, SE (Laser) = 9.79*** LSD = 14.54, SE (Treflan x Laser) = 13.85**						

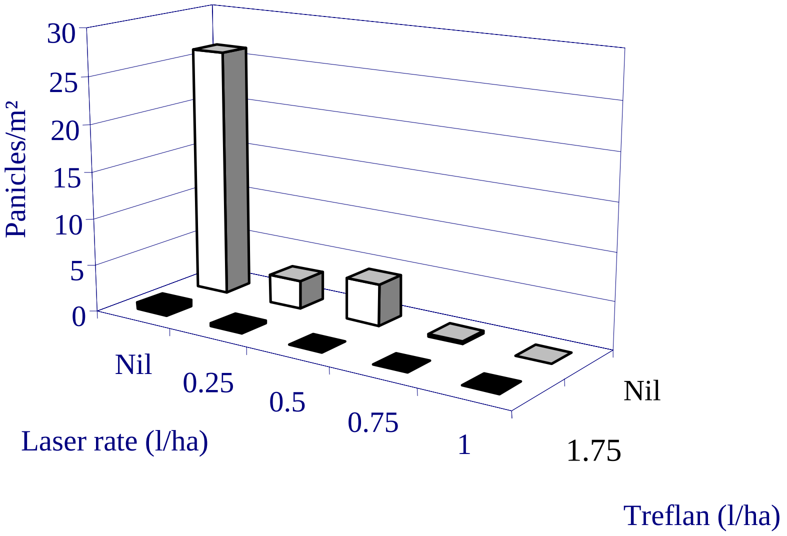


Figure 3.1. Effect of Post-drilling Treflan application and post-emergence Laser application on black-grass head populations – Bridgets, June 1999

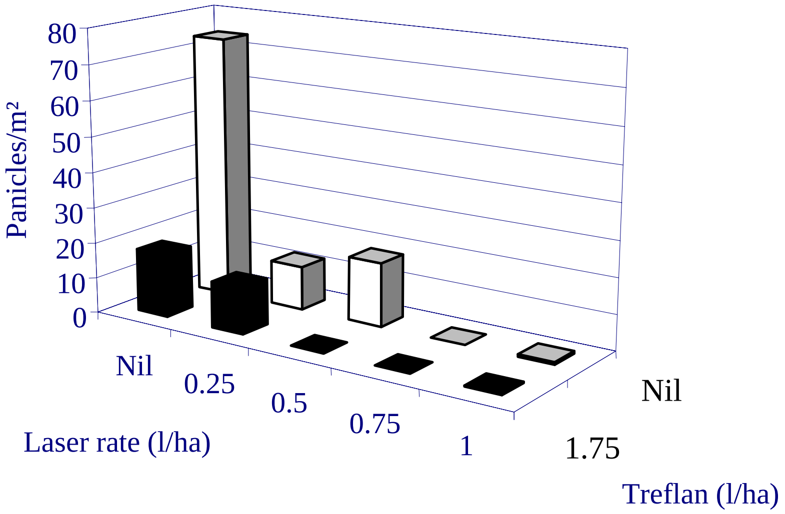


Figure 3.2. Effect of post-drilling Treflan application and post-emergence Laser application on black-grass head populations – Bridgets, June 1999

broadcast to boost grass-weed populations. Broadcast and shallow incorporated seed may have emerged in a single flush and being shallowly buried may have been subject to greater Treflan uptake.

Laser was very effective in reducing populations of all grass-weeds present, and efficacy was closely related to dose rates. Linseed is not a competitive crop to grass-weeds and relatively high dose rates of 0.5 to 1.0 l/ha were required to effectively control barren brome and volunteer wheat populations (Table 3.15), where application of Laser was delayed until December and both weeds had started to tiller.. Black-grass was effectively controlled by dose rates of 50-75% of the full label rate, even at very high populations. Growth stage of black grass at treatment application (i.e. time of application) was less sensitive with black-grass than with wheat and barren brome.

Table 3.15. Dose of Laser required to give 50, 75 and 99% or more
control of grass-weeds in winter linseed.

Grass Species	Population In untreated control (plants/m²)	Site & year	Dose of Laser required (l/ha) 50% Control	75% Control	90%+ control
Black-grass	(643)	Boxworth 1999	<0.25	0.25	0.5 +
	(77)	Boxworth 1998	<0.25	0.25	0.5+
	(17)	Bridgets 2000	<0.25	0.5	0.75+
Barren Brome	(176)	Boxworth 1999	0.5	0.75	1.0
	(9)	Boxworth 1998	0.5	0.5	0.75+
Wheat	(17)	Boxworth 2000	0.25	0.75	0.75+
	(10)	Boxworth 1999	0.5	0.75	0.75+

3.2.3. Yield responses to weed control

With the exception of Boxworth in 2000, where weed populations were relatively low, there were positive yield responses to both Treflan and Laser application on each site each year. Responses were related to weed control. The biggest yield responses were recorded at Boxworth in 1999, where very high black-grass populations were present (Table 3.8). Unfortunately a problem during harvesting meant that only one replicate of the treatments at this site was reliably harvested.

Averaged over all Laser treatments, the yield response to Treflan was only significant in one (Boxworth 2000) out of 5 cases studied (Table 3.16). In all cases, yield responses to Treflan were either uneconomic or just covered the costs of application (costs of treatment and yield responses required to cover costs are detailed in Appendix B). However, where Treflan was applied in the absence of any Laser treatment, yield

Table 3.16. Yield responses (t/ha, 91% DM) of Treflan and Laser applications

(Underlined figures in brackets indicate actual mean yield (t/ha) of untreated controls)

Boxworth Laser application rate (l/ha)	- Treflan	+ Treflan	**Bridgets** Laser application rate (l/ha)	- Treflan	+ Treflan
1998					
Nil	(0.41)	0.01			
0.25	0.29	0.25			
0.5	0.09	0.29			
0.75	0.27	0.34			
1.0	0.28	0.13			
LSD	0.311 ns				
Teflan response	(0.60)	0.01			
LSD	0.139 ns				
1999			**1999**		
Nil	(0.38)	0.15	Nil	(1.38)	0.21
0.25	0.64	0.30	0.25	0.09	0.15
0.5	0.62	0.99	0.5	0.26	0.23
0.75	0.57	0.71	0.75	0.11	0.05
1.0	0.93	0.81	1.0	0.06	0.36
LSD	-		LSD	0.378 ns	
Teflan response	(0.93)	0.04	Teflan response	(1.48)	0.10
LSD	-		LSD	0.168 ns	
2000			**2000**		
Nil	(1.82)	0.26	Nil	(1.01)	0.16
0.25	0.11	0.19	0.25	0.22	0.18
0.5	-0.14	0.27	0.5	0.33	0.25
0.75	0.13	0.21	0.75	0.34	0.28
1.0	0.18	-0.02	1.0	0.26	0.30
LSD	0.279*		LSD	0.284 ns	
Teflan response	(1.84)	0.16	Teflan response	(1.24)	0.01
LSD	0.126*		LSD	0.126 ns	

responses were higher, and an economic return on the cost of treatment was achieved in 4 out of 5 cases in the grass-weed situations studied.

In most cases there were few significant yield responses to Laser application (Table 3.16). No significant yield responses were achieved by controlling black-grass dominated grass-weed populations at densities of 42 plants/m² or less (Bridgets 1999 and Boxworth 2000). Even at populations as high as 75 black-grass plants/m² in untreated plots, a significant yield response to weed control was only recorded in one case (Boxworth in 1998). In economic terms, costs of graminicide application were only consistently recovered at high weed populations, i.e. in black-grass-dominated grass-weed populations at densities of around 70 plants/m² or more, where returns correlated with dose rates applied and efficacy of weed control achieved. On the one site dominated by wheat volunteers (Boxworth 2000), at a population of around 20 wheat plants/m² in untreated control plots, there was no economic return from Laser application at any dose rate applied. This wheat population is close to the economic thresholds derived by Carver *et al.*,(1997) and Lutman (1997) for control of oats in spring linseed, demonstrating that winter linseed does not appear to have any greater sensitivity to cereal volunteers than the spring sown crop.

Where grass-weeds were abundant and present in a range of treatments, it was possible to examine the relationship between grass-weed populations and final yield (Figures 3.3 to 3.5). Winter linseed appeared to be relatively insensitive to winter wheat dominated grass-weed populations of up to 20 plants/m² (Figure 3.4). In a high yielding situation, yields were affected as black-grass dominated weed populations rose to 10 plants/m² or more (Figure 3.5). In a lower yielding situation, black-grass dominated weed populations of up to 40 plants/m² had little effect on yield (Figure 3.3).

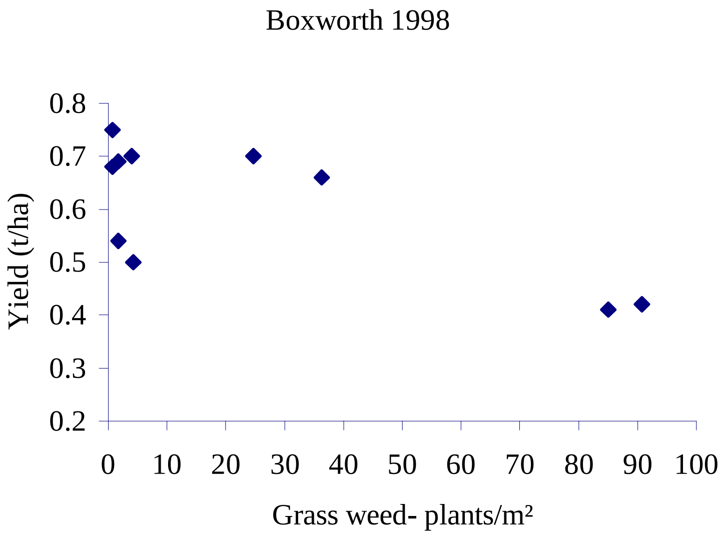


Figure 3.3. Relationship between post-treatment spring grass-weed population and yield – Boxworth 1998

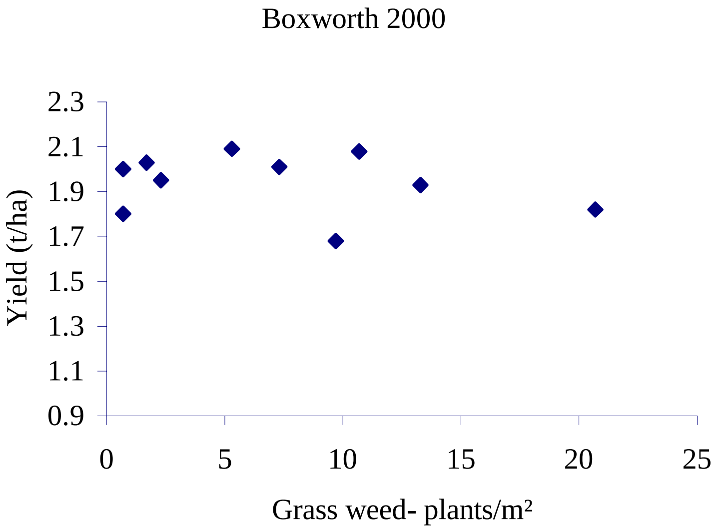


Figure 3.4. Relationship between post-treatment spring grass-weed population and yield – Boxworth 2000

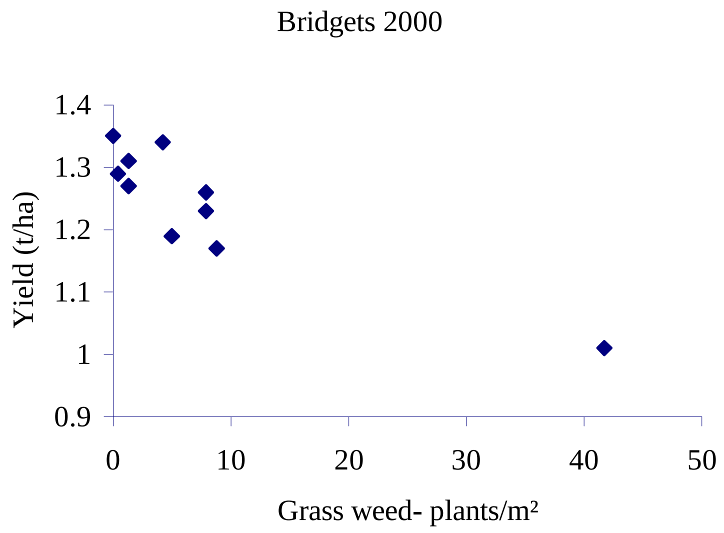


Figure 3.5. Relationship between post-treatment spring grass-weed population and yield – Bridgets 2000

3.3. DISCUSSION

In this study there was no evidence of any detrimental effect of either Treflan or graminicide application on the crop, and no suggestion that post-drilling Treflan application could predispose the crop to damage by Laser applications later in the season.

Treflan did provide a useful reduction in autumn grass-weed populations, but these effects did not appear to persist until spring, perhaps as a result of poor control of later emerging grasses. Relatively high doses of Laser were required to control competitive brome and black-grass populations, and there were few significant yield responses to grass-weed control, except at very high grass-weed populations. The black-grass populations at each site have been subjected to resistance testing. At the Boxworth site, the population present in 1999 showed some target-site resistance to 'fop' and 'dim' graminicides, but there was no resistance to trifluralin. Grass-weed populations were classed as 'susceptible' types in all other cases.

There were no economic benefits in applying Treflan in sequence with Laser treatments, though there were economic benefits when used on its own. This is because Laser is a much more effective herbicide for controlling grass-weeds and gave consistent control, outweighing any benefits gained from the use of Treflan. The only occasion where Treflan appeared to provide some additional benefit when applied in sequence with Laser, was in suppression of black-grass heads. This probably warrants further study as part of the development of herbicide resistance strategies for black-grass-weed control in break crops.

4.0. EFFECT OF PRE-EMERGENCE HERBICIDES ON SENSITIVITY OF BROAD-LEAVED WEEDS TO POST-EMERGENCE HERBICIDE APPLICATION.

4.0.1. OBJECTIVES

To evaluate the effect of pre-emergence herbicide application on broad-leaved weed sensitivity to spring-applied herbicides, and to assess the need for use of pre-emergence trifluralin in winter linseed.

To evaluate the crop safety of herbicide programmes in winter linseed, based on the extension to use of products approved for use on spring linseed.

4.1. MATERIALS AND METHODS

4.1.1. Sites and soil types

The experiment was run at two ADAS sites (Table 4.0) in harvest years 1998 to 2000. These sites had naturally-occurring high densities of broad-leaved weeds and a diversity of weed species. Where this could not be guaranteed then additional broad-leaved weed seed was sown (e.g. chickweed and mayweed at Bridgets in 1999/2000)

Table 4.0. Sites and soil types

Site	Soil Type
ADAS Bridgets, Hants	Shallow silt clay loam overlying chalk – Andover series
ADAS High Mowthorpe, N Yorks	Shallow silt clay loam overlying chalk - Andover series

4.1.2. Experiment treatments

The experiment was run as three separate self-contained studies for three years (harvest years 1998-2000). Herbicides currently approved for use in spring linseed crops were selected for study including Ally (20% w/w mestsulfuron methyl); Basagran (480 g/l bentazone) and Vindex (240 g/l bromoxynil plus 50 g/l clopyralid). The following treatment sequences were established in each study:

Treflan/Ally sequences

	Pre-emergence herbicide	Follow-up spring herbicide treatment
1	No Treflan	Nil
2		10 g/ha Ally
3		20 g/ha Ally
4		30 g/ha Ally
5	0.875 l/ha Treflan	Nil
6	(not incorporated)	10 g/ha Ally
7		20 g/ha Ally
8		30 g/ha Ally
9	1.75 l/ha Treflan	Nil
10	(not incorporated)	10 g/ha Ally
11		20 g/ha Ally
12		30 g/ha Ally

Study B. Treflan/Basagran sequence

	Pre-emergence herbicide	Follow-up spring herbicide treatment
1	No Treflan	Nil
2		1.0 l/ha Basagran
3		1.5 l/ha Basagran
4		2.0 l/ha Basagran
5	0.875 l/ha Treflan	Nil
6	(not incorporated)	1.0 l/ha Basagran
7		1.5 l/ha Basagran
8		2.0 l/ha Basagran
9	1.75 l/ha Treflan	Nil
10	(not incorporated)	1.0 l/ha Basagran
11		1.5 l/ha Basagran
12		2.0 l/ha Basagran

Study C. Treflan/Basagran + Vindex sequence		
	Pre-emergence herbicide	Follow-up spring herbicide treatment
1	No Treflan	Nil
2		0.5 l/ha Vindex + 1 l/ha Basagran
3		0.75 l/ha Vindex + 1.5 l/ha Basagran
4		1 l/ha Vindex + 2 l/ha Basagran
5	0.875 l/ha Treflan	Nil
6	(not incorporated)	0.5 l/ha Vindex + 1 l/ha Basagran
7		0.75 l/ha Vindex + 1.5 l/ha Basagran
8		1 l/ha Vindex + 2 l/ha Basagran
9	1.75 l/ha Treflan	Nil
10	(not incorporated)	0.5 l/ha Vindex + 1 l/ha Basagran
11		0.75 l/ha Vindex + 1.5 l/ha Basagran
12		1 l/ha Vindex + 2 l/ha Basagran

Treflan treatments were applied on the day of drilling. The post-emergence treatments were applied as soon as possible in spring when the crop was at least 5 cm tall, acctiual dates of application are detailed in Table 4.1

Table 4.1. Actual dates of spring-herbicide application.

Harvest year	Bridgets	High Mowthorpe
1998	12.03.1998	31.03.1998
1999	02.04.1999	17.03.1999
2000	31.03.2000	16.03.2000

4.1.3. Experiment Design

Treatments were grouped by post-emergence herbicide treatment into three self-contained studies. The studies were grouped together on each site to ensure that a common weed flora was present in each study. A fully randomised block was used for each study, with 3 replicates of each treatment. Data was subject to analysis of variance as appropriate. No statistical comparisons were made between the individual studies.

4.1.4. Methodology

Sites were selected with a high natural population of broad-leaved weeds. Sites were prepared by ploughing, followed by levelling of soil with appropriate cultivation machinery. At Bridgets in 1999, it was thought broad-leaved populations may be low so seed of chickweed (at 250 g/ha) and Mayweed (at 200 g/ha) were broadcast over the plot areas and incorporated by tines during drilling of the linseed crop. Linseed (cv Oliver) was drilled in either the third or fourth week of September to avoid excessive winter loss. Linseed was sown at a rate calculated to achieve a target population of 450 plants/m^2. The crop was sown to a depth of 10 mm and all plots were rolled to conserve moisture and level the soil surface.

Prior to harvest crops were examined for any lodging damage. Yields were assessed using plot combines. Trash contamination of seed was determined by hand sorting a minimum of 200 grams of harvested seed, and where significant levels of trash were present, linseed yields were adjusted for trash content.

4.1.5. Assessments

At fixed points in each plot linseed populations were assessed prior to any follow up herbicide application and again in April.

At fixed points, weed populations were assessed:-

a) In the autumn after Treflan treatment
b) At the time of spring herbicide application
c) 30 days after spring herbicide application

At the timings above, linseed was examined for occurrence of any chlorosis or crop stunting. Linseed was examined again at early flowering for any sign of delay in flowering, and prior to desiccation to assess any differences in maturity attributable to herbicide treatments. Where herbicide damage was observed, damage was ranked on a 0-9 scale, where zero = no damage, and 9 = crop dead.

4.2 RESULTS

4.2.1. Effects on linseed plant populations.

Treflan applied as a post-drilling treatment only had a significantly effect on autumn plant populations in 17% of cases studied (Table 4.1). Effects were small and of no consequence and were inconsistent across studies on the same site. In spring, in only one case were spring plant populations reduced by Treflan application (Table 4.2). As in the autumn, effects were small and inconsistent across studies on the same site.

Spring-applied herbicides had no effect on linseed plant populations.

4.2.2. Effects of Treflan on early season weed control

In 27% of cases studied, Treflan gave a significant reduction in the total weed population present in the autumn (Table 4.3). In spring, this increased to 61% of cases studied (Table 4.4). The scale of the reductions achieved by the 1.75 l/ha rate ranged from 27 to 71% in the autumn and 27 to 84% in the spring, dependant on the balance of weed species present.

The weed flora at Bridgets was often dominated by field pansy which is resistant to Treflan. This masked effects of herbicide treatment on smaller populations of more susceptible species. At the Bridgets site, effects of Treflan on the total weed flora were primarily due to the effects on populations of field speedwell, (commonly a dominant weed on the site) and annual meadow-grass, as well as to cumulative effects on much smaller populations of sensitive weeds. At High Mowthorpe, effects of Treflan were most commonly due to effects on common poppy (in autumn 1998 and spring 1999), and chickweed, field speedwell and forget-me-not in 1998/99, all of which were common weeds on the site and dominated the weed flora in each season.

Where there were significant effects of Treflan on total weed populations, relationships with dose rate were not always clear. In many cases weed control achieved by the half dose rate of 0.875 l/ha was as effective as the full label dose rate. In the majority of cases, the significant benefits from Treflan application occurred on sites which were dominated by weeds, such as field speedwell and annual meadow grass at the Bridgets sites in 1997/98 and 1998/99, and poppy in 1997/98 and chickweed, field speedwell and forget-me-not in 1998/99 at High Mowthorpe, all of which Treflan controls well.

4.2.3. Interaction of autumn and spring herbicides.

The interactions of Treflan and spring-applied herbicides on total weed populations after treatment are presented in Tables 4.5 to 4.7 for each herbicide sequence.

There are weaknesses in the spectrum of weed control provided by herbicides approved for use in linseed (see Appendix A). One particular weakness is field pansy, which is only moderately susceptible to Ally and Vindex. Unfortunately field pansy was a major constituent of the weed flora at Bridgets, and where prevalent, made it difficult to distinguish the significant interactions of herbicide sequences on other weed species (for example in the Treflan/Ally study at Bridgets in 2000 (Table 4.5). Similarly where weed populations were very low, it was not possible to distinguish interactions between herbicides. However within the cases studied, there were a number of instances where effects were clearly visible. Complementary interactions between herbicides were observed where either a significant proportion of the

Table 4.1. Effect of post-drilling Treflan on linseed populations in autumn (plants/m²)

(Bas= Basagran, Vind = Vindex)

Year/Study	**Bridgets**				**High Mowthorpe**			
Treflan rate:	Nil	0.875 l/ha	1.75 l/ha	SE	Nil	0.875 l/ha	1.75 l/ha	SE
Autumn 97								
Ally	751	734	752	14.7 ns	588	583	602	12.3 ns
Bas	602	662	649	28.2 ns	606	626	619	11.6 ns
Bas + Vind	589	602	575	15.2 ns	643	618	606	9.4 *
Autumn 98								
Ally	589	605	580	24.3 ns	641	643	583	20.3 ns
Bas	564	571	570	23.1 ns	571	571	641	17.2 *
Bas + Vind	527	543	517	24.9 ns	520	551	552	19.8 ns
Autumn 99								
Ally	515	503	522	21.0 ns	501	535	514	16.8 ns
Bas	537	587	498	23.6 *	452	511	514	18.2 *
Bas + Vind	543	582	546	19.4 ns	548	561	524	27.4 ns

Table 4.2. Effect of post-drilling Treflan on linseed plant populations in spring (plants/m²)

(Bas= Basagran, Vind = Vindex)

Year/Study	**Bridgets**				**High Mowthorpe**			
Treflan rate:	Nil	0.875 l/ha	1.75 l/ha	SE	Nil	0.875 l/ha	1.75 l/ha	SE
Spring 98								
Ally	494	510	461	20.6 ns	412	445	446	16.8 ns
Bas	495	519	518	16.7 ns	498	508	525	14.9 ns
Bas + Vind	585	531	534	16.5 ns	457	462	473	13.9 ns
Spring 99								
Ally	504	528	481	16.3 ns	514	535	463	19.3 *
Bas	414	410	410	17.1 ns	396	383	426	23.8 ns
Bas + Vind	458	430	449	17.0 ns	346	354	381	18.5 ns
Spring 00								
Ally	370	360	364	13.8 ns	403	421	420	10.3 ns
Bas	415	441	394	19.2 ns	386	431	434	12.0 ***
Bas + Vind	423	477	462	17.1 ns	436	464	458	13.0 ns

Table 4.3. Effect of post-drilling Treflan on autumn total weed populations (plants/m²) (Bas= Basagran, Vind = Vindex).

Year/Study	Bridgets				High Mowthorpe			
Treflan rate:	Nil	0.875 l/ha	1.75 l/ha	SE	Nil	0.875 l/ha	1.75 l/ha	SE
Autumn 97								
Ally	133	63	52	9.91***	129.0	128.0	102.0	27.80 ns
Bas	169	126	125	8.15***	49.8	46.4	41.7	4.14 ns
Bas + Vind	245	154	104	20.4***	34.6	27.3	27.4	3.91 ns
Autumn 98								
Ally	3.8	1.2	2.1	1.34 ns	64.2	16.3	32.5	9.44 *
Bas	7.9	1.3	1.7	2.17 ns	13.3	4.6	9.2	4.46 ns
Bas + Vind	10.0	1.3	2.9	2.24*	4.2	0.8	1.3	1.22 ns
Autumn 99								
Ally	225	207	168	22.1 ns	2.1	2.1	4.6	2.85 ns
Bas	227	297	229	31.2 ns	3.3	2.5	4.2	1.49 ns
Bas + Vind	260	214	214	29.6 ns	2.5	2.9	2.5	1.11 ns

Table 4.4. Effect of post-drilling Treflan on total weed populations prior to spring herbicide application (plants/m²) (Bas= Basagran, Vind = Vindex).

Year/Study	Bridgets				High Mowthorpe			
Treflan rate:	Nil	0.875 l/ha	1.75 l/ha	SE	Nil	0.875 l/ha	1.75 l/ha	SE
Spring 98								
Ally	64	46	38	5.2***	121.4	57.3	36.7	13.38***
Bas	99	91	92	4.7 ns	48.2	37.2	28.1	2.91***
Bas + Vind	155	141	113	13.3 ns	38.7	25.3	24.2	2.90**
Spring 99								
Ally	7.9	2.7	1.9	0.88***	55.8	9.0	12.7	8.33 ***
Bas	6.0	1.4	0.6	1.38*	9.9	4.3	6.1	2.70 ns
Bas + Vind	10.8	1.2	1.9	1.93**	5.9	1.4	1.0	1.04 **
Spring 00								
Ally	160	157	118	9.97**	5.2	6.3	4.9	1.28 ns
Bas	167	180	149	14.6 ns	13.8	11.3	6.5	1.97 *
Bas + Vind	168	184	164	16.3 ns	17.7	11.5	10.6	3.51 ns

Table 4.5. Weed populations after spring herbicide treatment (Treflan/Ally sequence)

(figures in brackets denotes SE's (and LSD's where significant difference observed))

Autumn pre-emergence herbicide	Spring follow-up herbicide (Ally)				Mean
	None	10 g/ha	20 g/ha	30 g/ha	
Bridgets					
1998		(10.4 ns)			(5.2**LSD =15.2)
None	62.0	77.0	62.0	53.0	64.0
Half-rate Treflan	54.0	39.0	50.0	40.0	46.0
Full-rate Treflan	55.0	42.0	25.0	29.0	38.0
Mean (5.9 ns)	57.0	53.0	46.0	41.0	
Dominant weed species: field pansy, field speedwell, common poppy					
1999		(0.88** LSD =2.59)			(0.44**LSD=1.29)
None	11.2	0.4	2.9	0.8	3.8
Half-rate Treflan	1.7	0.4	0.0	0.4	0.6
Full-rate Treflan	0.8	1.2	0.8	1.2	1.0
Mean (0.51** LSD =1.50)	4.6	0.7	1.2	0.8	
Dominant weed species: field speedwell					
2000		(10.61 ns)			(5.30 ns)
None	42.9	65.8	65.0	36.7	52.6
Half-rate Treflan	68.7	52.9	42.9	40.0	51.1
Full-rate Treflan	72.5	58.7	47.5	55.4	58.5
Mean (6.08 ns)	61.4	59.2	51.8	44.0	
Dominant weed species: field pansy, mayweed, scarlet pimpernel					
High Mowthorpe					
1998		(5.83** LSD =17.09)			(2.91** LSD =8.55)
None	90.3	24.0	18.7	21.0	38.5
Half-rate Treflan	54.7	24.7	18.7	23.0	30.3
Full-rate Treflan	37.7	11.0	21.3	11.0	20.3
Mean (3.36*** LSD =9.87)	60.9	19.9	19.6	18.3	
Dominant weed species: common poppy, field pansy, field speedwell					
1999		(12.09 ns)			(6.05 ns)
None	67.9	6.3	2.1	15.0	22.8
Half-rate Treflan	16.7	1.7	6.3	9.2	8.4
Full-rate Treflan	9.6	2.9	1.3	2.5	4.1
Mean (6.98* LSD =20.48)	31.4	3.6	3.2	8.9	
Dominant weed species: forget-me-not, chickweed, cleaver, speedwell					
2000		(1.74 ns)			(0.87 ns)
None	4.6	5.8	4.2	2.9	4.4
Half-rate Treflan	2.5	5.8	3.8	1.7	3.4
Full-rate Treflan	7.5	5.0	2.1	3.8	4.6
Mean (1.00 ns)	4.9	5.6	3.3	2.8	
Dominant weed species: field speedwell, cleaver					

Table 4.6. Weed populations after spring herbicide treatment (Treflan/Basagran sequence) (figures in brackets denotes SE's (and LSD's where significant difference observed))

Autumn pre-emergence herbicide	Spring follow-up herbicide (Basagran)				Mean
	None	1.0 l/ha	1.5 l/ha	2.0 l/ha	
Bridgets					
1998	(9.5 ns)				(4.7 ns)
None	93	116	81	104	99
Half-rate Treflan	85	90	86	100	91
Full-rate Treflan	89	93	94	92	92
Mean (5.5 ns)	89	100	87	99	
Dominant weed species: field pansy, field speedwell, shepherds purse					
1999	(1.93 ns)				(0.96* LSD =2.82)
None	6.6	1.3	6.3	3.3	4.4
Half-rate Treflan	1.7	2.3	0.3	1.0	1.3
Full-rate Treflan	0.3	0.0	1.0	0.3	0.4
Mean (1.11 ns)	2.9	1.0	2.6	1.6	
Dominant weed species: field speedwell, groundsel					
2000	(8.49 ns)				(4.24 ns)
None	38.4	52.5	57.5	63.4	52.9
Half-rate Treflan	46.7	50.8	45.4	44.6	46.9
Full-rate Treflan	65.4	65.5	60.5	40.4	58.0
Mean (4.86 ns)	50.2	56.3	54.5	49.5	
Dominant weed species: field pansy, mayweed, chickweed					
High Mowthorpe					
1998	(6.84 ns)				(3.42** LSD =10.0)
None	46.0	31.3	23.7	37.0	34.5
Half-rate Treflan	33.3	13.0	14.7	15.0	19.0
Full-rate Treflan	45.0	5.3	7.7	12.3	17.6
Mean (5.59** LSD =11.59)	41.4	16.6	15.3	21.4	
Dominant weed species: oilseed rape, common poppy, shepherd purse					
1999	(3.79 ns)				(1.89*, LSD =5.55)
None	17.9	17.1	2.5	2.5	10.0
Half-rate Treflan	2.5	1.7	7.9	0.8	3.2
Full-rate Treflan	7.5	1.3	7.5	1.3	4.4
Mean (2.19 ns)	9.3	6.7	6.0	1.5	
Dominant weed species: cleaver, field speedwell					
2000	(2.20 ns)				(1.10 ns)
None	14.1	9.2	12.1	6.3	10.4
Half-rate Treflan	10.4	2.9	10.4	9.2	8.2
Full-rate Treflan	12.9	7.5	7.5	4.6	8.1
Mean (1.79* LSD = 3.72)	12.5	6.5	10.0	6.7	
Dominant weed species: field speedwell, cleaver					

Table 4.7. Weed populations after spring herbicide treatment (Treflan/Vindex + Basagran sequence)
(figures in brackets denotes SE's (and LSD's where significant difference observed))

Autumn pre-emergence herbicide	Spring follow-up herbicide (Vindex + Basagran)				Mean
	None	0.5 + 1.0 l/ha	0.75 + 1.5 l/ha	1.0 + 2.0 l/ha	
Bridgets					
1998	(26.6 ns)				(13.3 ns)
None	107	161	193	158	155
Half-rate Treflan	176	138	116	133	141
Full-rate Treflan	78	135	139	102	113
Mean (15.4 ns)	120	145	149	131	
Dominant weed species: field pansy, field speedwell, shepherds purse					
1999	(1.48 ns)				(0.74* LSD =2.18)
None	1.7	1.0	6.3	2.7	2.9
Half-rate Treflan	0.3	0.3	0.0	0.0	0.2
Full-rate Treflan	1.3	0.0	0.3	0.3	0.5
Mean (0.86 ns)	1.1	0.4	2.2	1.0	
Dominant weed species: field speedwell, black bindweed					
2000	(8.34 ns)				(4.17 ns)
None	57.9	42.1	46.3	47.9	48.6
Half-rate Treflan	56.3	44.2	59.3	37.1	49.3
Full-rate Treflan	42.1	42.1	46.3	45.4	44.0
Mean (4.81 ns)	52.1	42.8	50.7	43.5	
Dominant weed species: field pansy, mayweed, chickweed					
High Mowthorpe					
1998	(1.75 ns)				(0.87** LSD =2.56)
None	34.3	10.7	10.7	12.0	16.9
Half-rate Treflan	26.0	7.3	5.0	8.0	11.6
Full-rate Treflan	25.0	4.7	7.0	5.7	10.6
Mean (1.00** LSD = 2.96)	28.4	7.6	7.6	8.6	
Dominant weed species: commmon poppy, oilseed rape, cleaver, chickweed					
1999	(2.04 ns)				(1.02 ns)
None	7.9	0.8	0.8	2.5	3.0
Half-rate Treflan	3.3	0.0	2.5	0.4	1.6
Full-rate Treflan	0.4	0.8	0.0	0.0	0.3
Mean (1.18 ns)	3.9	0.6	1.1	1.0	
Dominant weed species: common poppy, field speedwell, cleaver					
2000	(4.49 ns)				(2.24* LSD 6.58)
None	18.3	20.4	13.3	8.8	15.2
Half-rate Treflan	8.8	13.3	10.8	4.2	9.3
Full-rate Treflan	8.8	8.3	7.9	2.5	6.9
Mean (2.59 ns)	11.9	14.0	10.7	5.1	
Dominant weed species: field speedwell, fumitory, cleaver					

weed flora was sensitive to herbicides applied in both the autumn or spring, or, the spring-applied herbicide covered a weakness in the autumn herbicide, which then influenced a significant proportion of the weed flora. In both cases, the effectiveness of the herbicide is a key factor and interactions were more prevalent where Ally was used in the sequence rather than Basagran with or without Vindex. This partly arises as a result of the weed growth stages at the time of treatment. In winter crops, many weeds have overwintered and herbicide application is delayed until crops reach up to 5 cm in height or more, or the risk of frosty conditions has passed. This means spring herbicides are generally applied in March at the earliest opportunity. In this study, well established weeds of up to 5cm in diameter were commonly found at the time of spring-herbicide application. Weed sensitivity to Basagran and Vindex is optimised when weeds are at 2-4 expanded leaves. Ally controls many weeds with up to 6 true leaves, but the spectrum of activity declines as weed size increases, though many common weeds are controlled at up to 20cm in height (e.g. chickweed, mayweed, field speedwell and common poppy (thought the latter two are only moderately susceptible)). Because of this problem, of the herbicides available for use in linseed, Ally tends to be more effective on well established weeds.

Treflan/Ally sequence

In three out of six cases there were good examples of weed control interactions between Treflan and Ally (Table 4.5). At Bridgets in 1998 and 1999, the weed flora was dominated by field speedwell. This weed is controlled by Treflan, but is only moderately susceptible to Ally. In 1998, a combination of Ally and Treflan gave better control of weed populations than the individual herbicides used alone, with control optimised at a full rate of Treflan followed by 20 g/ha of Ally (Table 4.8). In 1999, where field speedwell populations were lower, acceptable levels of control were achieved with Treflan alone.

Table 4.8. Percent reduction in total weed flora achieved by autumn applied Treflan and spring-applied Ally herbicide sequences (compared to untreated control) – Bridgets 1998

Treflan rate	Ally rate			
	None	10 g/ha	20 g/ha	30 g/ha
None	-	+24%	0%	-15%
0.875 l/ha	-13%	-37%	-19%	-36%
1.75 l/ha	-11%	-32%	-60%	-53%

At High Mowthorpe in 1998, the weed flora was dominated by common poppy. Treflan gave some control and Ally gave good control, however, control was optimised by high rates of Treflan with doses as low as 10 g/ha Ally (Table 4.5). Control was better than that achieved by each herbicide individually. Similar effects were observed in 1999 where forget-me-not and chickweed dominated the weed flora, where control was again optimised with high rates of Treflan and 20 g/ha Ally (Table 4.5).

Treflan/Basagran sequence

There were no clear interactions between Treflan and Basagran at the Bridgets site, due to high populations of field pansy in the weed flora, which was unaffected by treatment, or low weed populations. However, at High Mowthorpe, in weed situations dominated by poppy and oilseed rape (1998) or field speedwell (1999 and 2000), there were additional benefits from using sequences of Treflan and Basagran, allowing good control from Basagran rates as low as 1 l/ha (Table 4.6), though control was inconsistent across dose rates.

Treflan/Basagran + Vindex sequence

There were no clear interactions between Treflan and Vindex plus Basagran at the Bridgets site, due to high populations of field pansy in the weed flora, which was unaffected by treatment, or due to low weed populations. At High Mowthorpe, in weed situations dominated by poppy and oilseed rape (1998) or field speedwell (2000), there were additional benefits from using sequences of Treflan followed by Basagran or Vindex plus Basagran, which gave good control from rates as low as half the recommended label dose rate (Table 4.6 and 4.7), though levels of control were inconsistent across dose rates.

Although benefits from herbicide sequences were observed, products like Basagran and Vindex are expensive and their use needs to be fully justified, in terms of the yield response that can be expected from typical levels of weed control encountered in winter linseed crops. In addition, in some circumstances, spring-applied herbicides did cause damage to crops which also needs to be taken into consideration.

4.2.4. Damage to crops

Throughout the study no damage to crops was observed from use of Treflan, Basagran or Vindex. However, Ally had a significant effect on crops at High Mowthorpe in 1998, and at both High Mowthorpe and Bridgets in 1999. In 1998 at High Mowthorpe, Ally caused severe stunting and reduction in crop vigour some time after herbicide application, when the crop was approximately 10-15 cm tall. Observed effects were clearly related to dose rate applied. In 1999, on both sites a widespread crop yellowing was observed during stem extension of the crop prior to flowering, though in this case crop vigour was unaffected. Both crop yellowing and the extent of the damage were related to dose rate. Visual scores of the degree of crop chlorosis demonstrated the dose rate relationship with observed levels of damage (Figures 4.1 and 4.2). Autumn Treflan treatments had no influence on this effect. Effects were transient and in both years within 2-3 weeks of first appearance had disappeared. In the first year this was due to rapid extension growth which compensated for earlier poor growth. In 1999, there was a gradual return to normal green colouring of the crop over time.

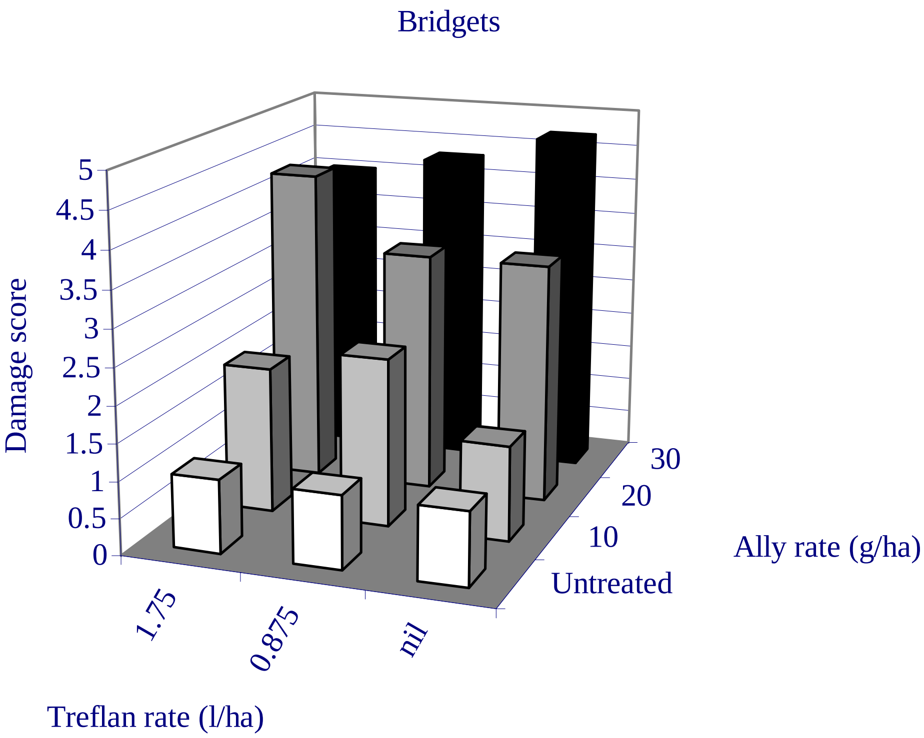


Figure 4.1. Visual damage scores (0 = no effect, 5= whole of crop yellow) at Bridgets - 5 April 2000

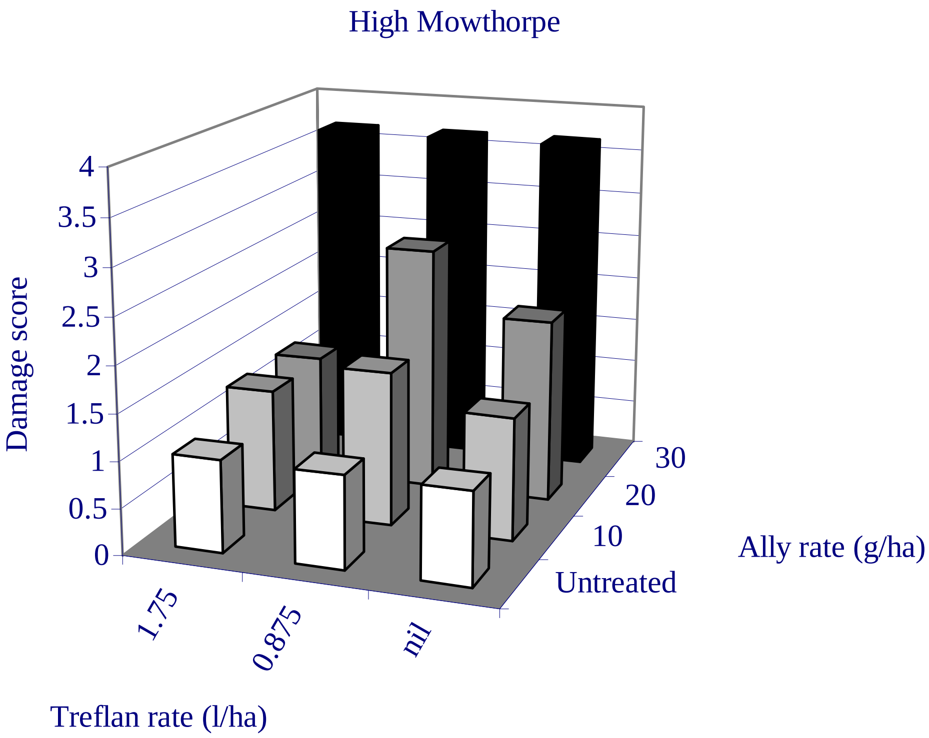


Figure 4.2. Visual damage scores (0 = no effect, 5= whole of crop yellow) at High Mowthorpe – 5 May 2000

4.2.5. Yield response to herbicides

The yield response to herbicide sequences on each site each year are detailed in Tables 4.9 to 4.11. The costs of each herbicide sequence, and the yield response required to cover costs of the herbicide and its application are detailed in Appendix B.

Treflan/Ally sequence

In 1998 at Bridgets and 1998 and 1999 at High Mowthorpe, all herbicide treatments in the Treflan/Ally sequence gave yield responses that more than covered the costs of treatment. These were sites where weed populations ranged from 60-90 weeds/m² in untreated plots, and yield responses to treatment were typically of the order of 0.5 t/ha or more (Table 4.9). The yield response at High Mowthorpe in 1999 was also partly due to control of crop lodging, with high weed populations causing extensive lodging. Where there was little yield response to herbicide application, weeds were either poorly controlled and yield potential was low (Bridgets 2000), or weed populations were low (i.e. < 11 field speedwell plants/m²) (Bridgets 1999, High Mowthorpe 2000). There was one example which demonstrated additional benefits from the combination of autumn and spring weed control. At Bridgets in 1998, In comparable treatments, the yield potential was higher where Treflan had been applied in the autumn, and it was not possible to achieve the same yield potential from herbicide application in the spring alone.

There was no evidence that the damage from Ally observed in 1998 and 2000 affected final yields (Table 4.9).

Treflan/Basagran and Treflan/Vindex + Basagran sequences

At £35/litre Basagran is an expensive herbicide, requiring a linseed yield response of 0.7 t/ha to cover costs of application of a full label rate (Appendix B). In all cases studied, there was only one instance in which costs of Basagran application were covered by yield response to treatment (Table 4.10). Adding Vindex to the sequence adds to costs increasing the return required. However, in one exception to this, there were economic responses these herbicides at High Mowthorpe in 1999 (Table 4.11). In this case, linseed was high yielding (2.4 t/ha in untreated plots) and there were yield responses to weed control that typically ranged from 0.6 to 1.09 t/ha. However, weed populations were very low (Table 4.7), dominated by common poppy, speedwell and cleavers. The difference in this situation was that linseed plant populations in spring were lower than the target population (see Table 4.2). This may have reduced interplant competition allowing the small weed population to take advantage. At High Mowthorpe, in weed situations dominated by poppy and oilseed rape (1998) or field speedwell (1999 and 2000), there were additional benefits from using sequences of Treflan and Basagran, allowing good control from Basagran rates as low as 1 l/ha (Table 4.6).

Table 4.9. Yield response (t/ha) to herbicide treatment by comparison with untreated controls - Treflan/Ally sequence (figures in brackets denote control yield (t/ha)).

Treflan	Ally treatment	Bridgets 1998	Bridgets 1999	Bridgets 2000	High Mowthorpe 1998	High Mowthorpe 1999	High Mowthorpe 2000
Nil	Nil	(2.18)	(1.53)	(0.84)	(0.76)	(2.50)	(1.24)
	10 g/ha	0.28	0.05	0.12	0.92	0.35	-0.08
	20 g/ha	0.15	-0.03	0.10	0.88	0.76	-0.06
	30 g/ha	0.46	0.01	-0.12	0.90	0.67	0.23
0.875 l/ha	Nil	0.42	0.05	-0.08	0.36	0.50	0.25
	10 g/ha	0.52	0.04	0.05	0.72	0.73	0.05
	20 g/ha	0.44	-0.10	0.10	0.87	0.69	0.25
	30 g/ha	0.52	-0.01	-0.06	0.72	0.67	0.19
1.75 l/ha	Nil	0.59	-0.01	0.30	0.49	0.56	-0.18
	10 g/ha	0.6	0.04	-0.17	0.37	0.42	0.14
	20 g/ha	0.58	-0.05	0.07	0.68	0.75	0.47
	30 g/ha	0.81	-0.05	0.27	0.72	0.56	-0.16
	LSD Treflan x Ally	0.52 ns	0.21 ns	0.58 ns	0.29 **	0.36 ns	0.40 *
Treflan effect							
Nil		(2.43)	(1.54)	(0.87)	(1.43)	(2.95)	(1.26)
0.875 l/ha		0.22	-0.02	-0.03	0.0	0.20	0.16
1.75 l/ha		0.40	-0.03	0.09	-0.1	0.12	0.05
	LSD	0.26 **	0.10 ns	0.29 ns	0.14 ns	0.18 ns	0.21 ns
Ally effect							
Nil		(2.54)	(1.54)	(0.91)	(1.04)	(2.85)	(1.26)
10 g/ha		0.10	0.03	-0.07	0.39	0.15	0.02
20 g/ha		0.02	-0.07	0.02	0.53	0.39	0.20
30 g/ha		0.23	-0.03	-0.04	0.50	0.28	0.07
	LSD	0.31 ns	0.12 ns	0.33 ns	0.17***	0.21 *	0.23 ns

Table 4.10. Yield response (t/ha) to herbicide treatment by comparison with untreated controls – Treflan/Basagran sequence (figures in brackets denote control yield (t/ha)).

Treflan	Basagran treatment	Bridgets 1998	Bridgets 1999	Bridgets 2000	High Mowthorpe 1998	High Mowthorpe 1999	High Mowthorpe 2000
Nil	Nil	(2.15)	(1.45)	(1.16)	(1.03)	(2.78)	(1.28)
	1.0 l/ha	0.14	0	0.20	0.05	-0.24	0.17
	1.5 l/ha	-0.04	-0.06	0.13	0.26	0.26	-0.08
	2.0 l/ha	0.07	0.06	0.36	0.28	0.37	-0.01
0.875 l/ha	Nil	0.18	0.06	0.28	0.51	0.18	-0.12
	1.0 l/ha	0.24	0.06	0.03	0.36	0.35	-0.10
	1.5 l/ha	0.34	0.03	0.14	0.31	0	-0.26
	2.0 l/ha	0.4	0.09	0.6	0.35	0.38	-0.21
1.75 l/ha	Nil	0.44	-0.04	0.14	0.18	0.27	0.16
	1.0 l/ha	0.56	-0.03	0.44	0.36	0.20	0.10
	1.5 l/ha	0.48	0.12	0.46	0.51	-0.37	0
	2.0 l/ha	0.50	-0.02	0.55	0.37	0.39	0.03
LSD Treflan x Basagran		0.17 ns	0.18 ns	0.58 ns	0.41 ns	0.71 ns	0.36 ns
Treflan effect							
Nil		(2.20)	(1.46)	(1.33)	(1.18)	(2.87)	(1.30)
0.875 l/ha		0.24	0.05	0.09	0.23	0.13	-0.19
1.75 l/ha		0.44	0	0.23	0.20	0.03	0.05
	LSD	0.09 ***	0.09 ns	0.29 ns	0.14 **	0.36 ns	0.18 *
Basagran effect							
Nil		(2.36)	(1.46)	(1.30)	(1.26)	(2.93)	(1.29)
1.0 l/ha		0.11	0.01	0.08	0.02	-0.05	0.05
1.5 l/ha		0.05	0.02	0.10	0.13	-0.19	-0.12
2.0 l/ha		0.11	0.03	0.36	0.11	0.23	-0.07
	LSD	0.10 ns	0.12 ns	0.33 ns	0.23 ns	0.41 ns	0.21 ns

Table 4.11. Yield response (t/ha) to herbicide treatment by comparison with untreated controls – Treflan/Vindex + basagran sequence (figures in brackets denote control yield (t/ha)).

Treflan	Vindex + Basagran treatment	Bridgets			High Mowthorpe		
		1998	1999	2000	1998	1999	2000
Nil	Nil	(2.46)	(1.41)	(1.56)	(1.11)	(2.35)	(1.20)
	0.5 + 1.0 l/ha	-0.17	-0.08	-0.17	0.08	0.62	-0.03
	0.75 +1.5 l/ha	-0.39	0.04	0.11	0.16	0.79	0.10
	1.0 + 2.0 l/ha	0.03	-0.02	-0.01	0.18	0.16	0.11
0.875 l/ha	Nil	0.11	0	-0.06	0.29	0.72	0.07
	0.5 + 1.0 l/ha	0.08	0.19	-0.16	-0.04	0.82	0.14
	0.75 +1.5 l/ha	0.28	0.06	0.23	0.01	0.82	0.21
	1.0 + 2.0 l/ha	0.18	0	-0.4	0.08	0.82	0.02
1.75 l/ha	Nil	0.33	0.09	0.43	0	1.09	0.06
	0.5 + 1.0 l/ha	0.27	0.10	-0.10	-0.11	0.72	-0.03
	0.75 +1.5 l/ha	0.37	0.18	0.08	0.11	0.52	0.22
	1.0 + 2.0 l/ha	0.45	0.05	-0.16	-0.07	0.73	0.23
LSD Treflan x Vin. +Basag.		0.28 ns	0.19 ns	0.60 ns	0.37 ns	0.62 ns	0.35 ns
Treflan effect							
Nil		(2.33)	(1.39)	(1.54)	(1.22)	(2.74)	(1.25)
0.875 l/ha		0.29	0.08	-0.08	-0.03	0.40	0.06
1.75 l/ha		0.48	0.12	0.08	-0.13	0.37	0.07
	LSD	0.14 ***	0.09 *	0.29 ns	0.18 ns	0.31 *	0.18 ns
Vindex +Basagran effect							
Nil		(2.61)	(1.44)	(1.68)	(1.21)	(2.95)	(1.25)
0.5 + 1.0 l/ha		-0.09	0.04	-0.26	-0.12	0.12	-0.02
0.75 +1.5 l/ha		-0.06	0.06	0.02	-0.01	0.11	0.13
1.0 + 2.0 l/ha		0.07	-0.02	-0.31	-0.04	-0.03	0.07
	LSD	0.16ns	0.10 ns	0.35 ns	0.21 ns	0.36 ns	0.21 ns

4.3. DISCUSSION

Post drilling, surface-applied, Treflan again proved to be a crop safe herbicide option in winter linseed. Treflan gave a useful reduction in the broad-leaved weed flora prior to spring herbicide application in around 60% of cases. Treflan is a cheap herbicide and there is no significant benefit to be gained from reducing application rates in the autumn. As seen in other studies, the benefits of Treflan are greatest where sensitive weed species dominate the weed flora. Where herbicides have a good broad spectrum of weed control, there can be clear beneficial interactions between autumn and spring-applied products to give benefits over and above those obtained from use of products individually, and in some cases these can also be expressed in yield. For example at Bridgets in 1998, failure to apply autumn weed control resulted in an un-recoverable loss in yield potential of 0.35 t/ha when using Ally alone, and 0.45 t/ha when using Basagran alone in spring.

Some of the herbicide products available for use in linseed are very expensive. A yield response of only 0.2 t/ha will cover the application costs for a full dose of Ally, and 0.3 t/ha the costs of a sequences of Treflan and Ally at full label dose rates. In contrast, Basagran requires a yield response of at least 0.5 t/ha to cover costs. However products like Basagran and Vindex are not very effective products for use in winter linseed, because of the large, well established weeds they are required to control. In this situation it is difficult to obtain large yield responses in linseed crops, except in exceptional circumstances, and reducing dose rates reduces the already weakened effectiveness. Use of Ally is the most cost-effective broad-leaved herbicide treatment when weed populations are high, and where Treflan-sensitive weeds dominate the weed flora, dose rates can be greatly reduced with confidence when used with Treflan.

Though Ally did cause some transient crop damage after application, this did not appear to cause any long term problems, effects were quickly outgrown and did not affect yield potential of the crop. However it serves as a warning that herbicides used safely on the spring crop will not necessarily be so benign when used on a winter sown linseed crop, which makes extrapolation of use from spring-sown to winter-sown crops difficult in some circumstances.

5.0. EFFECT OF INCORPORATION OF TRIFLURALIN ON WEED CONTROL AND OVERWINTER SURVIVAL OF WINTER LINSEED

5.0.1. **OBJECTIVE**

To compare the effects of pre-drilling incorporation and post-drilling surface application of trifluralin on weed control and overwinter survival of winter linseed.

5.1. MATERIALS AND METHODS

5.1.1 Sites and soil types

The experiment was located on three sites (Table 5.1). Sites were selected which had a naturally high weed seed burden. These sites typified linseed growing areas on medium textured soils, and up and coming areas of production on heavy soil types. The experiment was run for 2 years on each site (harvest years 1998 and 1999).

Table 5.1. Sites and soil types

Site	Soil Type
Boxworth, Cambs.	Clay – Hanslope series
Bridgets, Hants.	Shallow silt clay loam overlying chalk - Andover series
High Mowthorpe, N Yorks.	Shallow silt clay loam overlying chalk - Andover series

5.1.2. Experiment Treatments

Treatment		Short notation
1.	No Treflan applied, no incorporation cultivation	Untreated
2.	Incorporation cultivation only prior to drilling	Cultivated only
3.	1.75 l/ha Treflan incorporated into soil prior to drilling	Treflan incorporated
4.	1.75 l/ha Treflan applied to soil surface (within 48 hours of drilling)	Treflan post-drilling

Treflan (a.i.= 480 g/l (46% w/w) trifluralin) was applied at the label approved rate of 1.75 l/ha for use in linseed (medium to heavy soils) in a water volume of 200 l/ha. Incorporation (where required) was carried out at each site using equipment detailed below. As linseed is small seeded and sensitive to seedbed conditions, particularly the influence of seed-soil contact and soil moisture content, a control treatment was included where incorporation cultivations were done without applying Treflan, to separate any effects due to cultivation from those due to Treflan application.

Incorporation methods at each site were as follows;
Boxworth - incorporated to 50 mm with one pass of Howard rotovator.
Bridgets – two passes of Dowdeswell power harrow, 2nd pass at right angles to first pass (100 mm deep).
High Mowthorpe - one pass of ‘L’ -blade rotovator to 50 mm.

5.1.3. Design

A randomised block design was used with three replicates at Bridgets and High Mowthorpe and four at Boxworth. Plot sizes were 3 m wide by 24 m long at Bridgets and High Mowthorpe and 4 m wide by 24 m long at Boxworth.

5.1.4. Methods

All sites were ploughed and levelled prior to drilling and herbicide application. Linseed was drilled in either the 2nd or 3rd week of September to avoid excessive overwinter loss, or forward crops more susceptible to lodging. Seedrates were targeted to produce a plant population of 450 plants/m². Post-drilling Treflan treatments were applied within 48 hours of drilling. Plots were monitored for any pest and disease damage and appropriate protective treatments were applied. In the spring, where necessary, plots were oversprayed with a full-label rate dose of Ally (metsulfuron-methyl) to control any remaining broad-leaved weeds. Where cleavers were also a significant problem, Eagle (amidosulfuron) was applied as an overspray in 1999 (after it gained approval for use on linseed in this year). Graminicides were also applied as an overspray where cereal volunteers were deemed to be a significant problem, capable of compromising the results of the study.

5.1.5. Assessments

Linseed populations were assessed in 4 x 0.5 m lengths of row at fixed points in each plot at full establishment and again at the end of March/early April.
Weed populations and weed growth stages were assessed in at the same time as the assessment of linseed plant populations in 10 x 0.1 m² quadrats placed at fixed points in each plot.
At the same time as the above assessments, linseed plants were examined for any evidence of chlorosis or crop stunting, recording the extent and scale of the damage, or any effects on crop vigour. Linseed was also examined at early flowering for any sign of delay in flowering, and prior to desiccation to assess any differences in maturity attributable to herbicide treatments.

Prior to harvest plots were assessed for any lodging damage. Yields were assessed using plot combines.

5.2 RESULTS

5.2.1. Effects on plant populations

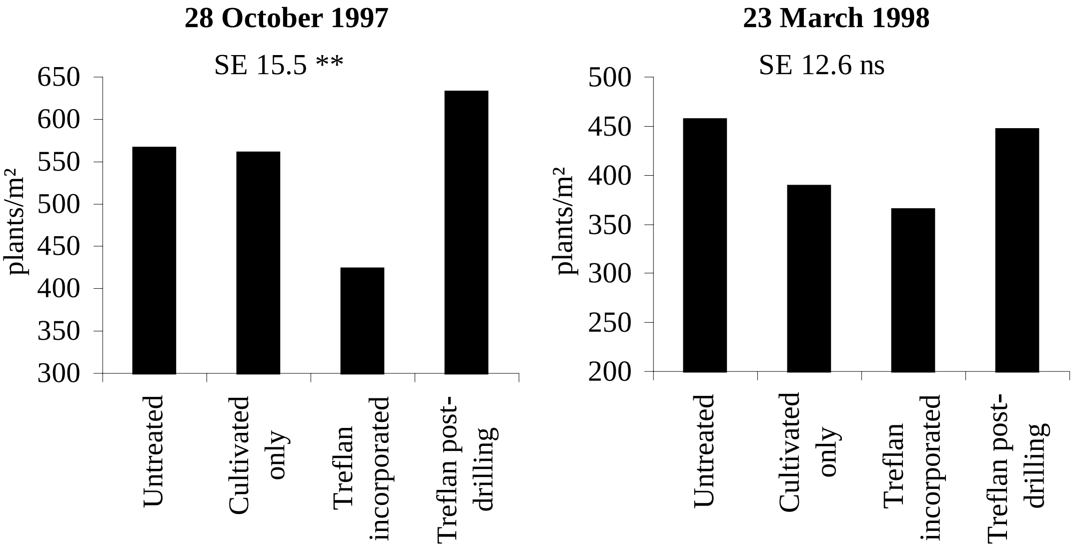
The effects of treatment on plant population at each site are presented in Figures 5.1a to 5.1c. Even in the absence of Treflan application there were significant reductions in plant populations between autumn and spring assessments as a result of overwinter loss. Overwinter loss in untreated plots ranged from 19 to 56% at Boxworth, 31 to 48% at Bridgets and 16 to 34% at High Mowthorpe. In some cases this reduction (e.g. Boxworth in 1999, Fig 5.1a) was large enough to have limited the yield potential of the crop. A spring plant stand of 400 plants/m² is advocated as the optimum post-winter population in normal field situations (Turley *et al*., 1999).

Effects of Treflan on plant populations were greatest in the autumn. At all sites, both in the autumn and spring, plant populations were lowest where Treflan had been incorporated into soil. Significant reductions, compared to the untreated control, were recorded in three out of six site years. A large reduction in plant population due to incorporation of Treflan was observed at High Mowthorpe in 1998/99, with vigour of the crop also reduced. The effect was sufficient to affect final yield potential. The average reduction in plant population due to Treflan incorporation, in both spring and autumn, across all sites and years was 24%. The effects could be clearly attributed to the impact of Treflan, as cultivation alone did not reduce plant populations compared to the untreated control. Where Treflan was applied as a surface treatment post-drilling, plant populations were similar to or higher than those in the untreated plots.

5.2.2. Effectiveness of weed control

In each case studied, where either broad-leaved weeds or susceptible grass-weed species dominated the weed flora present, application of Treflan (by any method) reduced both the autumn and spring total weed burden. In 67% of the cases studied, the reductions achieved were statistically significant compared to the untreated control (Table 5.1). Where significant reductions were achieved, the weed flora tended to be dominated by weed species which were susceptible to Treflan (Table 5.2), for example field speedwell, annual meadow grass or chickweed. Large reductions in weed populations were achieved where grass-weeds dominated the weed flora (e.g. Boxworth), but high natural variability in the populations of weeds such as black-grass made it difficult to attain statistically significant effects due to treatment.

1997/98 Season

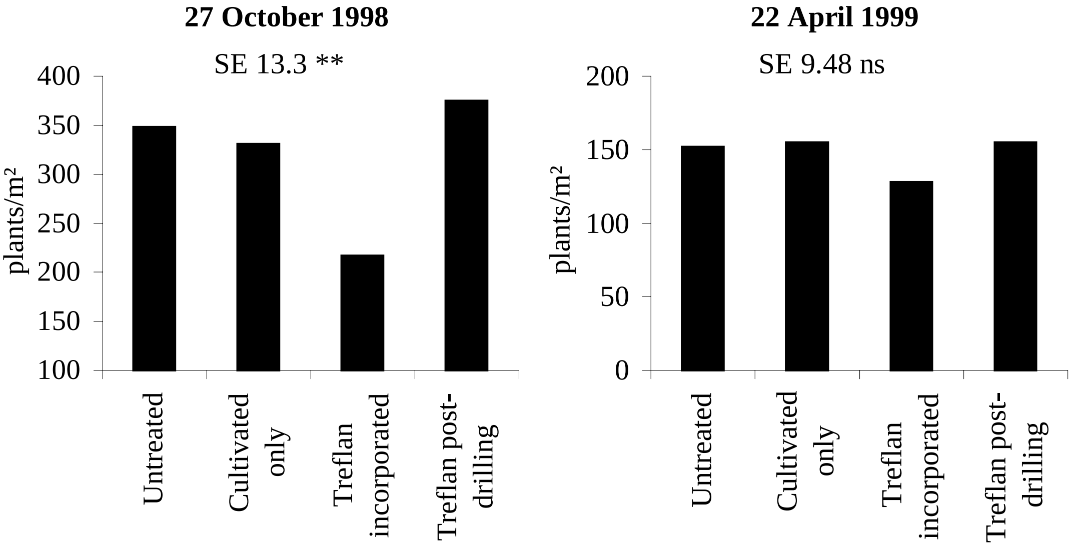

28 October 1997

SE 15.5 **

23 March 1998

SE 12.6 ns

1998/99 Season


27 October 1998

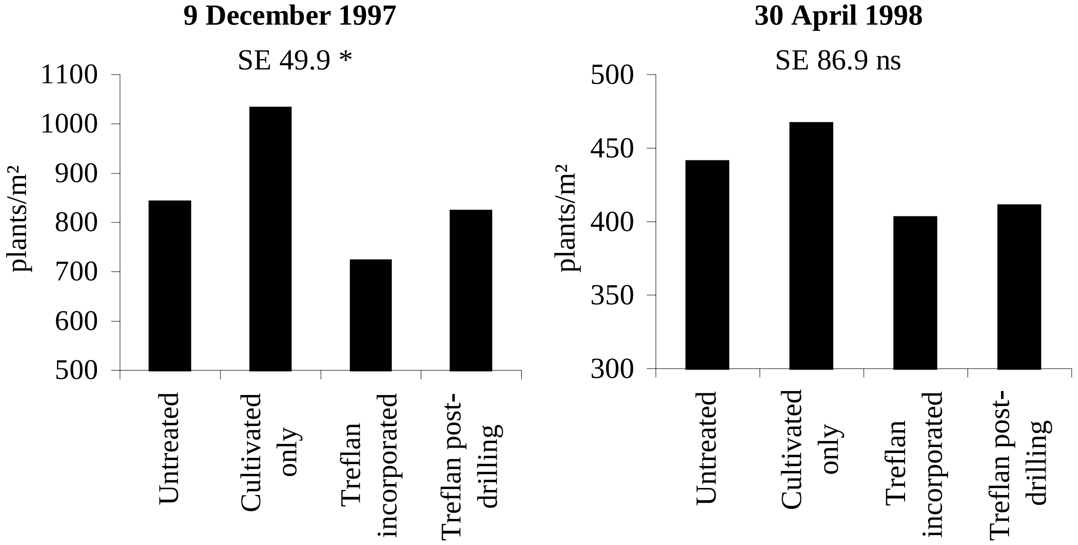
SE 13.3 **

22 April 1999

SE 9.48 ns

Figure 5.1a. Effect of method of Treflan application on autumn and spring plant populations at ADAS Boxworth in 1997/98 and 1998/99.

1997/98 Season



1998/99 Season

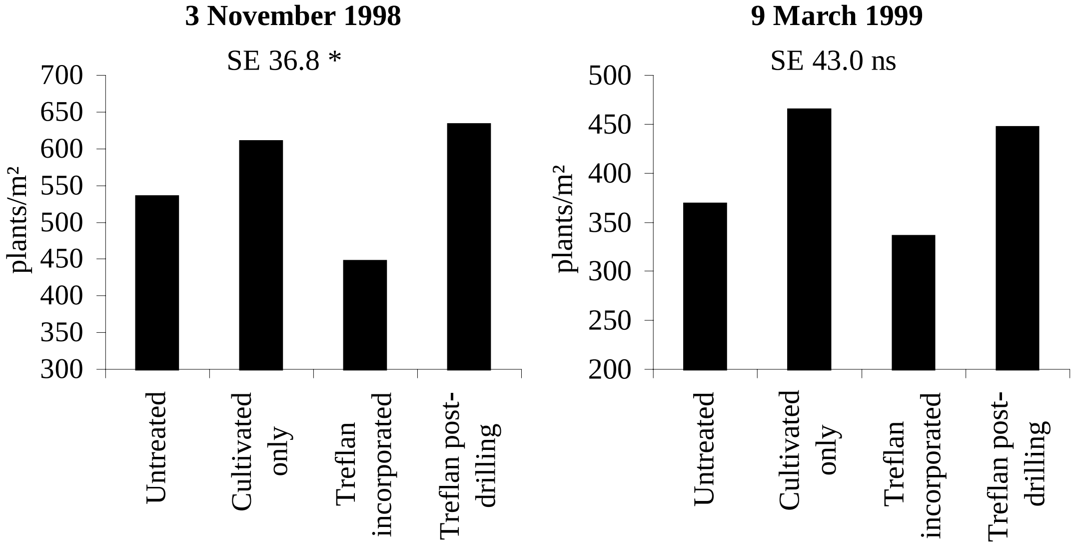
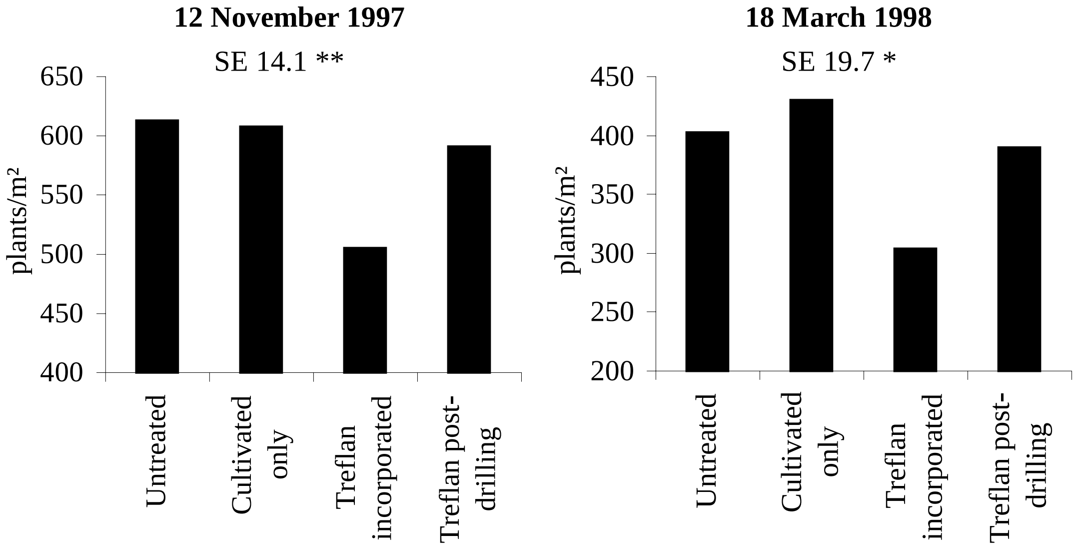


Figure 5.1b. Effect of method of Treflan application on autumn and spring plant populations at ADAS Bridgets in 1997/98 and 1998/99.

1997/98 Season



1998/99 Season

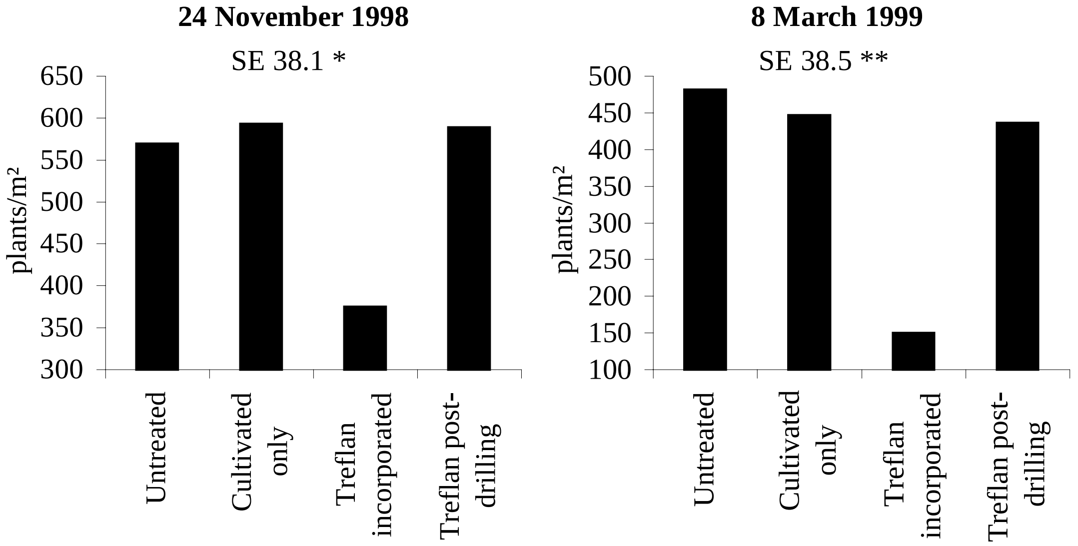


Figure 5.1c. Effect of method of Treflan application on autumn and spring plant populations at ADAS High Mowthorpe in 1997/98 and 1998/99.

Table 5.1. Percent reduction in total autumn and spring weed population, where Treflan incorporated or applied as a surface post-drilling spray, compared to untreated control treatments.

Site:	Boxworth		Bridgets		High Mowthorpe	
Harvest year:	1998	1999	1998	1999	1998	1999
Autumn						
(Untreated population)	18 plants/m²	428 plants/m²	106 plants/m²	24 plants/m²	347 plants/m²	84 plants/m²
Treflan incorporated	44%	46%	42%	67%	76%	81%
Treflan post-drilling	56%	35%	47%	67%	39%	67%
LSD	NS	NS	23% **	33% **	64% *	50% *
Spring						
(Untreated population)	168 plants/m²	157 plants/m²	112 plants/m²	18 plants/m²	226 plants/m²	77 plants/m²
Treflan incorporated	48%	7%	46%	67%	78%	99%
Treflan post-drilling	39%	21%	46%	40%	24%	79%
LSD	26% *	NS	33% *	NS	51% *	67% *

Table 5.2. The most abundant weed species present in untreated control treatments (plants/m² in untreated control in brackets). Shading indicates species is not susceptible to Treflan (i.e. species is not listed as controlled on product label (see Appendix A)).

Site:	Boxworth		Bridgets		High Mowthorpe	
Harvest year:	1998	1999	1998	1999	1998	1999
Autumn	Black-grass (13)	Black-grass (353)	F.Pansy (45)	F.Speedwell (15)	F.Speedwell (169)	Chickweed (54)
	Barren brome (2)	Barren brome (52)	Ann.meadow-grass (22)	Black-grass (4)	Comm. Poppy (170)	Forget-me-not (21)
	Sow Thistle (2)	W.wheat (24)	F.Speedwell (11)	Ann.meadow-grass (2)	Oilseed rape (4)	Comm. Poppy (8)
Spring	Black-grass (112)	Black-grass (140)	F.Pansy (52)	F.Speedwell (12)	Comm.Poppy (102)	Chickweed (51)
	Barren brome (22)	Barren brome (14)	F.Speedwell (16)	Black-grass (5)	F.Pansy (104)	Forget-me-not (15)
	F.Speedwell (15)	W.wheat (3)	Chickweed (12)	Groundsel (1)	F.Speedwell (9)	Comm.Poppy (7)

Table 5.3. Effects of method of Treflan application on post-winter populations of individual weed species.

(shading represents weeds not listed as controlled on label (i.e. not susceptible or no data available))

	Number of plants/m²				
Weed species/ Site and date	Untreated control	Cultivated only	Treflan incorporated	Treflan post-drilling	SE
Annual meadow grass					
Bridgets – 30/4/98	4.0	7.3	0.0	0.0	0.87 **
Bridgets – 9/3/99	0.7	2.0	1.3	0.3	0.4 ns
High Mowthorpe – 8/3/99	1.0	1.0	0.0	0.0	0.37 ns
Black-grass					
Boxworth – 23/3/98	111.8	145.5	43.5	54.3	13.0 ns
Boxworth – 22/4/99	139.5	143.8	136.3	102.5	5.6 ns
Bridgets – 30/4/98	3.0	6.0	0.0	2.3	1.4 ns
Bridgets – 9/3/99	5.3	3.0	0.7	8.0	3.9 ns
Chickweed					
Boxworth – 23/3/98	4.5	4.8	1.5	2.8	0.57 ns
Bridgets – 30/4/98	12.3	11.0	1.3	5.7	2.0 *
High Mowthorpe – 8/3/99	50.7	41.0	1.3	14.3	12.0 ns
Field Pansy					
Bridgets – 30/4/98	52.0	51.7	41.7	41.7	11.7 ns
High Mowthorpe – 18/3/98	104.0	136.3	42.0	160.7	34.2 ns
Field speedwell					
Boxworth – 23/3/98	15.3	27.3	0.8	0.8	4.9 ns
Bridgets – 30/4/98	16.0	13.7	1.3	0.0	2.0 **
Bridgets – 9/3/99	11.7	14.7	0.3	1.0	2.2 **
High Mowthorpe – 18/3/98	8.7	6.3	0.0	0.0	2.3 ns
High Mowthorpe – 8/3/99	1.0	1.7	0.0	0.3	0.5 ns
Forget-me-not					
High Mowthorpe – 8/3/99	15.3	11.3	0.0	1.0	4.7 ns
Fumitory					
Bridgets – 30/4/98	5.3	8.0	1.0	2.0	2.1 ns
Perennial rye-grass					
Bridgets – 30/4/98	4.3	5.0	0.7	0.7	1.0 *
Poppy					
High Mowthorpe - 18/3/98	101.7	109.7	0.0	1.3	6.4 ***
High Mowthorpe – 8/3/99	7.0	6.7	0.0	0.3	1.6 *
Red dead nettle					
High Mowthorpe – 18/3/98	2.0	1.7	0.0	0.0	0.7 ns

On the basis of figures presented in table 5.1, the overall effectiveness of post-drilling applications of Treflan were generally either similar to, or (more often) were less effective than, the traditional incorporation treatment. Though in real terms differences between the two methods of Treflan use were small, as demonstrated below in discussions of effects on individual weed species. In many cases the post-drilling treatment resulted in significant reductions in the total weed burden present. The difference between the two application methods tended to be greatest when Treflan was most effective, i.e. when there were large populations of susceptible broad-leaved weeds present in the flora (e.g. High Mowthorpe), where incorporation of Treflan led to greater reductions in the total weed burden, though in all but one case such differences were not statistically significant.

Where there were high populations of individual weed species common to all treatments, the efficacy of control of individual species was evaluated (Table 5.3). However, skewing of datasets made statistical analysis of treatment differences difficult and these need to be treated with caution. The following comments are based on common trends apparent in the means of each dataset.

Of the weed species found on the three sites, the limited information gained for forget-me-not, fumitory, red-dead-nettle, and the more extensive datasets for annual meadow-grass and field speedwell indicated that there was little difference in efficacy between the two methods of Treflan application. For black-grass and chickweed, the traditional incorporation method appeared to give slightly better control. However with black-grass there was at least one occasion where little or no control was achieved by either method of Treflan application. Of weeds not listed on the Treflan label, field pansy was not controlled by Treflan application. However, populations of perennial rye-grass and common poppy did appear to be significantly reduced by Treflan application.

5.2.3. Effects on yield

Table 5.4. Seed yields at each site in each season (t/ha @ 91% DM).

Site:	Boxworth		Bridgets		High Mowthorpe	
Harvest year:	1998	1999	1998	1999	1998	1999
Untreated	0.38	0.41	2.17	1.58	2.04	3.02
Cultivated only	0.32	0.50	2.14	1.53	2.03	2.90
Treflan incorporated	0.51	0.78	2.43	1.52	2.15	1.47
Treflan post-drilling	0.29	0.44	2.44	1.44	1.97	3.04
SE	0.123 ns	0.050 **	0.122 *	0.094 ns	0.101 ns	0.064 ***

Despite the effects on crop establishment, with few exceptions the effects on crop establishment were compensated for later in the season and yields were not reduced by Treflan application (Table 5.4). The one exception to this was at High Mowthorpe in 1998/99, where incorporation of Treflan reduced spring plant populations by 68%, to an average of 150 plants/m²; below the value of 400 plants/m² seen as optimal for the linseed crop. Where plant populations remained above 300 plants/m², incorporation of Treflan either had little effect on yield or, in some instances, increased yields. Yield responses to black-grass control were inconsistent at Boxworth in both 1998 and 1999 in what were low yielding crops due to lodging in all treatments in 1998, and low linseed plant populations in 1999. Where Treflan was applied as a post-drilling treatment, yields tended to be lower than where Treflan was incorporated. These differences did not relate to effects on weed control (discussed earlier). There was a significant yield response to Treflan application on only two occasions. These occurred at Boxworth in 1999, where there where very high populations of black-grass in the autumn and spring, and at Bridgets in 1998, where there were high populations of field speedwell and chickweed which responded to Treflan treatment.

5.3. DISCUSSION

Treflan is absorbed below ground, in the hypocotyl region of plants (Appendix A), and cloddiness of soil can have an impact on the level of plant exposure to the herbicide. In this study, soil texture appeared to have little influence on the occurrence or severity of overwinter plant kill caused by incorporation of Treflan. Potential differences in the rate at which concentrations of Treflan might migrate in soils, related to clay content, appears to have little overall effect on the scale of overwinter plant loss in the cases studied, though there was considerable year to year variation in the severity of the effect which could perhaps relate to factors influencing migration of the herbicide and accumulation in the vicinity of the hypocotyl of linseed plants in different treatments.

Although Treflan has a limited weed spectrum, it did significantly reduce the overall overwinter weed burden. However, the spectrum and degree of weed control achieved by spring-applied products is far superior and in many cases can negate the need for autumn weed control. The current limitation to a maximum Treflan dose rate of 1.75 l/ha in linseed, compared to 2.1 l/ha in other arable crops also limits the spectrum and efficacy of weed control. For example, the control of black-grass would be improved at higher rates. The current limit on application rate restricts the products usefulness for linseed grown on heavy clay soil types.

In the majority of cases, Treflan treatments were used in sequence with spring herbicide treatments after the final weed assessment. Yield advantages over untreated controls in Table 5.4 relate to gains due to early season weed control. The interactions between Treflan and spring-applied herbicides are examined in more detail in Section 4.0.

Treflan is a relatively cheap herbicide and requires only a small yield response to cover costs when applied as a post-drilling spray (Appendix B). However, the requirement to incorporate Treflan, with up to two machinery passes, adds considerably to the costs of application (an extra £24/ha at current prices), as well as adding to labour time, which makes Treflan an unpopular herbicide choice in other crops. At current prices, a yield response of 0.32 t/ha is required to cover the cost of incorporation of a full rate of Treflan, but only

0.1 t/ha to cover the cost of a post-drilling spray. In this study, in no case was there an economic response to incorporation of Treflan, and only in one case was there an economic response to a post-drilling spray, where very susceptible weeds represented a significant proportion of the weed flora.

Efficacy of Treflan was not significantly affected by method of application where sensitive species were concerned, but effects on linseed were strongly influenced. Post-drilling, surface application must help to limit Treflan concentrations in the vicinity of the hypocotyl region of linseed plants during the critical period of crop establishment and early growth, allowing the crop to safely metabolise the active ingredient. Winter sown linseed exhibits some susceptibility to Treflan, but not enough to be affected by surface application under the conditions encountered to date. Treflan and related products have not been reported as causing similar problems in spring-sown crops. The increased sensitivity of winter crops to Treflan probably occurs as a result of frost damage sensitising the crop to further damage. However, it is difficult to see any clear relationship between minimum air temperatures and/or number of frost days per month (Appendix C) and severity of effects on plant populations. At all sites, there were periods overwinter where there were a considerable number of frosts per month with low minimum temperatures, and successions of months with a large number of frost events. The overwinter conditions encountered at High Mowthorpe in 1998/99, where large reductions in plant populations occurred, were not unusual across the three sites studied. The factors influencing the mechanism by which incorporated Treflan exerts its influence on linseed crops requires further more detailed study.

Treflan has a role to play in winter linseed crops where the weed spectrum is dominated by significant populations of weed species susceptible to the 1.75l/ha dose rate, particularly speedwells and chickweed, or where Treflan is applied as part of a strategy, to be followed by later herbicide treatments. Incorporation of the herbicide poses a serious risk to the crop. Treflan can be safely applied as a post drilling spray without seriously compromising its efficacy. As a result of findings from this and other in-house studies by the manufacturers, Treflan labels have recently been revised to recommended post-drilling applications in winter linseed.

6.0. CONCLUDING DISCUSSION AND IMPLICATIONS FOR GROWERS

The advent of winter-sown linseed has caused weed control problems for agronomists and growers, because of lack of information on safe active ingredients. Similarly the limited number of active ingredients approved for use on the crop limits the strategies available for weed control in the crop.

In a number of cases, Treflan was shown to be a significant aid in reducing the total overwinter weed burden, both in grass-weed and broad-leaved weed dominated situations. Its effects are only limited by particular weaknesses in its spectrum of weed control (i.e. cleaver, charlock, field pansy, common poppy, mayweed and shepherds purse) which means it will need to be used in sequence with spring-applied products in most field situations. Treflan is a cheap herbicide and there is no significant benefit to be gained from reducing application rates in the autumn.

Where herbicides have a good broad spectrum of weed control, there can be clear beneficial interactions between autumn and spring-applied products to give benefits over and above those obtained from use of products individually. These occur where Treflan and spring-applied herbicides interact on the same weed species, or complement weaknesses in the control spectrum of each product.

A linseed yield response of only 0.2 t/ha will cover the application costs for a full dose of Ally, and 0.3 t/ha the cost of a sequence of Treflan and Ally at full label dose rates for use in linseed. In this study, this scale of yield response to weed control was not difficult to achieve. In contrast, Basagran requires a yield response of at least 0.5 t/ha to cover costs. However products like Basagran and Vindex are not very effective products for use in winter linseed, because of the large, well established weeds they are required to control at the time of application. In this situation it is difficult to obtain large yield responses in linseed crops, except in exceptional circumstances, and reducing dose rates reduces the already weakened effectiveness

Where weed populations are high (>40 weeds/m²), Ally will continue to be the most cost-effective broad-leaved herbicide treatment used in winter linseed. Where Treflan-sensitive weeds dominate the weed flora, dose rates of spring herbicides can be greatly reduced with some confidence when Ally is used in conjunction with Treflan. In very low weed populations (10 weeds/m² or less), Treflan alone may be sufficient where sensitive weed species predominate (e.g. field speedwell and chickeweed).

One of the factors that limits the usefulness of Treflan in linseed is the restriction on maximum dose rate to 1.75 l/ha, compared to up to 2.3 l/ha in other crops such as cereals and oilseed rape. Weed control could be increased if the linseed crop could tolerate higher dose rates. As a safer application method, post-drilling application may allow rates of application to be increased in linseed, and this warrants further study.

Though Ally did cause some transient crop damage after application, this did not appear to cause any long-term problems. However, it serves as a warning that extrapolation of use from spring-sown to winter crops is not without potential risk. One of the problems that besets development of minor crops such as linseed is that the initial reliance on off-label or minor crop approvals, that are not always tried and tested, can lead to problems and lack of confidence in a crop before its well established.

Black-grass, brome and volunteer cereals are very competitive in linseed crops. Yield responses to control ranged from 0.29 to 0.74 t/ha in the grass-weed competition study. Relatively high rates of graminicide were required to control barren brome and volunteer cereals in winter linseed if control was delayed until December or later in the season, when these weeds had started to tiller. Black-grass was easier to control and doses of 0.5 l/ha of Laser were very effective in most cases studied. Costs of graminicide application were only recovered where weed populations were very high (i.e. > 70 black-grass plants/m^2). Despite this, costs of control should not be considered in the context of linseed alone, but in the context of rotational control, as grass-weed control is much more cost-effective in break crops than in cereals.

Graminicides were much more effective at controlling grass-weeds than Treflan, which limits the opportunity for any interaction between autumn and spring-applied herbicides, but the effect observed on black-grass head populations by sequences of Treflan and Laser warrants further study. With the advent of widespread herbicide resistance in black-grass, such sequences (from different herbicide groups) could help reduce the build-up of herbicide resistance, though the low rate of Treflan permitted in linseed restricts the usefulness of this technique. Treflan and related products are currently used in wheat in herbicide-resistant situations as a strategic resistance management tool.

It was demonstrated in the study that linseed could tolerate a high level of grass weed competition over the winter period without affecting yield potential. The optimum time for removal of grass-weed competition was when weed biomass had increased to match that of the crop, in practical terms this meant that in most situations grass-weed control could be delayed until March without compromising yield potential. Although it is advisable to remove grass-weed competition as soon as possible in the season, if weather conditions early in the season were likely to affect the crops susceptibility to herbicide damage (i.e. if a period of frosty weather was predicted), then it should be possible to delay weed control until the following spring without any detrimental effects on yield, provided that the linseed crop is healthy and actively growing. However, later application of graminicides reduces the opportunity to use reduced rates. A further difficulty in trying to target application of graminicides early in the season is the slow growth of winter linseed, which consequently delays attainment of the target growth stage for application (typically when the crop is a minimum of 2.5cm tall).

Guidelines on weed control for winter linseed growers

- Grass-weeds are particularly competitive in winter linseed, and control leads to significant yield responses. Economic response to control depends on high grass-weed populations.
- In most cases, removal of grass-weeds can be delayed until March without compromising the yield potential of the crop. Herbicide application timings can therefore be selected with safety of the crop in mind, avoiding periods of frosty weather. However, earlier spraying allows the opportunity to use reduced rates effectively.

- Treflan should not be incorporated into soil prior to drilling winter linseed, but applied as a post-drilling spray.
- Typically, on medium and light textured soils, where the weed flora is dominated by species such as chickweed, field speedwell and even common poppy, application of Treflan should provide a useful reduction in the autumn weed flora.
- There is no benefit in reducing dose rates of Treflan applied in the autumn.
- For control of broad-leaved weeds, of the limited spring herbicide options available, spring application of Ally is most likely to provide an economic return.
- Where Treflan has been applied in the autumn, and sensitive weeds dominate the flora, Ally rates can be reduced by up to 60% (to 10 g/ha) without compromising weed control.
- There is evidence of some complementary activity between autumn Treflan and spring herbicide applications (particularly with Ally) which can lead to better control of the total weed flora than that achieved by each product alone.
- Use of Ally in winter linseed can cause temporary stunting and/or yellowing of the crop. Such effects are transient and do not appear to influence the crop yield potential.
- Relatively high dose rates of graminicide are required to control grass-weeds in winter linseed, particularly where application is delayed until late winter and grass weeds, such as brome and volunteer wheat have started to tiller.
- There was no evidence that autumn application of graminicides caused any damage to winter linseed.
- There is evidence of some interaction between Treflan application and post-emergence graminicide treatments to reduce black-grass head populations.

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APPENDIX A- Broad-leaved weed herbicides for use in winter linseed - their spectrum of control* and mode of activity

Active Ingredients	Trifluralin	Bentazone	Bentazone + Clopyralid + Bromoxynil	Metsulfuron methyl	Amidosulfuron
Product	Treflan	Basagran/Basagran SG	Basagran + Vindex	Ally	Eagle
Concentration of active	480 g/l	480 g/l (SG 87% w/w)	480:240:50 g/l	20% w/w	75% w/w
Label approval (spring linseed)	Yes	Yes	Yes	Yes	Yes
Pre/Post emergence	Pre	Post	Post	Post	Post
Max. possible rate of use	1.75 l/ha in linseed	3 l/ha (SG 1.65 kg/ha)	2+1 l/ha	30 g/ha	40 g/ha
Annual Meadow-Grass	S	R	R	-	-
Annual Nettle	MS	S	S	S	-
Black Bindweed	S	MS	S	MS	-
Black-Grass	S	R	R	-	-
Black Nightshade	R	S	S	-	-
Charlock	R	S	S	S	S
Chickweed	S	S	S	S	-
Cleavers	R	S	S	-	S
Common Orache	MS	MS	MS	MR	-
Common Poppy	-	MS	S	S	-
Corn Marigold	R	S	S	S	-
Corn Spurry	MS	S	-	S	-
Cranesbill	-	S	S	S	-
Creeping Thistle	-	(S)	(S)	S	-
Docks	-	-	-	S	-
Fat Hen	S	MS	S	MS	-
Field Pansy	-	R	MS	MS	-
Field Penny Cress	R	S	S	-	-
Field Speedwell	S	MS	S	MS	-

(cont'd)

(cont'd)

Active Ingredients	Trifluralin	Bentazone	Bentazone + Clopyralid + Bromoxynil	Metsulfuron methyl	Amidosulfuron
Product	Trelfan etc	Basagran/Basagran SG	Basagran + Vindex	Ally	Eagle
Concentration of active	480 g/l	480 g/l (SG 87% w/w)	480:240:50 g/l	20% w/w	75% w/w
Label Approval (spring linseed)	Yes	Yes	Yes	Yes	Yes
Pre-Post Emergence	Pre	Post	Post	Post	Post
Max. Possible Rate of Use	1.75 l/ha	3 l/ha (SG 1.65 kg/ha)	2+1 l/ha	30 g/ha	40 g/ha
Fools Parsley	-	S	S	MS	-
Forget Me Not	-	S	S	MS	S
Fumitory	MS	MS	MS	-	-
Groundsel	-	MS	S	S	-
Ivy-leaved Speedwell	-	MR	-	-	-
Knotgrass	S	MR	MS	MS	-
Mayweed	R	S	S	S	-
Pale Persicaria	S	S	S	S	-
Red Dead Nettle	MS	MS	MS	S	-
Redshank	S	S	S	S	-
Scarlet Pimpernel	S	S	MS	S	-
Shepherds Purse	R	S	MS	S	S
Sow Thistle	R	MS	-	S	-
Volunteer Rape	-	S	S	S	-
Wild Radish	R	S	S	-	-

*Control spectrums taken from product manuals and trials data

Key				
S	Susceptible	MR	Moderately Resistant
(S)	Suppression of top growth only	R	Resistant
MS	Moderately Susceptible	-	No data

APPENDIX A (continued) Mode of activity

Active Ingredient	Mode of action	Biochemistry
Bentazone	Selective contact herbicide, absorbed mainly by foliage, with very little translocation. Absorption by roots possible, resulting in upward translocation	Photosynthetic electron transport inhibitor
Bromoxynil	Selective contact herbicide with some systemic activity. Absorbed by foliage with limited translocation	Inhibits photosynthesis and uncouples oxidative phosphorylation
Clopyralid	Selective systemic herbicide, absorbed by foliage and roots with translocation both up and down plant. Accumulates in meristematic tissue	Auxin-type reaction. Acts on cell elongation and respiration
Metsulfuron-methyl	Selective systemic herbicide absorbed through roots and foliage, with rapid translocation both up and down plant. Stops cell division and growth. Selectivity based on speed of metabolism	Sulfonyl-urea. Inhibits amino acid (valine and isoleucine) biosynthesis
Trifluralin	Selective soil herbicide. Enters seedlings via hypocotyl region. Also inhibits root development	Cell division inhibitor

APPENDIX B – Yield responses required to cover costs of herbicide application (including application)

Costs used in calculations

Herbicide costs:	Other costs:
Treflan - £2.08/l	Cost of spray application - £7.40/ha
Ally - £0.40/g	Linseed crop value - £110/tonne
Basagran - £35.08/l	Typical cost of Treflan incorporation - £24/ha
Vindex – 11.80/l	
Laser - £23.00/l	

All Treflan applied as post-drilling spray unless stated otherwise

Treatment	Cost of chemical and application	Yield response required to cover costs (t/ha)
1.75 l/ha Treflan incorporated	£35.04	0.32
1.75 l/ha Treflan post-drilling	£11.04	0.10
0.875 l/ha Treflan post-drilling	£9.22	0.08
10 g/ha Ally	£11.40	0.10
20 g/ha Ally	£15.40	0.14
30 g/ha Ally	£19.40	0.18
1 l/ha Basagran	£42.48	0.39
1.5 l/ha Basagran	£60.02	0.54
2.0 l/ha Basagran	£77.75	0.71
1 l/ha Basagran + 0.5 l/ha Vindex	£48.38	0.44
1.5 l/ha Basagran + 0.5 l/ha Vindex	£68.87	0.62
2.0 l/ha Basagran + 0.5 l/ha Vindex	£89.36	0.81
0.875 l/ha Treflan plus:		
10 g/ha Ally	£20.62	0.19
20 g/ha Ally	£24.62	0.22
30 g/ha Ally	£28.62	0.26
1 l/ha Basagran	£51.70	0.47
1.5 l/ha Basagran	£69.24	0.63
2.0 l/ha Basagran	£86.78	0.79
1 l/ha Basagran + 0.5 l/ha Vindex	£57.60	0.52
1.5 l/ha Basagran + 0.5 l/ha Vindex	£78.08	0.71
2.0 l/ha Basagran + 0.5 l/ha Vindex	£98.58	0.90

APPENDIX B (cont)

Treatment	Cost of chemical and application	Yield response required to cover costs (t/ha)
1.75 l/ha Treflan plus:		
10 g/ha Ally	£22.40	0.20
20 g/ha Ally	£26.44	0.24
30 g/ha Ally	£30.44	0.28
1 l/ha Basagran	£53.52	0.49
1.5 l/ha Basagran	£71.06	0.64
2.0 l/ha Basagran	£88.60	0.81
1 l/ha Basagran + 0.5 l/ha Vindex	£59.42	0.54
1.5 l/ha Basagran + 0.5 l/ha Vindex	£79.91	0.73
2.0 l/ha Basagran + 0.5 l/ha Vindex	£100.40	0.91
1.0 l/ha Laser	£30.40	0.28
0.75 l/ha Laser	£24.65	0.22
0.5 l/ha Laser	£18.90	0.17
0.25 l/ha Laser	£13.15	0.12
1.75 l/ha Treflan plus:		
1.0 l/ha Laser	£41.44	0.38
0.75 l/ha Laser	£35.69	0.32
0.5 l/ha Laser	£29.94	0.27
0.25 l/ha Laser	£24.19	0.22

APPENDIX C – A) Meteorological information and long-term averages at ADAS Boxworth

1997-98 season

Month	Lowest minimum air temperature (°C)	Date of minimum	No of days with frost (air < 0°C)
September	2.1	22/09/97	0
October	-3.9	30/10/97	5
November	-1.4	1/11/97	1
December	-1.0	3/12/97	9
January	-3.1	23/1/98	8
February	-5.8	2/2/98	4
March	-2.6	9/3/98	5
April	-1.5	14/4/98	4

1998-99 season

Month	Lowest minimum air temperature (°C)	Date of minimum	No of days with frost (air < 0°C)
September	4.6	13/9/98	0
October	0.3	18/10/98	0
November	-4.8	18/11/98	8
December	-3.1	21/12/98	9
January	-3.8	12/1/99	6
February	-5.0	9/2/99	9
March	-2.7	11/3/99	2
April	-2.5	14/4/99	3

1999-00 season

Month	Lowest minimum air temperature (°C)	Date of minimum	No of days with frost (air < 0°C)
September	5.6	16/9/99	0
October	1.6	6/10/99	0
November	-0.6	18/11/99	1
December	-5.5	20/12/99	12
January	-4.8	25/1/00	12
February	-2.0	20/2/00	5
March	-2.1	4/3/00	3
April	-2.3	6/4/00	5

APPENDIX C – B) Meteorological information and long-term averages - ADAS Bridgets

1997-98 season

Month	Lowest minimum air temperature (°C)	Date of minimum	No of days with frost (air < 0°C)
September	2.4	14/9/97	0
October	-3.6	31/10/97	5
November	-3.8	1/11/97	6
December	-4.2	5/12/97	12
January	-3.4	29/1/98	12
February	-5.6	4/2/98	7
March	-2.0	23/3/98	6
April	-3.1	13/4/98	4

1998-99 season

Month	Lowest minimum air temperature (°C)	Date of minimum	No of days with frost (air < 0°C)
September	3.7	12/09/98	0
October	0.3	18/10/98	0
November	-2.4	17/11/98	8
December	-5.0	06/12/98	7
January	-4.1	12/01/99	6
February	-5.7	13/02/99	10
March	-3.3	10/03/99	7
April	-2.7	14/04/99	5

1999-00 season

Month	Lowest minimum air temperature (°C)	Date of minimum	No of days with frost (air < 0°C)
September	6.2	10/09/99	0
October	-1.4	06/10/99	5
November	-2.8	30/11/99	3
December	-10.8	20/12/99	11
January	-8.2	27/01/00	17
February	-4.9	20/02/00	7
March	-3.4	05/03/00	10
April	-2.3	08/04/00	4

APPENDIX C – C) Meteorological information and long-term averages at ADAS High Mowthorpe

1997-98 season

Month	Lowest minimum air temperature (°C)	Date of minimum	No of days with frost (air < 0°C)
September	4.1	13/09/97	0
October	-6.8	22/10/97	2
November	0.3	22/11/97	0
December	-3.4	02/12/97	5
January	-2.7	28/01/98	6
February	-2.7	03/02/98	5
March	-2.9	09/03/98	6
April	-2.1	16/04/98	5

1998-99 season

Month	Lowest minimum air temperature (°C)	Date of minimum	No of days with frost (air < 0°C)
September	5.1	12/09/98	0
October	-1.3	18/10/98	2
November	-0.6	05/11/98	4
December	-3.8	6 & 21/12/98	9
January	-3.8	12/01/99	9
February	-4.5	09/02/99	11
March	-1.1	11/03/99	2
April	-3.3	14/04/99	3

1999-00 season

Month	Lowest minimum air temperature (°C)	Date of minimum	No of days with frost (air < 0°C)
September	3.8	15/09/99	0
October	1.5	06/10/99	0
November	-0.6	18/11/99	3
December	-5.2	20/12/99	14
January	-5.3	10/01/00	5
February	-2.7	17/02/00	5
March	-3.2	04/03/00	5
April	0.6	15/04/00	3