SESSION 8D

WEED CONTROL IN NON-CEREAL CROPS

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Poster Papers 8D-1 to 8D-11

COMPETITIVE EFFECTS OF WEEDS IN LINSEED

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ABSTRACT

The competitive effects of oats (*Avena sativa*) (simulating *Avena fatua* (wild-oats)), *Stellaria media*, *Chenopodium album* and *Polygonum aviculare* on spring-sown linseed were studied in five experiments between 1992 and 1995. The oats were included in all four years and were particularly competitive. Their behaviour was found to be similar to *Avena fatua*. *P. aviculare* was also highly competitive but the other two species *S. media* and *C. album* were less damaging. The *S. media* appeared to form a mat at the base of the crop that had little effect on crop growth. The *C. album* plants never became very vigorous, which was surprising as this weed can be very competitive in other crops. This may be due to the late sowing of linseed and the dry conditions experienced in two of the four seasons. Preliminary economic analysis indicates that herbicide costs would be recouped by treating infestations in excess of 12 oats, 7 *P. aviculare*, 124 *S. media* and 17 *C. album*/m^2.

INTRODUCTION

The etiolated and sparse growth habit of the spring-sown linseed crop make it likely that this crop, despite the high plant densities recommended, would not be strongly competitive against weeds (Lutman, 1991). Thus, some form of weed control would seem to be essential to prevent loss of yield. However, whether these suppositions are in fact true has not been substantiated by relevant investigations. Although the high level of support for linseed in the EU has tended to discourage European farmers from pursuing the optimisation of inputs as intensively as they have in cereal crops, decreasing support and increasing costs make it necessary to look more closely at the inputs required for linseed. There is a particular need to establish the effects that weeds have on the productivity of linseed, so that the costs and benefits of weed control can be properly evaluated.

Research on weed control in linseed in Europe has been limited, but the extensive production of the crop in Canada has stimulated some research (Friesen, 1986, 1988; Friesen *et al*, 1990). However, differences in the climate between the flax/linseed growing areas of Canada and those in Europe make it difficult to extrapolate from one to the other. In the UK, Hack has demonstrated that the allied crop, flax, was very sensitive to competition from volunteer barley (Marshall *et al.*, 1995). Grass weeds such as cereal volunteers and *Avena fatua* certainly pose a threat to linseed, because of their vigorous growth habit. It is less clear whether the less competitive broad-leaved species such as *Stellaria media* (common chickweed), *Veronica* spp. (speedwells), *Polygonum aviculare* (knotgrass) and even *Chenopodium album* (fat-hen) are sufficiently competitive always to warrant control. This paper reports a series of five experiments designed to investigate the competitive effects of several weed species on linseed. Some of the work was part of a wider project, funded by the Home-Grown Cereals Authority to investigate the effects of weeds on linseed, recently summarised by Carver *et al.* (1997).

MATERIALS AND METHODS

Five experiments were carried out on the farm of IACR-Rothamsted between 1992 and 1995, on a clay loam soil. Each experiment investigated the competitive effects of up to three weed species selected from four candidate weeds: cultivated oats (*Avena sativa*) (simulating *A. fatua* (wild oats)), *S. media*, *C. album*, *P. aviculare*. Details are given in Table 1. A range of densities of the desired weeds was established by broadcasting weed seeds onto the 3 x 10 m plots, prior to drilling. The *P. aviculare* seed were pretreated in a refrigerator at *c.* 3°C for four weeks, prior to sowing, to break the dormancy of the seeds. Between 12 and 15 weed infested plots plus at least three weed free controls, laid out in three randomised blocks (except in Expt 1995b where there were only two), were established for each weed in all experiments. Unwanted weeds were removed by hand or with appropriately selective herbicides. With the exception of weed control, the linseed experiments were treated as conventional commercial crops. Weed densities were assessed towards the end of May or in early June, depending on the season and the weed species, using a number of random quadrats/plot. Quadrat sizes were altered according to the weed densities. Crops were harvested by hand, when mature, from 1 or 2 m^2 quadrats and yields were determined at 9% moisture after processing through a static thresher. Intermediate samples were also taken at least twice between May and August to record crop and weed growth, but because of limitations of space are not presented in this paper. Details are published in the report by Carver *et al.* (1997).

Table 1. Experimental details

Year	1992	1993	1994	1995a	1995b
Sowing date	22 April	29 April	26 April	20 April	21 April
Harvest date	8 August	12/13 Sept.	2 Sept.	22 August	16 August
Weed species and density range (plants/m^2)	oats 6-119 *S. media* 57-465	oats 6-65 *C. album* 2-32 *P. aviculare* 2-18	oats 9-150 *C. album* 6-55 *S. media* 57-260	oats 10-174 *P. aviculare* 20-145	*S. media* 50-650
Nitrogen	76 kg/ha	75	75	80	80
Linseed density (plant no./m^2)	294	350	572	283	242
Weed free yields	1.62 t/ha	2.36	0.93	1.11	1.35

Yield responses have been related to weed density using either a linear regression or a hyperbolic regression equation based on that proposed by Cousens (1985). His model has the following form: yield loss = Id/(1 + Id/A), where d = weed density, A = asymptotic (maximum) yield loss, I = yield loss/plant as weed density approaches zero. The Rothamsted Maximum Likelihood Programme (MLP) (Ross, 1978) was used to plot these models. The hyperbolic model was selected when it was clear that the data were following a hyperbolic response. From the analyses four relevant pieces of information have been selected:

i) the % variance accounted for, which identifies how well the data fit the model
ii) the I value from the Cousens equation, which shows how competitive the weeds are at low densities of the hyperbolic response
iii) the number of weeds causing a 5% yield loss
iv) the % yield loss caused by 20 weeds/m^2

The latter two pieces of information identify how competitive the individual species were at realistic field densities and ones that would approach an economic threshold for control.

RESULTS AND DISCUSSION

Table 2. Rainfall (mm) in summers 1992-95, compared to the 30 year mean (1960-90)

Month	1992	1993	1994	1995	30 year mean
April	64	89	65	11	53
May	103	45	69	28	53
June	36	131	18	28	57
July	62	59	23	19	47
August	114	39	54	2	53

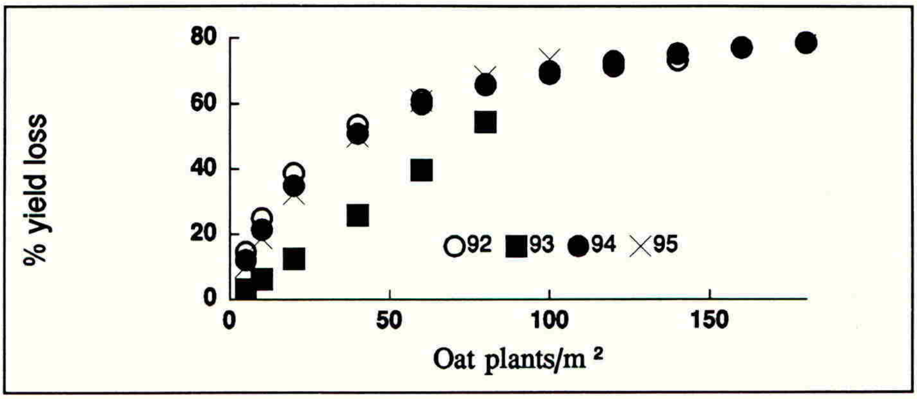

Fig.1. Calculated relationship between oat density and yield loss for four years 1992-95

The growth of the crops and weeds was significantly influenced by the weather experienced over the four seasons, particularly the rainfall (Table 2). The very dry summers of 1994 and 1995 reduced crop and weed growth appreciably and this may have affected the apparent competitiveness of the weeds. Regression relationships were calculated for all weeds in each year but only the raw data for the oat experiments are presented in the paper (Fig. 1), to provide an example of the types of responses observed.

Table 3. The responses of linseed to the four weed species, demonstrated by the I value (% yield loss/plant as weed density approaches zero), number of weeds to cause a 5% yield loss, and the yield loss caused by 20 weeds/m^2. Quality of the regression analyses are shown by the % of the error accounted for by the regression (% va) and by the standard errors (in parentheses) for the yield loss values.

Weed species	Year	% va	I	Weed plants/m^2 causing a 5% yield loss	% Yield loss caused by 20 weeds/m^2
Oats	92	94 (hyp)*	3.51	1.51 (0.436)	38.7 (4.67)
	93	81 (lin)		7.38 (0.813)	13.2 (1.42)
	94	93 (hyp)	2.72	1.89 (0.569)	34.9 (5.47)
	95	95 (hyp)	2.38	2.26 (0.535)	32.4 (4.56)
S.media	92	36 (lin)		82.7 (27.3)	1.21 (0.398)
	94	30 (lin)		66.2 (23.5)	1.51 (0.536)
	95	96 (lin)		37.8 (2.12)	2.64 (0.148)
P.aviculare	93	67 (lin)		4.78 (0.759)	20.9 (3.32)
	95	70 (hyp)	2.63	2.11 (2.172)	25.5 (9.73)
C.album	93	80 (hyp)	4.28	1.43 (0.787)	20.9 (2.48)
	94	21 (lin)		15.1 (6.77)	6.62 (2.96)

* hyp = rectangular hyperbolic regression model.
lin = linear regression model

Oats

The oats were studied in each of the four years and so should reflect the effects of weather on the competitive effects of the weeds. In all years the oats had a clear effect on the linseed, following a hyperbolic response in all years except 1993 which demonstrated only a linear relationship, but where the highest oat density was only 65 plants/m^2 (Fig. 1). In the other three years the yield losses caused by the oats were very similar. The I values only ranged between 3.51 and 2.38 and the number of weeds causing a 5% yield loss from 1.51-2.26 (Table 3). The oats were very competitive in 1992, 1994 and 1995 but were less so in 1993. This is not clearly correlated with the weather, as rainfall in 1992 and 1993 was higher than in 1994 and 1995 (Table 2). Samples taken in mid-July showed that the weed free crop was most vigorous in 1993 (638 g/m^2 in 1993, 486 g in 1992, 307 g in 1994 and 283 g in 1995). This may account for the lower competitive effect of the oats in 1993. Overall, 5% yield losses could be expected from 3.3 oat plants/m^2. Oats were chosen as mimics for *A. fatua*, but without the germination and persistence problems associated with the genuine weed. In 1993 and 1994 two additional treatments with *A. fatua* were included in the experiments. The competitive impact of equivalent densities of the two oat species were similar, indicating that the cultivated species reflected the behaviour of its wild relation (see Carver *et al.*, 1997).

S. media

In two of the three years when this weed was studied, the relationship between yield loss and weed density was poor (Table 3). Consequently, the standard errors of the estimates of yield loss were also very large. S.media had a marked effect on the growth of the crop only in 1995. In all three seasons the number of weeds causing a 5% yield loss was much larger (38-83 plants/m^2) than those recorded for oats. In all three experiments the response appeared to be linear, even in 1995 when the highest density was 650 plants/m^2. This weed was surprisingly uncompetitive. Observations of the plots indicated that a mat of *S.media* developed in the base of the crop, but this did not appear to affect the development of the linseed plants. The reasons may be that firstly, there was little competition for light from the shorter weed. Secondly, the crop needs little nitrogen, which this nitrophyllic weed extracts efficiently from the soil, and thirdly the shallower rooting of *S.media* meant that the crop's ability to acquire moisture was not greatly impeded. Overall, 5% yield loss was caused by 62 plants/m^2.

P. aviculare

In 1993, weed establishment was poor, but despite the maximum density of only 18 plants/m^2 a significant response was recorded on the linseed. The establishment of the weed was better in 1995. *P. aviculare* was as competitive as the oats and was more so than *S. media*. The 5% yield loss was caused by 2.1-4.8 *P. aviculare* plants/m^2.

C. album

The data collected for this weed were not as good as those for the others. In 1993 the maximum weed density was only 32 plants/m^2 and the response curve was rather atypical, as it was very steep initially, then flattened out at about 10 plants/m^2 at 20% loss of yield and then did not change thereafter. There was a very poor relationship in 1994, but weed competition appeared relatively low. The number of weeds apparently causing a 5% yield loss was 1.4 plants/m^2 in 1993 and 15.1 in 1994.

CONCLUSIONS

The considerable competitive effect of the oats in these experiments was expected as grass weeds and volunteer cereals are particularly aggressive weeds in spring-sown crops (Lutman *et al.*, 1994). *P. aviculare* was also highly competitive in these studies, although it was only studied in two trials. The wider data set reported by Carver *et al.* (1997) also concluded that this weed was as competitive as oats. That *C. album* was so poorly competitive was surprising as this can be a tall aggressive species. However, the *C. album* plants in these late April planted linseed crops were nowhere near as vigorous as those that appear in earlier planted, more highly fertilised crops such as sugar beet. Individual plants tended to be weak and spindly. This may be associated with the late sowing date or could be related to the rather dry conditions, particularly in 1994. Further work is needed to confirm the rather low competitive effect of this weed. *S. media* was also very poorly competitive on a per plant basis, but as natural infestation levels frequently exceed 100 plants/m^2 its control in natural situations may still be economically justified.

The critical conclusion of this type of work is identifying infestation levels that would be economic to treat with herbicides. Calculations based on the average yields of the weed free crops in the five trials (1.47 t/ha), the crop value (*c.* £120/t) and the costs of relevant herbicides for the control of the broad-leaved and grass weeds, indicate that herbicides costs would be recouped by treating infestations in excess of 12 oats (or *A. fatua*), 7 *P.aviculare*, 124 *S. media* and 17 *C. album*/m^2.

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EVALUATION OF PRE- AND EARLY POST-EMERGENCE HERBICIDES FOR USE IN WINTER LINSEED IN ENGLAND

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ABSTRACT

There are few herbicides with approval from UK regulatory authorities for use on winter linseed. A range of autumn pre- and early post-emergence herbicide treatments were compared on a silty clay loam soil in southern England. These included pre-emergence treatments of trifluralin, linuron, linuron + lenacil, linuron:trifluralin and metazachlor and post-emergence treatments of cyanazine and bentazone + clopyralid:bromoxynil. There were significant reductions in plant population and crop vigour resulting from pre-emergence treatments of metazachlor and linuron + lenacil and from the autumn post-emergence herbicides. In a second experiment, trifluralin at two doses was applied as incorporated pre-drilling or post-drilling, pre-emergence treatments. There were significant reductions in linseed population when trifluralin was incorporated, particularly at the higher, 840 g a.i./ha dose. Autumn post-emergence treatments performed poorly. Whilst some pre-emergence treatments gave effective weed control, they lacked flexibility, particularly in crops, such as winter linseed, where over winter survival of the crop cannot be guaranteed. Incorporation of trifluralin caused significant crop loss, emphasising the dangers of relying upon off-label approvals when optimum application rates and conditions for the use of herbicides in new crops are not clearly identified.

INTRODUCTION

Winter linseed is a relatively new crop in England, with circa 20,000 ha sown commercially in autumn 1996. Whilst there is a thorough understanding of crop production techniques for the spring sown crop which is grown for both industrial oil uses and fibre, there is limited experience of winter linseed, particularly in terms of effective control of weeds.

Linseed production within the EU is supported through area payment subsidies of approximately £520/ha, whilst the output from seed sales is only £320-£370/ha. Growers therefore seek to minimise input costs, including those for herbicides, the most important agrochemical input.

UK government research on winter linseed began in 1994 and demonstrated the benefit of early sowing in the autumn, between early September and early October. Early sowing increases the risk of competition from both broad-leaved and grass weeds, and autumn sowing extends the growing season over which weeds must be controlled up to 10-11 months. Linseed competes poorly with weeds, reducing crop yields (Courtney, 1986). Whilst the crop can tolerate cold conditions during the winter, growth slows and plants are often stressed, a factor which could increase the risk of crop damage.

Current recommendations for herbicide use rely on approvals derived from the spring linseed crop and off-label 'minor crop use' approvals derived from oilseed rape. Linseed is traditionally sown on lighter soil types. Most spring sown linseed is treated with metsulfuron-methyl for the control of broad-leaved weeds, but even though approved, metsulfuron-methyl reduces crop vigour (Freer, 1991). Sulphonyl urea's are not approved in the UK for use before 1 February in the year of harvest, so their use is limited to spring treatment of winter linseed. There is, therefore, an urgent need to identify appropriate herbicides and programmes for effective control of broad-leaved weeds in autumn sown linseed.

MATERIALS AND METHODS

Two field experiments were carried out at the ADAS Bridgets Research Centre in Hampshire in autumn 1996. Winter linseed cv. Oliver was sown in both experiments at 75.5 kg/ha (1251 seeds/m^2). All herbicides were applied in 200 litres/ha water, through Lurmark SD02-F110 nozzles at 2 bar using an Oxford Precision pressurised sprayer mounted on an Avocet toolframe. Plots were 3 m x 12 m and arranged in randomised block designs with three replicates per treatment. Plant populations were recorded on 8 November and 25/26 March by measuring 5 x 1 m lengths of rows per plot. Crop vigour was assessed by visual scores on 8 November and 25/26 March (0-9, 9=healthy). Weed populations were counted on 5 December and 28 April in experiment 1 and on 2 December and 28 April in experiment 2 in 4 x 0.25 m^2 quadrats per plot. Meteorological data was obtained from an on-site recording station. Data was analysed using analysis of variance (Genstat version 5).

Experiment 1 compared pre-emergence herbicides applied on 9 October with early post-emergence treatments on 14 November (Table 1). There were three untreated plots per block.

Table 1. Herbicide treatments - experiment 1

Treatment	Herbicide	Dose (g a.i./ha)		
Pre-emergence				
1-3	Trifluralin	420	840	1260
4-5	Linuron	375	750	
6-7	Metazachlor	375	750	
8-9	Linuron:trifluralin	186:336	371:672	
10	Linuron + lenacil	840 + 896		
Post-emergence				
11	Cyanazine	625		
12	Bentazone + clopyralid:bromoxynil	960 + 240:50		
13	Untreated			

In experiment 2 incorporated pre-sowing and post-drilling surface treatments of trifluralin at two doses, 840 and 420 g a.i./ha, were compared in a crop of winter linseed sown on

2 October. There were no untreated plots. The site was ploughed, cultivated with tines and rolled prior to herbicide treatment. Trifluralin was incorporated to 5 cm soil depth with a power harrow and seed sown 1-1.5 cm deep using a Fiona D784 drilled fitted with Suffolk coulters. Surface herbicide treated plots were also power harrowed. Two bulk soil samples, consisting of 25 sub-samples, were taken at sowing to determine soil moisture and nutrient contents.

RESULTS

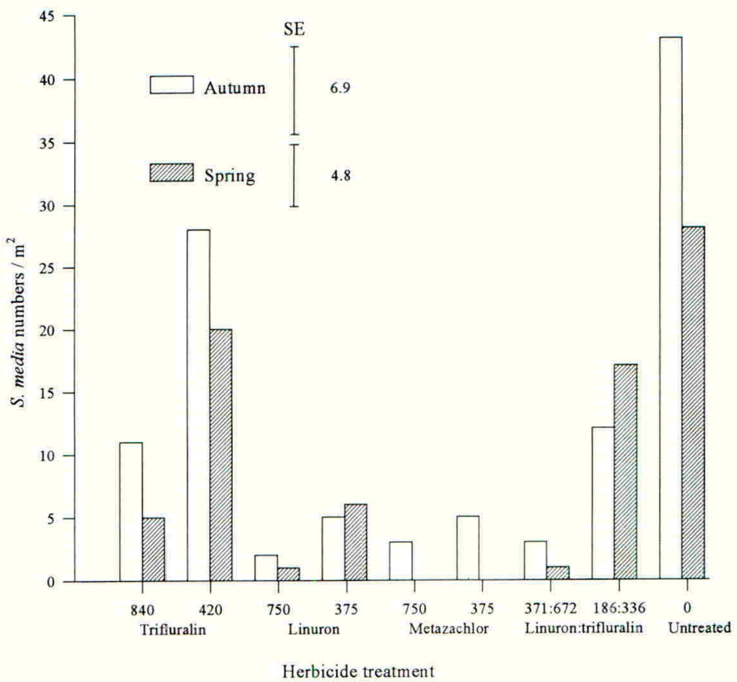
The effect of herbicide treatment in experiment 1 on crop emergence (as a percent of seeds sown), and on crop vigour score (0-9, 9=healthy) in autumn and spring is shown in Table 2.

Table 2. Effect of herbicide treatment on plant population and crop vigour, experiment 1

Herbicide	Dose (g a.i./ha)	Crop vigour score (0-9, 9=healthy)		Crop emergence (%)	
		8 Nov	25 Mar	8 Nov	25 Mar
Pre-emergence					
Trifluralin	1260	8.0	7.0	61	24
Trifluralin	840	8.0	7.3	52	25
Trifluralin	420	8.0	6.7	51	27
Linuron	750	8.0	7.0	59	29
Linuron	375	8.0	6.7	56	26
Metazachlor	750	8.0	0.7	51	4
Metazachlor	375	8.0	4.7	56	14
Linuron:trifluralin	371:672	8.0	7.0	60	27
Linuron:trifluralin	186:336	8.0	7.0	52	30
Linuron + lenacil	840 + 896	8.0	3.7	57	17
Post-emergence					
Cyanazine	625	-	0	-	1
Bentazone + clopyralid:bromoxynil	960 + 240:50	-	4.7	-	23
Mean of untreated	-	8.0	6.7	58	25
SEM (26 df/30 df) herbicide treatments				3.0	2.2
Probability				0.154	<0.001

The dominant broad-leaved weeds species were *Stellaria media, Viola arvensis, Papaver rhoeas* and *Fallopia convolvulus,* but others, including *Veronica persica* and *Senecio vulgaris* were observed, as were *Alopecurus myosuroides* and barley volunteers. Pre-emergence treatments of linuron, metazachlor, trifluralin:linuron and trifluralin controlled *S. media* and *P. rhoeas*, but none controlled *V. arvensis,* a non-competitive but common weed on this soil type. Trifluralin was less effective in reducing numbers of *S. media* and by April numbers of this weed had increased following the reduced dose trifluralin and linuron:trifluralin treatments, suggesting that their chemical activity was declining, but numbers of *P. rhoeas* remained low. A summary of the effect of core herbicide treatments on *S. media* is shown in Figure 1.

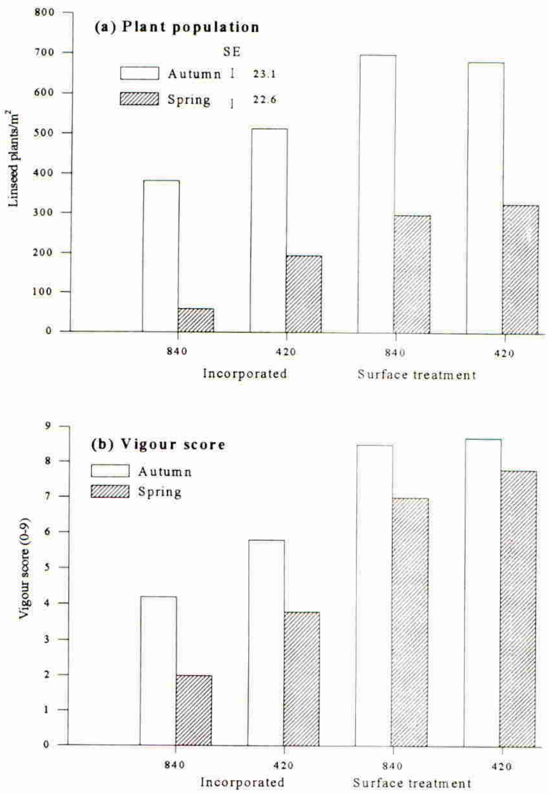
Figure 1. Effect of a range of autumn pre-emergence herbicides (g a.i./ha) on *S. media* numbers (m^2) in late autumn and spring.



In experiment 2, soil conditions were dry at sowing (average soil moisture 18.8% in the 0-5 cm soil layer. Soil analysis confirmed the site as a silty clay loam soil (overlying chalk) with pH 8.2, P 10 mg/litre, K 128 mg/litre, Mg 30 mg/litre, OM% 3.9 and $CaCO_3$ content of 44.0%.

The only weeds surviving treatment were *V. arvensis* (11-40 m^2) and *S. media* (<1 m^2). Control of *V. arvensis* was significantly improved by incorporation of trifluralin and by increasing the dose from 420 to 840 g a.i./ha. However, incorporation of trifluralin significantly reduced plant population (P<0.001) in both the autumn and spring and also reduced crop vigour. There was a significant interaction between dose and application method on plant population in both the autumn (P=0.005) and spring (P=0.041). Increasing the dose from 420 to 840 g a.i./ha significantly reduced plant populations when incorporated, but not when applied as post-drilling surface treatments. The effect of trifluralin treatments on plant population and crop vigour in autumn and spring is shown in Figs. 2a and 2b.

Figures 2a and 2b. Effect of trifluralin at two doses (g a.i./ha) applied as incorporated or surface treatments on (a) linseed population (m^2) and (b) crop vigour (0-9, 9=healthy) in autumn and spring.



DISCUSSION

In experiment 1 there was no effect of herbicide treatment on emergence or early crop vigour one month after treatment, but by March significant differences were observed. Plant populations were reduced by metazachlor, linuron + lenacil and cyanazine treatments. These also reduced crop vigour, as did the post-emergence bentazone plus clopyralid:bromoxynil treatment. Whilst growers normally prefer to wait and take into account weed number and species, the results clearly demonstrate the difficulty of this post-emergence approach. Autumn growth was slow and at the application date in mid-November, the crop was at GS1.1, approximately 5 cm high and increasingly cold and wet weather conditions probably exacerbated crop damage. Linuron, linuron:trifluralin mixtures and to a lesser extent trifluralin alone, gave effective control of the main broad-leaved weeds and the choking species *S. media* suggesting they would be useful alone or as a component in herbicide sequences.

Crop assessments in experiment 2 showed a consistent reduction in plant numbers and crop vigour from incorporation of trifluralin compared to a pre-emergence surface treatment at the same dose. At the lower dose of 420 g a.i./ha, trifluralin controlled the main weeds at the site and showed no obvious reduction in crop vigour when applied as a surface treatment. Even accepting that weed control would not be as effective without incorporation, this was obviously the best option for growers. The soil analysis results indicated a high $CaCO_3$ content and on such soils a low dose of trifluralin is recommended regardless of crop choice. Off-label approvals allow treatment with up to 1 104 g a.i./ha of trifluralin for linseed, but for spring linseed on light soils the recommended dose is reduced to 576 g a.i./ha.

Winter linseed must still be considered a risky crop and over-winter survival cannot be guaranteed. Whilst the results from both experiments indicated good autumn emergence, plant populations fell for all treatments, including untreated, over the winter period. The severest weather was in January with a minimum temperature of -10.1°C, but there were frosts each month from November to April. The interaction between crop stress and weather conditions at and following herbicide treatment are important if this results in crop loss. When selecting a herbicide programme growers should consider their options for following crops in the event of crop failure. Whilst trifluralin controlled weeds at the experiment site, there are restrictions on following crops, for example cereals cannot be sown until the autumn after treatment.

In the UK, there are currently no investigations into the possible interactions between frost stressed winter linseed and the potential risk of crop damage resulting from herbicide treatment. Herbicide tolerance in winter linseed appears to be marginal for several of the products available for legal use under minor crop approvals. These factors need to be carefully considered when deciding upon a herbicide strategy in the crop.

Whilst most researchers would agree that linseed is a poor competitor against weeds, weediness and lack of crop competitiveness does not automatically relate to large yield losses. This is particularly the case at low weed populations (Freer, 1991). There may be opportunities for growers to use lower doses of herbicides for broad-leaved weed control in the autumn in order to reduce weed competition effects until spring, when a wider and more effective range of herbicides, such as sulphonyl urea's, are available. This strategy also has the additional advantage that expenditure is minimised until crop survival is assured.

Winter linseed is a relatively new crop and therefore relies more heavily on farmers' management skills if it is to perform well. At present options for chemical weed control in the autumn are not straightforward, but growers can minimise problems in several ways. They can select field sites with historically low levels of problem weeds, avoid fields in frost pockets and take due account of soil type differences which impinge upon herbicide activity. Further research is required to identify appropriate doses for individual circumstances, both by estimating potential crop loss from autumn weed competition and evaluation of herbicide effects on crop population and vigour, if the crop's full potential is to be exploited in England.

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WEED CONTROL IN NEW INDUSTRIAL OILSEED SPECIES

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ABSTRACT

A range of herbicides were applied to the species *Calendula officinalis*, *Euphorbia lagascae*, *Lesquerella grandiflora* and *Lunaria annua*, in comparison with untreated and hand weeded controls, to identify crop safe herbicide options and the responsiveness of the species to weed competition. Trifluralin, isoxaben, chlorthal-dimethyl and propachlor were safe on *C. officinalis*. In *E. lagascae* only trifluralin, isoxaben, chlorpropham and linuron appeared safe. *L. grandiflora* was particularly sensitive to herbicides and only trifluralin and benazolin:clopyralid were considered suitable for further evaluation. Only trifluralin caused crop damage in *L. annua* but difficulties were experienced in achieving repeatable full season weed control. *L. grandiflora* gave a 60% response to total weed control, *E. lagascae* was intermediate, while *C. officinalis* and *L. annua* were least responsive, averaging 15%.

INTRODUCTION

A European Community AIR project 'Vegetable Oils with Specific Fatty Acids', commenced in 1994 to evaluate the potential and some aspects of the husbandry of five possible new industrial oilseed crops. The crops were selected on the basis of yield potential, range of fatty acid composition and potential applications (Princen and Rothfus, 1984, Muuse *et al.*, 1992). Weed control is a major problem in the development of new crops, and therefore featured in the agronomic investigations associated with determination of yield potential. A range of herbicides were selected on the basis of the literature (Robbelen *et al.*, 1994, Roseberg, 1996) and by interpolation of information from related species. Herbicide effects were compared with hand weeded and untreated controls to assess crop tolerance and the effect of weed competition. This paper reviews the information produced by the series of experiments.

MATERIALS AND METHODS

The species evaluated, site location and background information for each experiment is detailed in Table 1. Table 2 defines the range of herbicides applied to each species, application rates and timings. The individual experiments were laid out as a single treatment factor design in three randomised blocks with one complete set of treatments per block, except for the untreated control, which was replicated three times in each block. All species were sown between mid April and early May, except for *L. annua* which was sown in July to ensure floral initiation in the following year. Herbicides were applied by hand held Oxford Precision sprayer at a pressure of 2 bars in 200 litres/ha water. Pre-sowing treatments were applied to the prepared seedbed and worked in by passage of the drill. Pre-emergence applications were made within two days of drilling, post-emergence applications were made at the crop 2/4 leaves stage.

Table 1. Crop species, experimental locations and site details

Species	Sowing date	Location	Cultivar	Target plant density /m^2	Broad leaved weeds /m^2	Harvest date
(1)C. officinalis	April 1994	Hants.	Pot Marigold	60	32.9	Sept.
	April 1995	Somerset	Single Wild	60	18.9	August
(2)E. lagascae	May 1996	Devon	Murcia	90	20.7	Sept.
	April 1997	Devon	Murcia	90	16.0	-
(3)L. grandiflora	May 1996	Devon	CPRO 910846	250	31.3	Sept.
(4) L. annua	July 1994	Hants	Monnaie du pape	60	33.0	August
	June 1996	Devon	Monnaie du pape	60	70.6 % GC	-

Table 2 . Herbicide dose and timings

Herbicide	Dose g a.i. /ha	Timing	Species
Isoxaben	31.25	pre-em.	1, 2, 3
Trifluralin	1104	pre-sowing	1, 2, 3, 4
Pendimethalin	1320	pre-em.	1, 2, 3
Chlorthal-dimethyl	6750	pre-em.	1
	4500		4
Propachlor	4320	pre-em.	1, 2, 3, 4
Metazachlor 1	1250	pre-em.	1, 2, 3, 4
Metazachlor 2	1250	crop cotyledon	4
Phenmedipham	1140	post-em.	1
Chlorpropham	1120	pre-em.	1, 2
Propyzamide	500	pre-em.	1, 4 (crop 3 leaves)
Metamitron	1750	pre-em.	1
Benazolin: clopyralid	375 : 62.5	crop 3 leaves	3, 4
Carbetamide	2100	pre-em.	3, 4 (crop 3 leaves)
Bentazone	960	crop 4 leaves	2
Linuron	800	pre-em.	2
Hand weeded	-	-	1, 2, 3, 4
Untreated control	-	-	1, 2, 3, 4

Treatment effects were measured by crop vigour scores and plant density counts approximately six weeks after pre-emergence and post-emergence applications. Counts used four 0.25 m^2 fixed quadrats per plot. Assessment for *L. annua* took place at the end of autumn growth. Production of *C. officinalis* and *L. annua* was estimated by combine harvesting. In *E. lagascae* and *L. grandiflora* the total biomass yield was measured because seed shatter of these species prevented the accurate estimation of seed yield.

RESULTS AND DISCUSSION

Table 3. The effect of treatments on plant vigour (0= dead 9=very vigorous) six weeks after pre-emergence application (E) and six weeks after post-emergence application (L)

Herbicide	*C. officinalis*				*E. lagascae*				*L. grandiflora*		*L. annua*	
Year	94 E	94 L	95 E	95 L	96 E	96 L	97 E	97 L	96 E	96 L	94 Aut.	96 Aut.
Isoxaben	4.7	6.3	7.7	7.7	5.7	7.0	5.3	6.3	0	0	-	-
Trifluralin	7.0	6.7	7.7	7.7	6.0	7.3	5.7	6.7	5.4	5.9	2	-
Pendimethalin	1.7	3.3	7.7	7.0	3.7	7.7	5.3	6.7	2.3	5.3	-	-
Chlorthal-dimethyl	4.7	6.0	7.7	7.7	-	-	-	-	-	-	5	-
Propachlor	3.0	5.0	6.7	7.3	2.0	6.3			4.2	6.9	6	-
Metazachlor 1	3.0	4.7	6.3	8.0	6.7	5.3	2.0	7.7	7.4	5.4	5	9
Metazachlor 2	-	-	-	-	-	-	-	-	-	-	3	9
Phenmedipham	-	4.7	7.3	5.3	-	-	-	-	-	-	-	-
Chlorpropham	3.3	4.7	7.0	7.3	5.7	6.0	5.0	6.0	-	-	-	-
Propyzamide	4.7	6.0	7.7	7.7	-	-	-	-	-	-	5	-
Metamitron	4.3	5.7	7.3	7.7	-	-	-	-	-	-	-	-
Benazolin: clopyralid	-	-	-	-	-	-	5.7	5.7	6.7	7.0	5	-
Carbetamide	-	-	-	-	-	-	-	-	4.3	6.7	4	-
Bentazone	-	-	-	-	4.7	7.0	6.3	4.3	-	-	-	-
Linuron	-	-	-	-	6.3	8.0	6.3	6.0	2.3	5.3	-	-
Hand weeded	4.3	5.7	7.7	8.3	6.7	7.0	7.3	6.7	6.7	7.3	5	9
Untreated	4.3	4.7	7.6	7.3	6.7	6.3	5.7	4.7	7.0	7.3	5	9
SEM	1.44	1.23	0.55	0.29	0.63	0.53	0.40	0.56	1.21	1.22	0.45	0.23
CV %	35.5	23.4	12.7	6.8	20.5	13.5	12.5	16.0	50.4	41.2	26.1	4.5

Calendula officinalis

Overall, herbicide treatments had no significant effect on crop vigour or plant density (Tables 3 and 4). However, in 1994 pendimethalin tended to reduce crop vigour and plant density. In 1995 no adverse effect from this treatment was recorded, but in a preliminary observation in 1993 some crop damage was noted (Smith, 1993), suggesting crop safety was marginal. In 1995 post-emergence phenmedipham significantly reduced crop vigour. No damage was recorded in 1994, but the preliminary observation (Smith, 1993) reported a transient effect. It is postulated that the hot dry conditions put the crop under greater stress in 1995, thereby predisposing it to detectable damage. Robbelen *et al.* (1994) also reported crop damage from high application rates of phenmedipham. They also reported slight crop damage from propyzamide and significant crop damage from metamitron which were not duplicated in these experiments. As a result of good crop safety results in these experiments, metazachlor was used on all field experiments in 1997. Application was made to dry soil, but was quickly followed by a period of prolonged and heavy rainfall. A high proportion of plants died when they reached the 2/3 leaf stage, presumably as a result of uptake of herbicide leached into the root zone. It is concluded that only the pre-emergence herbicides trifluralin, isoxaben, chlorthal-dimethyl and propachlor have been shown to be entirely crop safe.

Hand weeding increased seed yield by an average of 13.2% (Table 5). A similar response was recorded to the majority of herbicide treatments but this was not statistically significant. The results suggest that the species is moderately tolerant of weed competition in the range of 20-30 /m^2 when the main species were *Chenopodium album, Atriplex patula* and *Fallopia convolulus*.

Table 4. The effect of treatments on plant density /m^2.

Herbicide	*C. officinalis* 1994	1995	*E. lagascae* 1996	1997	*L. grandiflora* 1996	*L. annua* 1994/5	1996/7
Isoxaben	40	60	39	37	0	-	-
Trifluralin	38	64	45	47	75	6	-
Pendimethalin	11	63	-	-	28	-	-
Chlorthal-dimethyl	35	61	-	-	-	14	-
Propachlor	33	59	43	-	67	20	-
Metazachlor 1	25	57	36	43	59	17	11
Metazachlor 2	-	-	-	-	-	17	10
Phenmedipham	19	60	-	-	-	-	-
Chlorpropham	18	65	46	53	-	-	-
Propyzamide	28	61	-	-	-	19	-
Metamitron	23	62	-	-	-	-	-
Benazolin : clopyralid	-	-	-	66	88	19	-
Carbetamide	-	-	-	-	63	20	-
Bentazone	-	-	38	47	-	-	-
Linuron	-	-	38	59	33	-	-
Hand weeded	33	62	45	58	82	16	11
Untreated control	24	62	41	51	75	22	10
SEM	9.14	3.85	3.36	5.29	14.6	2.44	2.00
CV %	48.9	10.8	14.0	17.8	50.4	36.2	38.6

Euphorbia lagascae

The number of plants established was below target but was not significantly affected by any of the herbicide treatments (Table 4). Pendimethalin, propachlor and bentazone in 1996 and metazachlor in 1997 significantly reduced crop vigour six weeks after pre-emergence application (Table 3). In 1996 this effect became less noticeable with time, in 1997 the same trend was observed following pre-emergence treatments but an adverse effect of bentazone on crop vigour was recorded 6 weeks after its post-emergence application. The safety of bentazone requires further evaluation because in contrast to these results Robbelen *et al.* (1994) reported no crop damage over a range of application rates. It is concluded that pre-emergence trifluralin, chlorpropham and linuron appear to be crop safe options.

The hand removal of weeds in 1996 increased whole plant yield by 36.7 % (Table 5), indicating that although the species appeared competitive, growing to a height of over 50 cm. Its biomass production potential was significantly impaired by modest levels of weed competition.

Table 5. The effect of treatments on seed yield t/ha at 85 % DM

	1994/5 Devon	Yorks.	Mean	1996 Devon
1	3.36	2.39	2.88	1.85
2	3.30	4.54	3.92	1.81
3	3.53	4.19	3.86	1.85
4	3.26	2.75	3.00	1.66
5	3.36	2.60	2.98	0.54
6	3.17	4.55	3.86	1.71
7	3.60	4.45	4.02	1.96
8	3.20	3.88	3.54	1.74
9	3.30	4.32	3.81	1.94
10	3.43	4.36	3.90	1.88
11	3.23	4.00	3.61	1.82
12	3.27	4.56	3.91	1.85
13	3.16	3.12	3.14	1.86
SEM	0.195		0.138	0.103
CV %		9.6		16.9

Table 5 indicates that in 1994/5 seed yields were high at both sites, while overall there was a significant (P>0.05) response to the application of herbicides, there was a significant site/treatment interaction (P>0.05). In South Devon there was no response to herbicide application. In contrast in North Yorkshire the response was over 1.5 t/ha. Differences between herbicide treatments were generally small with the exception of pre-emergence carbetamide, trifluralin followed by simazine and spring simazine. There was no advantage for an autumn and spring herbicide sequence.

In 1995/6 yields were lower, particularly in North Yorkshire, where due to the serious loss of plants, yields were under 0.6 t/ha. In South Devon the average response to herbicide application ranged from +0.11 to -1.07 t/ha. The only significant effect was the yield reduction caused by the post-emergence application of isoproturon:diflufenican.

DISCUSSION

The results confirm that terbuthylazine:terbutryne is safe and effective for weed control in lupins. However pendimethalin, which is currently used on peas, either alone or in combination, was equally safe and effective. The results identify diflufenican as an additional crop safe and effective option. Isoproturon is not crop safe when applied to emerged plants, and restricts the use of isoproturon:diflufenican products to a pre-emergence application window. In 1995/6 the combination of diflufenican with clodinafop-propargyl was safe at timings from early post-emergence until spring, but tended to be most effective when applied in the autumn. While there was an indication that trifluralin caused increased plant loss in 1994/5 this was not detected in 1995/6, and so requires further investigation. No clear advantage was demonstrated for a sequence of pre-emergence plus spring herbicides.

occurred over winter to further reduce crop density. The only herbicide to significantly reduce crop vigour (Table 3) and plant density was trifluralin in 1994/5. All other treatments appeared crop safe but considerable difficulty was experienced in achieving the long season weed control required in this species. A pre- or early post-emergence application of metazachlor was identified as the optimum first stage in a sequential weed control programme, and formed the basis of the 1996/7 treatments. However, the very dry summer soil conditions reduced the effectiveness of this option. Wet conditions in early autumn resulted in vigorous weed growth which was difficult to contain. Overall application of paraquat was one of the most effective late autumn herbicides investigated, some crop damage was caused, long term effects on production will be evaluated.

Seed yields in 1995 (Table 5) were low in comparison with previous experience (Cromack, 1997). Despite moderate weed numbers, particularly of *Chenopodium album*, hand weeding only increased yield by 17 %. A similar response was produced by the crop safe herbicides. It is concluded that the species is relatively tolerant of moderate levels of weed competition. Further investigations are necessary to quantify the response of this species to weed competition and to develop a cost effective and crop safe long term weed control strategy.

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WINTER LUPIN - THE IDENTIFICATION OF CROP SAFE AND EFFECTIVE HERBICIDE PROGRAMMES

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ABSTRACT

A range of herbicides were compared either alone, in combination or sequence to assess crop safety and efficacy in winter sown white lupins at two sites in the UK over the period 1994 to 1996. A number of crop safe products were identified, only early post-emergence application of isoproturon plus diflufenican significantly reduced crop vigour, plant density and yield. Herbicide application reduced weed density but differences between autumn applied treatments were small. In 1995 seed yield averaged 3.5 t/ha and showed a significant response to herbicide application, which reflected weed density. In 1996 serious plant loss in Yorkshire resulted in poor crop competition and low yields. In Devon a competitive crop and moderate density of less competitive weeds caused little yield reduction.

INTRODUCTION

The white Lupin (*Lupinus albus*) offers the potential under UK conditions to produce a substitute for imported soyabeans (Milford *et al.*,1993). The maturity of indeterminate types of spring sown lupins have been shown to be too late for UK conditions (Milford. *et al.*,1991). Milford *et al.*, (1993) indicated the benefits of semi-determinate types to enhance maturity. The selection in France of winter hardy and semi-determinate types (Huyghe, 1990) produced a type more suited to UK conditions and which produced yields of over 4 t/ha at Rothamsted (Julier *et al.*, 1993). Weed control is an important component of the developing agronomic package because the optimum UK sowing date is likely to be in September, subsequent crop growth is slow and full ground cover is not normally achieved until the following April. The only herbicide with label recommendations for broad-leaved weed control is terbuthylazine plus terbutryne (Whitehead, 1996). While off label provisions enable the application of products with label recommendations for peas and beans, the majority of these products are designed for spring sown crops.

A series of experiments was carried out to screen the crop safety and efficacy of a broad range of herbicides, concentrating on autumn application timing, and to investigate the crops response to weed competition.

MATERIALS AND METHOD

The experiments were carried out in the 1994/5 and 1995/6 growing seasons on winter white lupin crops (cv Lucyane), sown at 50 seeds/m^2, at sites in South Devon and North Yorkshire. Crops were sown in early September and harvested late the following September in Yorkshire and sown in late September and harvested in late August to early September in Devon. The herbicides and application timings investigated are detailed in Tables 1 and 2. In 1994/5 a broad range of chemicals were investigated, in 1995/6 the number of herbicides was reduced and application timings increased. Treatments were laid out as a single treatment factor design in three randomised blocks with one complete set of treatments per block, except for the untreated control, which was replicated three times in each block. Herbicides were applied by hand held Oxford Precision sprayer at 2 bars in 200 litres/ha water to plots of approximately 32 m^2.

Table 1. Herbicide treatments

	1994/5 Chemical	Timing	Rate g a.i./ha	1995/6 Chemical	Timing	Rate g a.i./ha
1	untreated control			untreated control		
2	terbutryne:terbuthylazine simazine	pre-em. spring	840:360 550	terbutryne:terbuthylazine simazine	pre-em. spring	840:360 550
3	terbutryne:terbuthylazine	pre-em.	840:360	terbutryne:terbuthylazine	pre-em.	840:360
4	simazine	spring	550	isoproturon:diflufenican	pre-em.	1000:50
5	carbetamide	pre-em.	2100	isoproturon:diflufenican	early post em.	1000:50
6	isoproturon:diflufenican		1000:50	isoproturon:diflufenican	pre-em.	1000:100
7	isoproturon:diflufenican	early post-em.	1000:50	pendimethalin	pre-em.	2000
8	pendimethalin	pre-em.	1320g	diflufenican:clodinafop-propargyl *	early post em.	50:30
9	pendimethalin	pre-em.	2000	diflufenican:clodinafop-propargyl *	late post em.	50:30
10	pendimethalin simazine	pre-em. spring	1320 550	diflufenican:clodinafop-propargyl *	spring	50:30
11	pendimethalin+isoxaben	pre-em.	750:75	trifluralin:diflufenican	pre-em.	1000:100
12	pendimethalin:simazine	pre-em.	750:250	terbutryne:terbuthylazine triasulfuron	pre-em. spring	840:360 7.5
13	trifluralin simazine	pre-em. spring	1104 550	pendimethalin+isoxaben	pre-em.	750+75

* Plus approved wetter

Weed counts were carried out on four 0.25 m^2 quadrats and plant counts on four quadrats of 1 m by 2 rows per plot, yield was measured by direct combining.

Table 2. Herbicide application dates

		South Devon		North Yorkshire	
Timing	Weed stage	1994/5	1995/6	1994/5	1995/6
Pre-emergence	Nil	27 Sept.	25 Sept.	19 Sept.	20 Sept.
Early post-emergence	2-4 leaves	17 Oct.	2 Nov.	19 Sept.	28 Oct.
Late post-emergence	4-6 leaves	-	6 Dec.	-	20 Nov.
Spring	Spring weeds < 2 leaves	13 March	27 March	11 April	17 April

RESULTS

Table 3. The effect of herbicide treatments on mean crop vigour and plant numbers

	Mean crop vigour (0=dead, 9= no effect)				Mean plant numbers /m^2					
	1994/5		1995/6		1994/5			1995/6		
DAT	40	60	20	60	Nov.	Feb.	May	Nov.	Feb.	May
1	7.2	7.7	7.8	7.9	33.1	34.0	28.2	36.9	34.7	21.8
2	6.3	7.5	7.0	7.5	31.7	34.5	27.6	34.2	31.8	14.9
3	7.2	7.7	7.3	7.8	34.4	35.3	28.7	37.8	31.3	21.8
4	7.8	8.3	7.2	8.2	38.4	36.4	26.8	36.5	37.3	23.2
5	7.7	7.7	4.5	4.0	33.5	32.7	27.9	38.5	15.6	3.2
6	6.7	8.0	6.8	7.7	32.4	31.6	29.5	36.7	32.4	19.9
7	6.0	7.5	7.5	7.5	35.3	35.1	29.4	36.3	31.3	20.3
8	6.7	7.5	7.7	7.2	32.3	31.4	27.2	37.0	32.3	15.2
9	7.2	7.5	8.0	7.5	41.8	33.8	29.5	37.8	33.1	16.2
10	7.2	7.7	7.6	8.3	30.1	32.3	25.3	34.8	32.1	19.0
11	7.0	8.0	7.3	7.8	40.9	35.9	26.5	36.2	33.4	20.8
12	7.3	7.5	7.2	8.2	34.7	35.1	27.5	34.4	31.1	21.7
13	7.3	7.7	7.5	7.5	30.1	29.2	21.5	40.7	31.5	21.6
SEM	0.30	0.35	0.26	0.27	2.64	2.09	2.10	2.42	1.96	1.74
CV%	10.5	11.1	8.7	8.7	18.8	15.2	18.7	16.1	145.1	22.6

Table 3 indicates that there was no significant effect of treatment on crop vigour, with the exception of the early post-emergence application of isoproturon:diflufenican (treatment 7 in 1994/5 and treatment 5 in 1995/6). In 1994/5, crop vigour 40 DAT was significantly (P>0.05) reduced by this treatment. Examination of the site data showed that only in South Devon, where the application of the herbicide was made when the crop was fully emerged, was crop vigour significantly impaired. In 1995/6 this treatment effect was significant (P>0.05) at both sites and at all assessment timings.

Table 3 also indicates that in both years a reasonable plant density was established in the autumn but declined during the season. In 1994/5 there was no significant effect of treatment on plant density. However, there was an indication from the spring data at both sites that trifluralin followed by simazine (treatment 13) reduced plant density. The decline in plant density, particularly from February to May was greater in 1995/6 than in 1994/5 and was severe in North Yorkshire, probably due to adverse spring weather. In

1995/6, the early post-emergence application of isoproturon:diflufenican dramatically reduced plant density. In this year however, there was no evidence of an adverse effect of trifluralin (treatment 11).

In 1994/5, the number of broad-leaved weeds in November on untreated plots were low in South Devon (5.4 /m^2) and high in North Yorkshire (60.5 /m^2). The main species were *Stellaria media, Veronica* spp., *Senecio vulgaris* and *Matricaria* spp.. Subsequently weed growth declined in South Devon but increased in North Yorkshire to reach a peak of nearly 100% ground cover on the control treatment. Table 4 indicates that herbicides significantly (P>0.05) reduced weed numbers at all assessment dates. Differences between autumn applied treatments were small, with trifluralin followed by simazine the least effective. A single spring application of simazine gave limited weed control.

In 1995/6 the number of broad-leaved weeds on untreated plots in November were low in North Yorkshire (5.2 /m^2) and moderate in South Devon (27.8 /m^2). The main species were *Veronica persica, Stellaria media, Senecio vulgaris, Galium aparine, Cirsium arvense* and *Matricaria* spp.. Subsequently weed growth declined in South Devon to under 10 weeds /m^2 in May but increased in North Yorkshire to over 75% ground cover on the control treatment. Herbicides significantly (P>0.05) reduced weed density at all assessment dates. Differences between autumn herbicide treatments were small.

Table 4. The effect of treatments on the mean number of broad-leaved weeds in November and February and the percentage weed ground cover in May at North Yorkshire

	Mean weeds /m^2		Ground cover % Yorks	Mean weeds /m^2		Ground cover % Yorks
	Nov. 1994	Feb. 1995	May 1995	Nov. 1995	Feb. 1996	May 1996
1	32.9	23.1	99	18.4	20.8	77
2	7.1	4.4	5	1.8	3.7	40
3	14.5	5.6	3	2.3	3.5	40
4	35.7	28.5	97	3.5	2.3	46
5	10.2	10.1	52	23.0	1.7	13
6	8.6	6.0	7	2.3	3.7	50
7	7.7	6.2	24	1.2	1.7	18
8	9.0	6.8	42	18.7	1.8	24
9	14.8	9.5	22	20.3	6.8	61
10	11.1	5.9	22	13.0	23.3	46
11	16.8	12.8	54	3.7	3.7	47
12	7.0	3.8	10	2.5	4.7	39
13	23.9	20.3	90	2.2	3.7	60
SEM	0.57	2.49	7.5	4.97	3.11	9.2
CV %	76.3	51.4	29.2	121.9	93.1	33.4

Table 5. The effect of treatments on seed yield t/ha at 85 % DM

	1994/5 Devon	Yorks.	Mean	1996 Devon
1	3.36	2.39	2.88	1.85
2	3.30	4.54	3.92	1.81
3	3.53	4.19	3.86	1.85
4	3.26	2.75	3.00	1.66
5	3.36	2.60	2.98	0.54
6	3.17	4.55	3.86	1.71
7	3.60	4.45	4.02	1.96
8	3.20	3.88	3.54	1.74
9	3.30	4.32	3.81	1.94
10	3.43	4.36	3.90	1.88
11	3.23	4.00	3.61	1.82
12	3.27	4.56	3.91	1.85
13	3.16	3.12	3.14	1.86
SEM	0.195	0.138	4.13	0.103
CV %		9.6		16.9

Table 5 indicates that in 1994/5 seed yields were high at both sites, while overall there was a significant (P>0.05) response to the application of herbicides, there was a significant site/treatment interaction (P>0.05). In South Devon there was no response to herbicide application. In contrast in North Yorkshire the response was over 1.5 t/ha. Differences between herbicide treatments were generally small with the exception of pre-emergence carbetamide, trifluralin followed by simazine and spring simazine. There was no advantage for an autumn and spring herbicide sequence.

In 1995/6 yields were lower, particularly in North Yorkshire, where due to the serious loss of plants, yields were under 0.6 t/ha. In South Devon the average response to herbicide application ranged from +0.11 to -1.07 t/ha. The only significant effect was the yield reduction caused by the post-emergence application of isoproturon:diflufenican.

DISCUSSION

The results confirm that terbuthylazine:terbutryne is safe and effective for weed control in lupins. However pendimethalin, which is currently used on peas, either alone or in combination, was equally safe and effective. The results identify diflufenican as an additional crop safe and effective option. Isoproturon is not crop safe when applied to emerged plants, and restricts the use of isoproturon:diflufenican products to a pre-emergence application window. In 1995/6 the combination of diflufenican with clodinafop-propargyl was safe at timings from early post-emergence until spring, but tended to be most effective when applied in the autumn. While there was an indication that trifluralin caused increased plant loss in 1994/5 this was not detected in 1995/6, and so requires further investigation. No clear advantage was demonstrated for a sequence of pre-emergence plus spring herbicides.

The 1995 yield response suggested that like other crops, lupins can tolerate low levels of weed competition but that a large yield response, in this case over 60%, can be obtained by controlling high populations. The results also indicate the important effect of weed species, *Stellaria media,* which was the dominant weed in Yorkshire was more competitive than *Veronica persica*, the dominant weed in Devon. Crop competition effects are also important, as illustrated in 1996 by the large weed development under a low crop density in Yorkshire. This reduction in plant density appeared to be caused by adverse weather conditions, (40 air frosts and 55 ground frosts between February and April), rather than herbicide treatments. The current data set is inadequate to do more than outline the crops response to weed competition and identify some contributory factors.

Galium aparine was present, particularly in Yorkshire and was poorly controlled by the herbicides tested. Observations showed this species to be at least as great a potential weed problem in lupins as in other crops. With the restricted herbicide options currently available, the development of a specific control strategy for this weed is required.

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EFFECT OF WEATHER ON EFFICACY OF HERBICIDES IN SUGAR BEET

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ABSTRACT

A series of experiments was carried out over the years 1993-96 to determine if the weather conditions at the time of application could influence weed control in sugar beet based on mixtures of phenmedipham and residual herbicides. Treatments were applied on different dates and at various times of day in order to utilise a range of weather conditions. Weed control was seldom related to growth stage of weeds. Results in 1993 suggested that soil moisture and air temperature also influenced weed control. In experiments in later years, high air humidity also appeared to influence control.

INTRODUCTION

Most sugar beet growers in the UK use low dose, low volume herbicide programmes (Smith, 1983). The timing of these sprays is all important and treatments delayed, for instance by unfavourable weather, usually give poorer control than those applied timely to weeds at an earlier stage of growth. However, on some occasions delayed treatments can result in improved control compared to those applied earlier. This was indicated also in experiments carried out by Morley Research Centre in 1992 (unpublished data), the results of which suggested that soil moisture and temperature were important factors. In the years 1993-96, experiments were carried out to determine whether weather conditions before, during or after spraying affected herbicide activity.

MATERIALS AND METHODS

The experiments were situated in commercial sugar beet crops at one site in 1993-5 inclusive and at three in 1996. These were all in East Anglia on sandy loam (1993, 1994,1996 [2]), sandy clay loam (1995, 1996) and loamy sand (1996) soils. A post-emergence mixture of 262.2 g a.i./ha phenmedipham (as 'Betanal E') + 275 g a.i. chloridazon + 170 g a.i./ha ethofumesate (as 'Magnum') was applied at a range of dates corresponding to the cotyledon up to the ten leaves stage of the sugar beet. In 1993 this was applied with or without a pre-emergence treatment of 1625 g a.i./ha chloridazon. Pre-emergence treatments were included in other seasons but data is not presented owing to lack of space. In 1993 post-emergence treatments were applied at four dates only but in other years up to 28 application timings on up to ten dates were

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used. At two dates in 1994 and 1995, treatments were applied at two hour intervals during the day from 05.00 to 23.00 hours. The growth stages of crop and weeds were recorded and weather monitored and recorded by the use of a meteorological station ('Hardi Metpole'; Hostgaard, 1994) placed in the crop adjacent to the experiment. Details of treatment dates and weather conditions at the time of treatment are provided in the results tables. Weeds and crop were assessed during the season by counts (between 5 and 15 m^2 areas per plot) and by visual scores which used a linear scale.

RESULTS

A range of weeds was present at most sites but over all the sites *Chenopodium album*, *Fallopia convolvulus* and *Polygonum aviculare* were predominant. In 1996 the dominant weed in the sandy loam (site 2) experiment was *Aethusa cynapium* and it was not controlled by the treatments.

In 1993 (Table 1), treatments applied at the recommended stage on 30 April gave poorer weed control than those applied either 5 or 12 days later. Temperature at time of treatment did not appear to be the main factor influencing herbicide activity. There was slow crop growth during a dry period following drilling but after rainfall on the 14 and 18 May growth rate of the beet increased.

Table 1. Weed control in 1993

Date	Air temperature °C	Total weeds /m^2 no pre-em.	Total weeds /m^2 with pre-em.
30:04:93	14.0	19.9	7.0
05:05:93	8.3	11.7	9.1
12:05:93	14.2	13.1	8.3
18:05:93	16.1	32.5	12.0
Untreated		46.5	34.3
LSD $P \leq 0.05$		6.51	11.10

In 1994 (Table 2), the results showed that there was no direct relationship between date of treatment and weed control achieved, whereas a decline in weed control during this period would have been expected. During April and May, the soil humidity (Hostgaard, 1994) appeared to be the main factor influencing weed control (r^2=0.82). However, during June and July it did not appear to have any effect (r^2=0.08). There was a sharp reduction in air humidity during the morning of 1 June and this corresponded (r^2 =0.75) with a decline in weed control. Air temperatures increased to a maximum of 22°C in mid afternoon but increasing temperature appeared to reduce weed control.

In 1995 (Table 3), the relationship between date of treatment and weed control was closer than in 1994 (r^2=0.70 compared to 0.24) but over the two month period weed control was not related to air humidity or temperature (r^2=0.22 and 0.01 respectively). On both 26 May and 7 July air humidity changed but overall weed control was poor and did not change significantly.

Table 2. Date and time of treatment, relative air humidity, air temperature and soil humidity at the time of treatment, weed vigour reductions and total weeds present in 1994 experiment

Date	Time	RH % at 1.5 m	Air temp. °C at 1.5 m	Soil humidity % at -0.1 m	Reduction in weed vigour %	Total weeds /m²
09:05:94	18.00	72	10.7	41	45	29.9
11:05:94	12.00	80	11.9	37	75	2.0
16:05:94	18.30	65	12.0	30	65	11.0
19:05:94	17.30	85	8.2	31	75	6.1
20:05:94	17.00	83	11.8	35	65	4.7
24:05:94	05.00	97	8.7	43	75	9.9
	07.00	95	9.1	43	80	5.5
	09.00	96	9.6	43	70	4.8
	11.00	89	11.1	43	75	4.2
	13.00	91	10.8	43	65	3.8
	15.00	87	11.0	43	75	4.5
	17.00	88	10.4	43	70	6.0
	19.00	89	9.5	43	80	3.9
	21.00	93	8.5	43	75	4.5
	23.00	94	8.5	43	80	6.2
27:05:94	17.00	72	8.7	36	75	7.7
01:06:94	05.00	90	7.9	32	75	6.2
	07.00	73	12.3	32	80	5.2
	09.00	65	16.9	32	70	7.3
	11.00	54	19.3	32	65	8.8
	13.00	47	21.4	32	45	9.5
	15.00	41	22.0	32	60	14.1
	17.00	48	21.2	32	70	14.2
	19.00	59	18.9	32	80	7.3
	21.00	68	16.2	32	75	6.4
	23.00	74	14.7	32	80	11.9
06:07:94	17.30	75	19.0	31	70	9.5
11:07:94	12.00	73	16.0	28	30	36.7
LSD $P \leq 0.05$					15.1	11.12

In 1996 (Table 4), there was no relationship between weed control and date of treatment at any site ($r^2<0.12$). At no individual site was there a statistically significant relationship between weed control and weather factors recorded. However, when all sites were combined weed control tended to increase with increasing air humidity but decrease with increasing air temperature.

Table 3. Date and time of treatment, relative air humidity and temperature at the time of treatment and weed vigour reductions in 1996 experiments

Date	Time	RH % at 1.5 m	Air temperature °C at 1.5 m	Reduction in weed vigour %
05:05:95	17.00	44	24.1	85
20:05:95	16.00	47	15.1	75
21:05:95	09.00	58	14.9	55
23:05:95	18.30	61	17.2	73
26:05:95	05.00	79	13.9	58
	07.00	75	14.9	65
	09.00	87	14.7	65
	11.00	78	16.9	55
	13.00	54	20.1	45
	15.00	62	17.8	63
	17.00	78	16.1	58
	19.00	76	16.3	55
	21.00	85	13.6	60
	23.00	90	11.5	48
07:07:95	05.00	89	13.4	38
	07.00	76	17.7	30
	09.00	68	19.5	28
	11.00	62	21.7	45
	13.00	55	23.8	35
	15.00	52	24.7	45
	17.00	53	24.4	45
	19.00	58	22.8	30
	21.00	68	19.2	17
	23.00	81	15.5	28
LSD $P \leq 0.05$				18.3

DISCUSSION AND CONCLUSION

The 1993 experiment suggested that speed of growth of the weeds (and crop) was a major factor in the effectiveness of the phenmedipham plus residual herbicide mix used in these experiments. This appeared to be related to soil moisture and air temperature. Whilst soil humidity was recorded in all of the subsequent experiments, records were either incomplete (1995) or showed no relationship to weed control (1996). In 1993 the use of chloridazon pre-emergence probably sensitised weeds to the post-emergence herbicide and thereby reduced the day-to-day variability of the weed control. Pre-emergence treatments were used in subsequent experiments and generally resulted in better and less variable weed control compared to where they were omitted. Alternative phenmedipham + residual herbicide post-emergence programmes were included in 1995 and 1996 and showed similar effects to the data presented here.

Table 4. Site, date and time of treatment, relative air humidity and temperature at the time of treatment and weed vigour reductions in 1996 experiments

Site	Date	Time	RH % at 1.5 m	Air temperature °C at 1.5 m	Reduction in weed vigour %
Sandy loam site 1	26:04:96	15.40	58	19	50
	06:06:96	09.15	61	21	20
	06:06:96	10.55	53	25	60
	06:06:96	16.30	56	23	40
	12:06:96	10.20	54	17	20
	12:06:96	15.00	52	18	50
	12:06:96	18.15	46	19	60
	25:06:96	12.40	74	19	60
	25:06:96	16.25	67	21	0
Sandy clay loam	29:04:96	16.15	59	13	50
	06:06:96	08.50	61	21	50
	06:06:96	11.30	53	25	80
	06:06:96	17.50	55	23	70
	12:06:96	09.30	54	17	50
	12:06:96	14.00	51	20	70
	12:06:96	17.35	46	19	70
	25:06:96	12.00	74	19	50
	25:06:96	17.00	67	21	40
Loamy sand	29:04:96	14.10	58	13	10
	14:05:96	17.00	60	13	20
	14:05:96	18.00	69	13	10
	02:06:96	09.00	69	14	10
	02:06:96	11.15	63	15	20
	02:06:96	14.45	63	16	30
	01:07:96	11.20	59	15	30
	02:07:96	14.45	84	15	10
Sandy loam site 2	11:05:96	12.30	65	13	10
	21:05:96	09.45	74	13	0
	21:05:96	10.00	74	13	0
	21:05:96	10.15	74	13	0
	03:06:96	10.50	50	19	0
	03:06:96	13.40	49	18	0
	03:06:96	16.05	70	17	0
	17:06:96	10.25	57	22	0
	17:06:96	14.00	47	27	0

Bee *et al.* (1995) suggested that delaying post-emergence herbicide treatment until the 2-4 leaves stage of sugar beet could provide as good or better weed control than treatments applied at the cotyledon stage of the crop. The results of these experiments suggest that growth stage of weed (and crop) is not always the main factor influencing post-emergence weed control in sugar beet. The growth rate of the weeds and the waxiness of leaves may be a major influence and this is likely to be affected by soil moisture and other growing conditions.

The results of the experiments reported here suggest that air humidity at time of treatment affects the effectiveness of post-emergence herbicide programmes. It is likely that temperature also plays a role but whilst the data in these experiments suggest a negative interaction the close relationship between air humidity and temperature means that the individual effects could not be determined from these experiments with complete certainty. The 1994 experiment suggests that weed control may be reduced under conditions of falling air humidity and, that when this happens, poor control may result during the midday period. This may be the result of stomatal closing during such periods.

The factors are complex and inter-related such that the effect of individual components measured under controlled laboratory conditions has not always reflected effects noticed by growers and advisers in the field. Overall, the results of the experiments suggest that growers and advisers should take note of previous growing conditions and the likely air humidity and temperature at time of treatment when selecting field treatment order, herbicide products and dose for post-emergence control of weeds in sugar beet. However, more detailed work is required to determine the interactions involved.

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EVALUATION OF PRE-PLANT AND PRE- AND POST-EMERGENCE HERBICIDES FOR NO-TILL COTTON IN CERRADOS AREAS

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ABSTRACT

The planted area of cotton in the Brazilian Cerrados is increasing. However, this does not use the no-till system, which is an excellent conservationist system. Work in other crops showed the great advantages of this system. Information for cotton crop is rare in Brazilian literature. The work reported here evaluated these no-till areas, where herbicides were applied at pre-planting (support), pre- and post-emergence. At pre-planting glyphosate was used alone and in mixture with 2,4-D at different intervals. Post-planting herbicides clomazone, acetochlor (with and without protector), trifluralin (non-incorporated) + alachlor + diuron and oxyfluorfen, clomazone + diuron were used. Trifluralin / pirytiobac-sodium, fluazitop-P-butyl + pirytiobac-sodium, and MSMA + pirytiobac-sodium were tested with other pre-and post-emergence treatments. The results showed a good weeds control. The best results obtained - comparing control, costs and yield - were from clomazone + diuron, trifluralina + pirytiobac-sodium and acetochlor (with protector).

INTRODUCTION

Brazilian Cerrados cover an area of approximately 200 million ha, the major part of which has topography suitable for intensive agriculture. The predominant climate is tropical with about 1500 mm rain/year. The dry season varies from 4-6 months. Dystrophic soil covers 89% of the total area, formed by acid soils with low natural fertility and phosphorus deficiency (Goedert, 1985). Today, approximately 65 million ha are exploited, mostly for pastures, but initially for rice and pastures. In the early 1970, with the new cultivars available, there was a boom in the planting of soybean.

The main objective of cultivation methods is to improve the chemical properties of the soil in order to increase the yield potential. In general, the most common practice is liming to eliminate acidity (Haynes, 1983) which associated phosphorus fertilisation has resulted in economic improvements. The intense movement of the soil to implant new crops, together with the occurrence of high rainfall during the growing stages, has resulted in long term excessive losses due to erosion (Wunche et al, 1978; Mondardo et al, 1978). Cogo (1991) estimated erosion losses at about 30 t/ha/year, with damage to the environment and consequences to unit productivity. The main advantages, of the no-till system in relation to the conventional preparation are erosion control, humidity preservation, weed control, better soil structure and phytosanitary conditions of the crop, (Muzzili, 1981; Dick, 1985), not to mention economy in fertilisers and equipment (Dick, 1985).

The tentative introduction of the no-till system in 1985 was very limited (500 ha) and was not viable because there was not a crop in the rotation that could provide mulching to the summer crop of soybeans. The difficulty was rainfall. After some years of research, in the early 1990s, the no-till system became viable for maize (*Pennisetum typhoides*), planted at the end of the rainy season (May). This is tolerant to the water deficit and produces 10-12 t/ha of dry mass, and has associated benefits. The planted area today is pproximately 1 million ha on Cerrados soil, with the possibility of reaching 3-4 millions by the year 2000. Brazilian production of cotton in 1996 was 1,177,000 t (cotton seed), 30% of which from the central-west region (Cerrados) (Agrianual, 1996). Several soybean producers, who practice the no-till system, are planting cotton instead, but there is little knowledge of the herbicides that can be used. The objective of this work was to evaluate a range of possible treatments, using three experiments, in three different regions.

Cotton crop - losses

Cotton crop (*Gossypium hirsutum* L.) is one of the most demanding crops in relation to cultivation, and elimination of weeds is essential to increase yields. Results from several researches show that the first 20-60 days are critical to the development and growing of the cotton plant. During this period weeds competition is intense (Blanco & Oliveira, 1976). Researchers have reported losses in the range of 20-98% (Laca-Buendia, 1992).

The pioneer work by Leiderman et al (1965) studied the efficacy of trifluraline and diuron, whilst Alves and Forster (1968) studied application methods. Increased use of herbicides on cotton crop is a result of labor scarcity and the more efficient, rapid and prolonged action of those products compared to manual or mechanical cultivation (Cruz & Linderman, 1980). Other work showed the possibilities and advantages of residual herbicides in cotton crop. Foloni (1996) tested the use of clomazone at pre-emergence on cotton. Selectivity was obtained when seeds were treated with disulfoton instead of carbofuram.

The paradigm for sustainable development of agricultural ecosystems aims to increase agricultural yields whilst considering nature assimilation capacity and maintenance of natural resources. According to these principles, the no-till system is the best practice to soil and fauna conservation (Gaassen, 1995).

MATERIALS AND METHODS

The assays were conducted in three areas, one of them in Sao Paulo State (Bariri) and the other in Goias State (Itumbiara and Edeia), which are traditional cotton areas. Soil types were clay and the experimental design was randomized blocks with four replicates, with each plot eight rows (spacing of 0.90 cm) x 10 m. Treatments (Table 1) were similar in the three areas.

Weed infestation

Weeds infesting the first experimental area were: *Cenchrus echinatus* (40%), *Merremia cissoides* (20%), *Acanthospermum hispidum* (10%), *Bidens pilosa* (20%), *Sida rhombifolia* (5%), *Ipomoea grandifolia* (5%); in the second area: *Digitaria horizontalis* (10%), *Alternanthera tenella* (40%), *Commelina benghalensis* (25%), *Amaranthus retroflexus* (15%). others (10%); and in the third area: *Eleusine indica* (15%), *Digitaria horizontalis* (10%), *Commelina benghalensis* (40%), *Acanthospermum hispidum* (20%), *Ipomoea grandifolia* (10%), others (5%).

Table 1. Tested treatments in cotton, in no-till system

N° of treatments	Product	Dose (kg a.i./ha)	Type of application
			pre planting
0	2,4-D	0.72	30 days before
00	Glyphosate	0.72	30 days before
1	Trifluraline+Alachlor+Diuron	1.8+0.86+0.90	pre
2	Clomazone + Diuron	1.0+1.0	pre
3	Trifluraline/Pirytiobac-sodium	1.8+0.07/0.07	pre/post
4	Acetochlor *	2.70	pre
5	Fluazifop-p-butyl+Pirytiobac-sodium	1.8+0.07	post
6	MSMA+Pirytiobac-sodium	1.44+0.07	post
7	Clomazone	1.0	pre
8	Oxyfluorfen	0.48	pre
9	Control	-	-
+	MSMA + Diuron		

* one trial with Acetochlor (SP) and two assays with Acetochlor + protector (GO)

Applications and evaluations

Cotton was planted on 17.11.95 in Bariri, SP, on 30.12.95 in Itumbiara, GO and 08.12.95 in Edeia, GO. The herbicides were applied on 18.11.95, 30.12.95 and 08.12.95, respectively, through a CO_2 powered sprayer, operating at 2.78 bar, equipped with four Spraying Systems XR.110.03 nozzles, applying 185 l/ha, at pre planting and pre and post emergence. The same equipment was used for directed spray but with TK.VS.Z nozzles at 165 l/ha, at 50-60 days after planting in the three areas. Assessments were made by visual scores 15 and 30 DAT using the EWRC scale (1964) for selectivity and at 30, 45 and 75 (except SP) DAT, using visual scale (percentage) for efficacy, where zero equals no control, 100% total death.

RESULTS AND DISCUSSION

The results are summarised in Tables 2, 3 and 4. Table 2 presents phytotoxicity data, Table 3 control of the main weeds and Table 4 yields. Phytotoxicity data showed a higher damage level for oxyfluorfen, followed by the mixture MSMA + p. sodium (area 2); the other treatments presented very slight symptoms. Weed control data varied according to species.

Table 2. Observed phytotoxicity 15, 30 and 45 DAT on cotton, for the three areas

	Bariri - SP - 1		Itumbiara - GO - 2		Edeia - GO - 3	
Treatment	15	30	15	30	15	30
1	1.5	1.2	1.5	1.0	1.0	1.0
2	2.0	2.0	2.5	2.0	2.0	1.5
3	1.7	1.7	1.5	1.0	1.0	1.0
4	2.7	1.5	2.5	1.0	2.0	1.0
5	1.2	1.0	1.5	1.0	1.0	1.0
6	1.2	1.0	3.5	2.5	2.0	1.75
7	1.7	1.5	2.5	2.0	2.0	1.5
8	5.0	3.0	4.2	2.7	4.0	2.0
9	1.0	1.0	1.0	1.0	1.0	1.0
F	4.45**	3.80**	22.59**	33.21**	4.86**	3.92**
CV	33.79	48.99	24.53	17.29	18.39	27.77
DMS	1.295	1.619	1.168	0.659	3.403	0.894

Table 3. Percent control of main weeds 30, 45 and 75 DAT

	Area 1 - SP - % Control					
	C. echinatus		*M. cissoides*		*B. pilosa*	
Treatment	15	30	15	30	15	30
1	88.7	80.0	67.5	60.0	98.7	90.0
2	88.7	92.5	83.7	75.0	100.0	92.5
3	96.5	92.5	64.3	88.5	100.0	90.0
4	87.5	80.0	67.5	60.0	95.0	97.5
5	87.5	77.5	61.2	75.0	100.0	92.5
6	87.5	76.2	83.7	82.5	92.5	83.7
7	83.7	80.0	57.5	46.2	92.5	90.0
8	69.7	48.7	71.7	51.2	80.0	72.5
9	0	0	0	0	0	0
F	10.51**	7.76**	2.25**	3.45**	12.24**	6.63**
CV	34.61	38.87	59.71	54.92	22.92	32.42
DMS	32.057	53.676	79.941	71.304	43.858	57.334

	Area 2 - GO - % Control								
	D. horizontalis			*A. tenella*			*C. benghalensis*		
Treatment	30	45	75	30	45	75	30	45	75
1	97.5	67.5	95.0	100.0	60.0	95.0	85.0	72.5	90.0
2	100.0	87.5	97.5	85.0	75.0	90.0	90.0	91.2	90.0
3	100.0	72.5	85.0	90.0	85.0	82.5	77.5	91.2	90.0
4	100.0	87.5	90.0	87.5	80.0	82.5	90.0	87.5	89.0
5	100.0	87.5	100.0	90.0	77.5	75.0	85.0	87.5	92.5
6	77.5	65.0	75.0	92.5	75.0	90.0	90.0	95.0	97.5
7	100.0	87.5	87.5	52.5	30.0	62.5	90.0	78.7	82.5
8	97.5	87.5	97.5	92.5	80.0	92.5	85.0	75.0	92.5
9	0	0		0	0	0	0	0	0
F	233.47**	82.54**	88.74**	77.63**	51.22**	37.94**	33.98**	61.59**	83.59**
CV	5.03	8.87	8.21	9.39	14.07	13.24	13.07	10.25	8.33
DMS	10.242	13.549	15.533	12.138	18.605	22.322	23.242	17.176	15.701

	Area 3 - GO - % Control								
	E. indica			*C. benghalensis*			*A. hispidum*		
Treatment	30	45	75	30	45	75	30	45	75
1	95.0	100.0	100.0	85.0	82.5	100.0	98.7	91.2	93.7
2	96.2	91.2	100.0	87.5	85.0	100.0	97.5	91.2	100.0
3	97.3	96.2	100.0	97.5	100.0	100.0	97.5	87.5	92.5
4	87.5	83.7	95.0	95.0	92.5	92.5	98.7	70.0	91.2
5	86.2	70.0	100.0	95.0	92.5	95.0	90.0	95.0	98.7
6	86.2	80.0	95.0	97.5	95.0	90.0	100.0	91.2	98.7
7	90.0	95.0	97.5	75.0	70.0	92.5	77.5	68.7	97.5
8	97.5	96.2	100.0	90.0	85.0	100.0	85.0	80.0	95.0
9	0	0	0	0	0	0	0	0	0
F	160.44**	115.26**	314.03**	26.35**	14.89**	58.24**	11.53**	6.13**	146.01**
CV	6.44	7.61	4.57	15.00	20.23	10.65	22.87	32.94	6.72
DMS	12.229	14.527	9.249	29.059	38.116	20.957	42.607	56.295	13.135

Table 4: Yielding of cotton seed - kg/ha

N°	Treatments	Doses kg a.i./ha	Bariri (1)	kg / ha Itumbiara (1)	Edeia (1)
1	Trifluraline+Alachlor+Diuron	1.8+0.86+0.40	166.6	1.575	2.120
2	Clomazone + Diuron	1.0+1.0	2.194	1.680	2.480
3	Trifluraline/Pirytiobac-sodium	1.8+0.07/0.07	2.276	1.693	2.425
4	Acetochlor *	2.70	1.449	1.559	1.820
5	Fluazifop-p-butyl+Pirytiobac-	1.87+0.07	1.166	1.653	1.727
6	sodium	1.44+0.87/0.07	1.721	1.505	1.915
7	MSMA+Pirytiobac-sodium	1.0	1.666	1.505	2.016
8	Clomazone	0.48	1.277	1.451	1.666
9	Oxyfluorfen		943	1.088	976
	Control				
F	(Treatments)		2.17**	10.29**	10.36**
CV	(%)		49.50	7.51	19.0
DMS	Tukey 5%		1.755.44	272.34	154.810

SP - acetochlor; GO - acetochlor + protector

The performance of the products was improved when supplemented with directed spray at 50-60 days. This ensured crops were clean at harvest. Trifluraline (pre-) + pirythiobac-sodium (post-) and the tank mixture of clomazone + diuron gave the best yields.

ACKNOWLEDGMENTS

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POSSIBILITIES FOR CHEMICAL WEED CONTROL IN SOYBEAN

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ABSTRACT

The effectiveness of some pre- and post-emergence herbicides applied alone, in combinations and in sequences was studied in soybean and 52 spp. of annual and perennial grass and broad-leaved weeds on a chernozem soil under field conditions during the period 1990-1994.

INTRODUCTION

Soybean is very susceptible to competition during its post-emergence, growing and seed formation periods. Weed competition in both critical periods represses and slows down soybean growth, thins out the crops and greatly decreases yields (Lyubenov *et al.*, 1987). The correct choice of herbicides is of great importance to avoid damage (Fetvadgieva *et al.*, 1986, Arabadgiev, 1993, Schmidt, 1996).

MATERIALS AND METHODS

During 1990-1994 field trials were conducted in soybean on a chernozem soil containing 3.31% o.m. and with pH = 6. Half of the area was fertilised with 50 kg/ha nitrogen and half left unfertilised. The doses of the following herbicides are all given as kg a.i./ha. The pre-emergence herbicides were: 0.96 trifluralin (ppi) + 1.00 linuron, 0.45 imazaquin and 3.36 acetocholor. The post-emergence herbicides applied in sequence with these pre-emergence herbicides were: 0.36 acifluorfen, 0.75 fluazifop-P-butyl, 0.48 bentazone + 0.16 acifluorfen (Galaxy), 1.44 bentazone, 0.72 bentazone with lutensol spray additive (Basagran forte), 0.375 fomesafen, 0.45 imazaquin, 0.12 imazethapyr and 0.17 lactofen. These herbicides were applied at the 2-3 trifoliate stage of soybean. A hand sprayer was used (Matabi, mod. Merk 5, nozzle type 1A, operating pressure 2 bar, 0.40 litres/min). The water volume applied was 1,000 litres/ha. The plot size was 5x2m.

The effectiveness of herbicides was measured by the following parameters: the average number/m^2 of the weed spp. and their fresh and dry *wt*/m^2 determined three times during the vegetation period, i.e. 30 and 60 DAT for the pre-emergence and 14 DAT for the post-emergence herbicides. The average % weed control was estimated relative to the untreated control.

RESULTS AND DISCUSSION

In these experiments 52 weed spp. were identified, most important of which were *Veronica tournefortii (V. persica), Sinapis arvensis, Amaranthus retroflexus, Chenopodium album, Kochia scoparia, Fallopia convolvulus, Polygonum aviculare, Solanum nigrum, Xanthium strumarium, Echinochloa crus-galli, Eleusine indica, Setaria glauca, S. viridis, Convolvulus arvensis, Cirsium arvense, Elymus repens,* etc.

In the fertilised area the number of the weeds/m^2 was higher and the effectiveness of the herbicides was relatively lower than in the area without fertiliser.

The results in Figure 1 indicate the effectiveness of the pre-emergence herbicides 30 and 60 DAT. 30 DAT the most effective were acetocholar and the combination of trifluralin + linuron. Less effective were imazaquin and trifluralin alone. The least effective was linuron alone. 60 DAT the established gradation in the effectiveness of these herbicides was maintained.

The results in Figure 2 indicate the effectiveness of the pre-/post-emergence sequences 14 DAT with the post-emergence. herbicides.

Figure 1. Effectiveness of pre-emergence herbicides

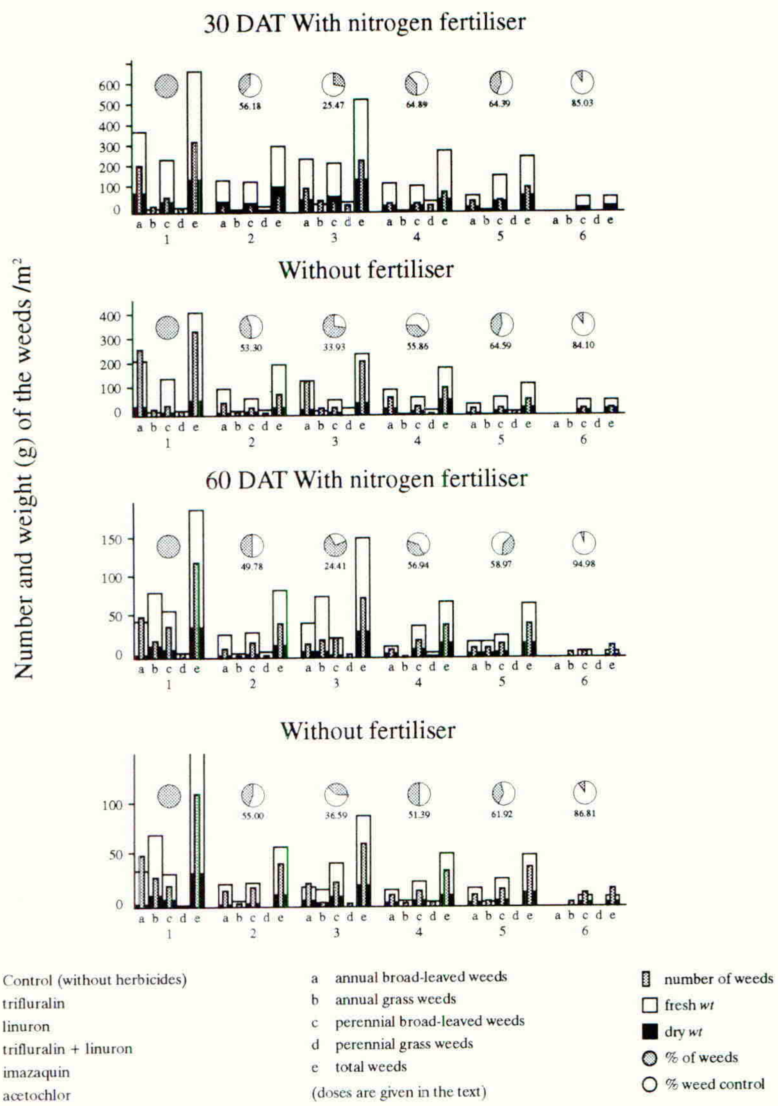
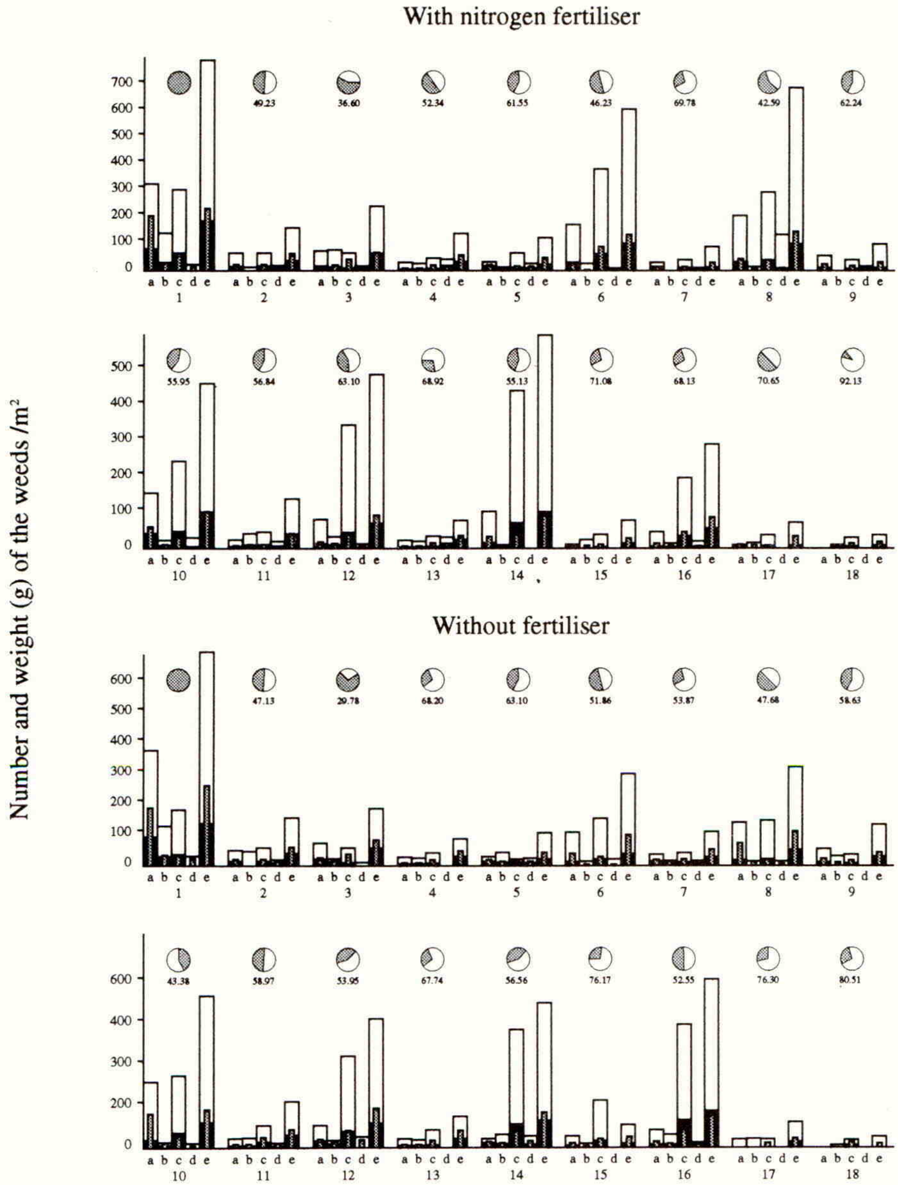


Figure 2. Effectiveness of post-emergence herbicides 14 DAT
(in sequence with pre-emergence treatments)



1 Control (without herbicides)
2 trifluralin/acifluorfen
3 linuron/fluazifop-P-butyl
4 trifluralin + linuron/bentazone + acifluorfen
5 imazaquin/bentazone + acifluorfen
6 trifluralin/bentazone
7 trifluralin/bentazone + lutensol
8 trifluralin/fluazifop-P-butyl
9 trifluralin/fomesafen
10 trifluralin/imazaquin
11 trifluralin/imazethapyr
12 imazaquin/bentazone
13 imazaquin/bentazone + lutensol
14 imazaquin/fluazifop-P-butyl
15 imazaquin/fomesafen
16 imazaquin/imazaquin
17 imazaquin/imazethapyr
18 acetochlor/lactofen

(doses are given in the text)

a annual broad-leaved weeds
b annual grass weeds
c perennial broad-leaved weeds
d perennial grass weeds
e total weeds
number of weeds
fresh *wt*
dry *wt*
% of weeds
% weed control

The most effective were sequences of acetochlor with lactofen, imazaquin or trifluralin with imazethapyr, fomesafen and bentazone with lutensol. Less effective were the sequences of imazaquin and trifluralin+linuron followed by bentazone+acifluorfen, trifluralin followed by acifluorfen and linuron followed by fluazifop-P-butyl. The least effective were the sequences of trifluralin or imazaquin followed by bentazone, fluazifop-P-butyl and imazaquin.

Consequently, if late spring broad-leaved weeds predominate in soybean crops, good results could be achieved with bentazone with lutensol, fomesafen, bentazone + acifluorfen, lactofen or imazethapyr. When there are mainly annual grass weeds, application of fluazifop-P-butyl would be sufficient for weed control.

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REDUCING HERBICIDE INPUTS IN NO-TILL SOYBEANS

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ABSTRACT

Field research was conducted in the years 1993 through 1997 to integrate reduced herbicide rates with narrow row spacing for weed control in no-till soybeans. The general methods of this research were: 1) use of early application timing to reduce post-emergence herbicide rates when weeds were small, and 2) use of a combined approach involving reduced rates of preplant followed by post-emergence herbicides. The herbicides investigated included most common broad-spectrum treatments, along with glyphosate or glufosinate applied to soybeans tolerant to these herbicides. Results showed that herbicide inputs could be reduced by up to 50 percent with no decrease in efficacy or soybean yield. In addition, multiple applications of reduced rates resulted in consistently effective weed control compared to a single application approach with recommended rates. The reduced rate approach places more emphasis on management and timely application, compared to use of recommended rates, but producers willing to improve management skills can reduce herbicide use and increase profitability.

INTRODUCTION

No-till soybean production has increased in the midwestern United States over the past ten years, and this practice usually precludes the use of post-plant cultivation due to the difficulty of accomplishing this in undisturbed soil. No-till production is often accompanied by a reduction in row spacing, often to between 18 and 38 cm, which also makes post-plant cultivation almost impossible. Soybean producers reduced row spacing to compensate for slower early crop growth under no-till conditions, and because recent planting equipment developments made it possible. Another advantage of narrow row production is the suppression of weeds that escape pre-em. and post-em. herbicide treatments due to a more rapidly developing crop canopy, compared to wider rows (Yelverton & Coble, 1991).

Weed populations shift under continuous no-till crop production. Typically, populations of biennial and perennial weeds increase, while populations of many annual weeds decrease compared to conventional tillage (Loux, 1995). No-till producers who manage weeds effectively and prevent weed seed production can often observe a great reduction in annual weeds. This should enable producers to reduce herbicide inputs, even without the availability of post-plant cultivation. Weed scientists in Arkansas and Missouri developed a programme for reducing post-em. herbicide inputs in conventional tillage soybeans. Rates were reduced by application to weeds smaller than the maximum size specified on the herbicide label and the use a sequential cultivation (Baldwin & Oliver, 1985, Steckel *et al.*, 1990). The objectives of our research were to determine: 1) the potential for reducing herbicide inputs in narrow row, no-till soybean production, using less than recommended rates of post-em. herbicides at early application timings, and 2) the effectiveness of less than recommended rates of pre-em. herbicides followed by post-em. herbicides.

MATERIALS AND METHODS

Field experiments were conducted in 1993 through 1994 using recommended and reduced rates of post-em. herbicides at various stages of weed growth in no-till soybeans. Replicated research was conducted at a total of eight on-farm sites in cooperation with soybean producers, and at two research branches of the The Ohio State University (OSU). Soybeans were planted in rows spaced 19 or 38 cm apart between late April and early June. Each experiment at an OSU branch used two different planting dates, approximately one month apart. All experiments were treated with various rates of glyphosate and/or 2,4-D ester prior to planting to control emerged weeds. Post-em. herbicides were applied in a volume of 20 l/ha using flat-fan nozzles at a pressure of 276 kPa. The herbicide program consisted of a single broad-spectrum herbicide or a mix of herbicides for grass and broadleaved weed control. This programme varied between sites based on weed populations. Across all sites, the herbicides used represented most of the common post-em. programmes currently used in soybean production in the midwestern United States (Table 1).

Table 1. Herbicides and herbicide combinations used in 1993-94 experiments.
Numbers in ( ) represent the recommended (1X) rate. All doses are in g a.i./ha.

chlorimuron-ethyl (4), thifensulfuron (4), fenoxaprop-ethyl (170), fluazifop-P-butyl (60)
bentazon (560), fomesafen (280), fenoxaprop-ethyl (136), fluazifop-P-butyl (48)
imazethapyr (70)
chlorimuron-ethyl (4), thifensulfuron (4), quizalifop-ethyl (69)
imazethapyr (70), lactofen (70)
bentazon + acifluorfen (840 + 190), sethoxydim (210)
glyphosate (630) [glyphosate-tolerant soybeans]

Herbicides were applied according to the following schedule, adapted from previous research (Baldwin & Oliver, 1985, Steckel *et al.*, 1990): 1/4X (25% of recommended rate) - 2.5 cm weeds; 1/2X (50% of recommended rate) - 2.5 to 5 cm weeds; and 1X (recommended rate) - 7.5 to 12.5 cm weeds. In addition to single applications at a reduced rate, three producer sites included treatments where a second 1/4X treatment was applied about 14 days after the first 1/4X treatment. All experiments at OSU branches included treatments where a second 1/4X or 1/2X application was made about 14 days after the initial application at the same rate. Where recommended, spray adjuvants at their recommended rates were used in herbicide treatments. Visual assessment of weed control and measurement of weed density were taken two and six weeks after the final herbicide application, and just prior to soybean harvest. Visual assessment (scale of 0 to 100, where 100 corresponded to complete control) at the latter time is presented here. Soybeans were harvested and grain yield measured. Treatments were arranged as a randomized complete block design with three (on-farm) or four (OSU) replications. Data were analyzed using analysis of variance, and means separatedwith Fisher's protected LSD ($p = 0.05$).

Recommendations for implementation of reduced-rate post-em. programs in no-till soybeans were formulated following the 1993-94 research. These recommendations were demonstrated and validated in 1995 in six on-farm demonstrations. Soybeans were planted in rows 19 cm apart. Glyphosate and/or 2,4-D ester was applied prior to soybean planting to control emerged weeds. Treatments at these sites consisted of 1/4X followed by 1/4X, 1/2X, and the recommended rate of various post-em. herbicide programmes. As in earlier research, a single herbicide or herbicide combination was used at each site, but herbicides varied among sites. The recommended rate of spray adjuvants was used in all treatments. Each treatment was applied by the producer or a custom applicator to one plot ranging in size from 2 to 6 ha, and application parameters varied among sites. Assessment of weed control was made just prior to soybean harvest, per the methods of the 1993-94 research. Soybeans were harvested and weighed by the producer. Each site was treated as a replication for the purpose of data analysis. Data were subject to analysis of variance, and means separated using Fisher's protected LSD ($p = 0.05$).

Reduced rate recommendations for total post-em. herbicide programs resulting from this research were adopted by some producers in Ohio. Other producers were reluctant to adopt the recommendations because of the requirement for intense assessment and the possibility of two post-em. applications within a fairly short period. In 1996 and 1997, additional research was conducted to determine the effectiveness of combinations of reduced rates of pre-em. herbicides with residual activity, followed by reduced rates of post-em. herbicides. A total of eight on-farm and four OSU sites were used in the two years. Pre-em. treatments included commercially available mixes of imazaquin and pendimethalin ('Squadron') applied at rates of 70 and 415 g a.i./ha, respectively, and chlorimuron-ethyl and metribuzin ('Canopy'), applied at rates of 22 and 135 g a.i./ha, respectively. These rates represent approximately one-half the common use rate of these herbicides. Pre-em. herbicides were combined with 2,4-D ester at 560 g a.i./ha and/or glyphosate at 560 to 1120 g a.i../ha to control emerged weeds prior to soybean planting, followed by application of post-em. herbicides at 1/4X, 1/2X and 1X. Post-em. herbicide selection was based on the weed population surviving preplant herbicides, and included glyphosate (1X = 630 g a.i./ha) and glufosinate (1X = 400 g a.i./ha) in addition to most of the herbicides shown in Table 1. Spray adjuvants varied with the post-em. herbicides selected, and were applied at recommended rates. The reduced rate pre-em./post-em. treatments were compared to broad-spectrum pre-em. and post-em. treatments. Assessment of weed control and experimental design and analysis were conducted as in 1993-94 experiments.

RESULTS AND DISCUSSION

In the 1993-94 study, all treatments where an initial post-em. application of a 1/4X or 1/2X was followed by a second application at the same rate provided weed control comparable to the recommended rate. The 1/2X rate applied alone provided control comparable to the recommended rate at all on-farm sites, but the 1/4X applied alone provided control comparable to the recommended rate at only two sites. While the 1/4X rate controlled weeds that were less than 2.5 cm tall, the timing of application was sufficiently early to allow reinfestation by later-emerging weeds. Averaged over all on-farm sites, control of annual grasses was as follows: 1/4X - 83%; 1/4X + 1/4X - 97%; 1/2X - 94%; 1/2X + 1/2X - 99%; and recommended rate - 96%. Control of broadleaved weeds was similar. There was no difference in soybean yield among treatments at on-farm sites, with the exception of one site in 1994. At that site, yield was reduced by 16% where 1/4X was applied once. Weed populations were higher at the OSU branches, compared to many of the on-farm sites, and single applications of 1/4X did not provide acceptable control or yield at any planting date. Single application of 1/2X provided acceptable control and yield only when soybeans were planted in mid May or later. Two applications of 1/4X or 1/2X always provided control and yield equal to or greater than the recommended rate. Results with glyphosate applied to glyphosate-tolerant soybeans were similar to those with conventional herbicides. Research at OSU branches demonstrated that the effectiveness of a single application at 1/4X or 1/2X is likely to increase as soybean planting is delayed from late April to late May, especially in more dense weed populations. Results from the 1994 experiment at OSU Western Branch illustrate the effect of planting date on control (Table 2).

Weed control and soybean yield with reduced rates in the 1995 on-farm demonstrations supported the conclusions from earlier research (Table 3). Weed control in the 1/4X followed by 1/4X and 1/2X treatments was similar to that from 1X, and there was no difference in soybean yield among treatments. However, control from the 1/2X treatment was more variable and occasionally lower than the other treatments.

Table 2. Effect of soybean planting date on weed control and soybean yield with reduced and recommended rates of post-em. herbicides at OSU Western Branch in 1994. Herbicides (1X rate in g a.i./ha): bentazon (560), fomesafen (280), fenoxaprop-ethyl (170), fluazifop-P-butyl (60). Weeds: grass - *Setaria faberi*; broadleaved - *Abutilon theophrasti*, *Chenopodium album*,and *Ambrosia artemisiifolia*.

	Planted April 21			Planted May 18		
Herbicide rate	Grass weeds	Broadleaved weeds	Yield	Grass weeds	Broadleaved weeds	Yield
	(% control)		(kg/ha)	(% control)		(kg/ha)
1/4X	50	78	3090	47	87	2560
1/4X + 1/4X	93	92	4710	97	99	4570
1/2X	75	88	4100	91	95	4640
1/2X + 1/2X	100	100	5050	100	100	4840
1X	90	82	3630	100	99	4840
LSD (p = 0.05)	11.7	7.2	875	9.5	2.9	531

Table 3. Weed control and soybean yield in 1995 on-farm demonstrations of the reduced-rate post-em. herbicide programme.

Herbicide rate	Grass weeds	Broadleaved weeds	Yield
	(% control)		(kg/ha)
1/4X + 1/4X	98	98	3010
1/2X	93	95	2990
1X	97	99	2990
LSD (p = 0.05)	NS	NS	NS

In 1996, combinations of pre-em. herbicides at 1/2X and post-em. herbicides at 1/2X or recommended rates provided control equal to or greater than recommended rates of total pre-em. or post-em. herbicide programs. While occasional differences occurred, there was little overall difference in control between the pre-em. treatments of chlorimuron/metribuzin and imazaquin/pendimethalin in combination with post-em. herbicides. The 1/4X post-em. rate was less effective than all other treatments in these combinations, although the reduction in control did not decrease soybean yield. Soybean yield was similar among all other treatments. Averaged over four sites in 1996, control of *Setaria faberi* was as follows: pre-em. (1/2X) + post-em. (1/4X) - 85%; pre-em. (1/2X) + post-em. (1/2X) - 94%; pre-em. (1/2X) + post-em. (1X) - 98%; pre-em. (1X) - 93%; post-em. (1X) - 96%. Control of broadleaved weeds was similar, with the exception that the 1/4X post-em. was more effective and the 1X total post-em treatment least effective. The 1X total post-em treatment of glyphosate provided more consistent control than conventional herbicides applied at 1X, and control was not improved with the addition of pre-em. herbicides. In contrast, the 1X total post-em. treatments of glufosinate were often less effective than conventional herbicides, and glufosinate was more effective following a pre-em herbicide. The combination of pre-em. and post-em. herbicide applications often provides more consistent weed control in no-till soybeans, compared to a single application of pre-em. or post-em. herbicides. Soybeans were planted late in 1996 relative to most years, due to wet spring conditions. As a result, single application herbicide programmes at the recommended rate provided adequate control, and the advantage of the two application program was not as evident compared to an earlier planting date. Mid-season data from 1997, when soybeans were planted earlier, show a greater benefit of a two- versus a one-application programme.

Results of these studies show that no-till soybean producers can reduce herbicide inputs and production costs in fields through intensive inspection and timely application of post-em. herbicides when weeds are small. This can be accomplished through single or multiple applications at a reduced rate of post-em. herbicides alone or combinations of reduced rates of pre-em. plus post-em. herbicides. Multiple application programmes provide consistently effective and better weed control compared to a single application, reducing the need for rescue treatments and extremely high herbicide costs. Reduced rate programmes can be adapted to glyphosate- and glufosinate-tolerant soybeans, although the former is more effective across a variety of weed species.

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USE OF NEW HERBICIDES IN CHICKPEA

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ABSTRACT

Weed infestation is one of the most important limiting factors in chickpea crops in the Mediterranean Basin. The lack of herbicides which control weeds effectively in post-emergence has determined the search for new active matters which could be selective in these crops. Chickpea exhibited a high tolerance to pyridate and herbicides belonging to aryloxyphenoxypropanoate and cyclohexanodione families. Pyridate, propaquizafop and their mixture applied at different temperatures did not show any significant differences between the treated and control chickpea plant weights. Field assays, carried out in three different varieties of chickpea in two different provinces of Andalusia to study the selectivity of the crop to pyridate, propaquizafop and their mixture, showed non-phytotoxic effects on the crop. Pyridate performed an effective control of *Chenopodium album*, *Amaranthus blitoides*, *Amaranthus cruentus*, *Solanum nigrum*, *Senecio vulgaris*, *Sinapis arvensis*, *Capsella bursa-pastoris*, *Portulaca oleracea*, *Daucus carota* and *Galium aparine*. It considerably decreased the fresh weight of *Convolvulus arvensis*, *Conium maculatum* and *Raphanus raphanistrum*; and it did not control *Ridolfia segetum* or *Papaver rhoeas* at all. Propaquizafop successfully controlled *Lolium rigidum*, *Avena fatua*, *Bromus tectorum* and wheat. Field assays showed the same results of efficacy of pyridate and propaquizafop in weeds present at the treatment time. In assays carried out in the growth chamber, the mixture of both herbicides had a synergistic effect in the control of: *Chenopodium album*, *Conium maculatum*, *Avena fatua* and *Lolium rigidum*. As a conclusion, it could be said that a mixture of pyridate and propaquizafop could be useful to control broadleaf and grass weeds in post-emergence in chickpea crops.

INTRODUCTION

The chickpea, like other Mediterranean legumes, is more tolerant to pre-sowing than to post-emergence herbicides. The growth rate of the crop is very slow during the first stages of its development and weeds are very competitive. Yield losses of 40-94% have been reported in India (Bhan and Kukula, 1987). In addition, weeds can interfere with harvesting or stain the seeds. The lack of post-emergence herbicides to control weeds determined the search for new active materials selective in chickpea.

MATERIALS AND METHODS

Chemical material and growth conditions

The formulated herbicides and rates used are shown in Table 1. Chickpea and weed plants were grown in pots following the method described by Giménez-Espinosa *et al.* (1995).

Selectivity of herbicides in chickpea

Sixteen commercially available post-emergence herbicides were assayed in chickpea (cv. Athenas) at the 3-4 leaf stage. Herbicides were applied at recommended field rates in a spray cabinet using a flat fan nozzle (TeeJet 8001) as described by Giménez-Espinosa *et al.* (1995). Fresh weights of treated and control plants were recorded 21 days after treatment, using four plants per replication and five replications per treatment.

The influence of temperature on the effect of pyridate, propaquizafop and their mixture was examined in two chickpea varieties. Plants were grown at three different temperature conditions named as: "Summer", 30/25°C light/dark; "Spring", 25/16°C light/dark; and "Winter", 10/6°C light/dark. Treatments were carried out using the spray cabinet as described above when plants were in the 3-4 leaf stage at 2 kg a.i./ha pyridate, 100 g a.i./ha propaquizafop, and 2 kg + 100 g a.i./ha pyridate + propaquizafop. Fresh weights of treated and control plants were recorded 7 and 15 DAT. Experiments were carried out using five replications per treatment and twelve plants per replication. Data were analysed using the Fisher test (LSD) with $P < 0.05$.

Herbicide efficacy

This bioassay consisted of a qualitative study of the effects of pyridate on a numerous collection of broad-leaved and grass weeds commonly found in chickpea crops in Spain (Table 5). In order to design a weed control strategy in this crop, the effects of pyridate, the graminicide propaquizafop and their mixture were studied on the weeds species. All broad-leaved weeds were treated with pyridate at 2 kg a.i. kg/ha, and with the mixture of pyridate and propaquizafop at 2 kg and 100 g a.i./ha, respectively. The grass weeds were treated with propaquizafop at 100 g a.i./ha and with the mixture described. Treatments were carried out in the 3-4 leaf stage in a spray cabinet using a flat-fan nozzle (TeeJet 8001) as described above (Giménez-Espinosa *et al.*, 1995). After two weeks, the effects of the herbicides were observed and classified in three categories depending on the phytotoxic symptoms: high control (100% of dead plants), medium control (decreased growth) and low control (herbicide did not affect growth).

Field assays

Field assays were performed in order to corroborate the results obtained in the bioassays. The selectivity of pyridate, propaquizafop and their mixture in chickpea was studied in winter and springsown crops. Experiments were conducted at Andujar (Jaén, Spain) in a wintersown and at Santaella (Córdoba, Spain) in a spring crop. They were arranged in a randomized complete block with 3 to 4 replications. The experiment at Andujar used plots of 4 x 7.5 m and cv. Athenas. Herbicides were applied with a pressure tank sprayer fitted with TeeJet 8001 nozzles at 250 kPa and 300 litres/ha. Treatments were applied on 23 March (plants 30 cm high) and consisted of 2.5 and 5 kg a.i./ha pyridate, 100 and 200 g a.i./ha propaquizafop, 2.5 kg + 100 g and 5 kg + 200 g a.i./ha pyridate + propaquizafop, with two untreated plots per block (control). The experiment at Santaella was performed with plots 4 x 5 m and cvs. PV60 and UC15. Herbicides were applied with a pressure tank sprayer fitted with Lurkmark AN5 nozzles at 250 kPa and 200 litres/ha. Treatments were 2 kg a.i./ha pyridate, 100 g a.i./ha propaquizafop and a combination of these two. Selectivity was evaluated 3 to 4 times a month until harvest. The determination of the effect of treatments on the chickpea was carried out visually using a linear scale from 0 to 100 where 0 is no effect damage and 100 is complete destruction of the crop.

Weed control efficiency was also assayed visually 3-4 times a month after treatments. The effects of herbicides were divided into three groups: high efficiency (death of weed), medium efficiency (reduced growth), and low efficiency (did not affect the plant).

RESULTS

Selectivity of herbicides in chickpea

The results of the bioassays allowed us to divide the sixteen herbicides into four groups (Table 1): **very phytotoxic** (> 70% inhibition of fresh weight): bentazone, metamitron, clopyralid, terbutryn, oxyfluorfen and dicamba; **phytotoxic** (40-70% inhibition of fresh weight): phenmedipham, phenmedipham:desmedipham:ethofumesate, cyanazine; **low phytotoxic** (10-40% inhibition of fresh weight): AC299263, Ethofumesate and chloridazon; **non-phytotoxic** (no significant difference between treated and control plants): pyridate, propaquizafop, diclofop and clethodim.

The selectivity and efficacy of herbicides depends on the climate and this determines the various recommendations for different geographic areas. Legumes are generally very susceptible to post-emergence herbicides and high or low temperatures can occasionally produce phytotoxic damage in crops (Knott and Halila, 1988). The influence of temperature on the effect of pyridate, propaquizafop and their mixture was examined for three different temperature conditions in two chickpea cvs.: PV60 and Athenas. Pyridate, propaquizafop and their mixture did not produce any phytotoxic effect or reduce the fresh weight of plants compared to untreated plants at any of the temperature conditions assayed (Tables 2, 3 and 4). Therefore, the tolerance of chickpea to these herbicides is not altered under different temperature conditions.

The evaluation of the effects of treatments carried out in cvs. Athenas, PV60 and UC15 did not exhibit any phytotoxic damage in chickpea plants even at high rates of herbicides (5 kg a.i./ha pyridate, and 200 g a.i./ha propaquizafop). These results corroborate the results obtained in the growth chamber at different temperatures.

Table 1. Effect of different herbicides on the fresh weight of chickpea (cv. Athenas), 21 days after treatment

Active matter	Commercial product	Doses/ha (Commercial product)	PT/ P0 (% of control)	Observations
Bentazone	BASAGRAN	3 litres	8.50**	Wilt and chlorosis
Ethofumesate	TRAMAT	2 litres	72.80**	Burnt leaves and shoots
Chloridazon	PYRAMIN	3 kg	76.75**	Reduced weight and burns
Metamitron	GOLTIX	5 kg	22.13**	Wilt and burns in treated leaves
Clopyralid	LONTREL	4 litres	11.51**	Deformation of shoots and burnt leaves
Phenmedipham	KEMIFAN	8 litres	51.68**	Burnt treated leaves, falling-out of leaves
Terbutryn	IGRAN	3 litres	11.51**	Wilt and burns
Oxyfluorfen	GOAL	1 litres	9.35**	Fast desiccation
Dicamba	BANVEL	300 ml	10.70**	Deformation of shoots and leaves
Phenmedipham: desmedipham: ethofumesate	BETANAL *Progress*	6 litres	43.11**	Reduced growth, burns in leaves and shoots
AC299263	BOLERO	6 litres	66.81**	Falling-out of leaves, burnt shoots
Cyanazine	BLADEX	3 kg	42.44**	Dried treated leaves
Pyridate	LENTAGRAN	2 kg	103.50*	No symptoms
Diclofop	ILOXAN	2.5 litres	97.65*	No symptoms
Clethodim	SELECT	800 ml	113.75*	No symptoms
Propaquizafop	AGIL	1 litres	95.85*	No symptoms

PT=fresh weight (g) of treated plants; P0=fresh weight (g) of untreated plants
*PT and P0 do not differ significantly for $P<0.05$ according to the Fisher test (LSD)
** PT and P0 differ significantly for $P<0.05$ according to the Fisher test (LSD)

Herbicide efficacy

Pyridate gave good control of *Chenopodium album*, *Amaranthus blitoides*, *Amaranthus cruentus*, *Solanum nigrum*, *Senecio vulgaris*, *Sinapis arvensis*, *Capsella bursa-pastoris*, *Portulaca oleracea*, *Daucus carota* and *Galium aparine*. All the plants died two weeks after treatment. However, this herbicide gave moderate control only of: *Convolvulus arvensis* and *Lolium rigidum*, and poor control of *Conium maculatum*, *Raphanus raphanistrum*, *Ridolfia segetum*, *Papaver rhoeas*, *L. multiflorum*, *Avena fatua*, *Bromus tectorum* and volunteer wheat (Table 5).

Table 2. Fresh weight of chickpea (cv. PV60 and Athenas) grown in a growth chamber at 25 °C/ 16 °C (day/night) and treated with pyridate (2 kg a.i./ha), propaquizafop (100 g a.i./ha) and their mixture

	DAT	Control*	Pyridate	Propaquizafop	Mixture
PV60	7	0.65a	0.84a	0.89a	0.88a
	15	1.94a	1.99a	2.18a	2.28a
Athenas	7	0.72ab	0.70b	0.86a	0.68b
	15	1.84a	1.84a	1.81a	1.88a

*Means followed by the same letter within a row do not differ significantly at $P<0.05$ according to Fisher test (LSD)

Table 3. Fresh weight of chickpea (cv. PV60 and Athenas) grown in a growth chamber at 10 °C/ 6 °C (day/night) and treated with pyridate (2 kg a.i./ha), propaquizafop (100 g a.i./ha) and their mixture

	DAT	Control*	Pyridate	Propaquizafop	Mixture
PV60	7	1.31a	1.15a	1.12a	1.16a
	15	1.69a	2.32b	2.04ab	2.27ab
Athenas	7	0.52a	0.64a	0.58a	0.54a
	15	0.97a	0.83a	0.82a	0.83a

*Means followed by the same letter within a row do not differ significantly at $P<0.05$ according to Fisher test (LSD)

Table 4. Fresh weight of chickpea (cv. PV60 and Athenas) grown in a growth chamber at 30 °C/ 25 °C (day/night) and treated with pyridate (2 kg a.i./ha), propaquizafop (100 g a.i./ha) and their mixture

	DAT	Control*	Pyridate	Propaquizafop	Mixture
PV60	7	0.78a	0.65a	0.60a	0.63a
	15	1.34a	1.23a	1.13a	1.36a
Athenas	7	0.48a	0.50a	0.58a	0.50a
	15	0.75a	0.87a	0.80a	0.81a

*Means followed by the same letter within a row do not differ significantly at $P<0.05$ according to Fisher test (LSD)

Propaquizafop at 100 g a.i./ha exhibited a good control over all the grass weeds assayed; and the mixture of both herbicides at the same rates good control over all the species except for *C. maculatum*, *R. raphanistrum*, *R. segetum*, and *P. rhoeas* and *C. arvensis*. These results showed that pyridate, although it does not control a wide spectrum of broadleaved weeds, could be used in mixture with the graminicide propaquizafop to control a range of weeds in chickpea (Table 5). In addition, some interactions were observed when using the mixture on *C. maculatum*, *L. rigidum*, *A. fatua* and volunteer wheat. In all the cases plants treated with the mixture displayed higher phytotoxic symptoms than plants treated with pyridate or propaquizafop alone (Table 5).

The efficiency of pyridate, propaquizafop and their mixture in the control of weeds was also studied on each field experiment. Pyridate was effective in controlling: *C. album*, *C. vulvaria*, *A. blitoides*, *A. albus*, *Anagallis arvensis*, *Chrozophora tintorea* and *Heliotropium europaeum*. The effect of pyridate on *Polygonum aviculare*, *Malva* sp. and *C. arvensis* depended on the plant stage, pyridate provided an unacceptable weed control when plants were very developed. With respect to *R. segetum*, *Diplotaxis* sp. and *P. rhoeas*, pyridate had no effect on their control at the rates tested. On the other hand, propaquizafop controlled volunteer wheat, which was the most important grass in all the field tests.

Table 5. Level of control of pyridate (2 kg a.i./ha) or propaquizafop (100 g a.i./ha) and their mixture on different Mediterranean weeds

Weeds	Pyridate	Propaquizafop	Mixture
Chenopodium album	H	--	H*
Amaranthus blitoides	H	--	H
Amaranthus cruentus	H	--	H
Solanum nigrum	H	--	H
Conium maculatum	L	--	L*
Senecio vulgaris	H	--	H
Sinapis arvensis	H	--	H
Raphanus raphanistrum	L	--	L
Capsella bursa-pastoris	H	--	H
Portulaca oleracea	H	--	H
Convolvulus arvensis	M	--	M
Ridolfia segetum	L	--	L
Daucus carota	H	--	H
Galium aparine	H	--	H
Papaver rhoeas	L	--	L
Lolium rigidum	--	H	H*
Lolium multiflorum	--	H	H
Avena fatua	--	H	H*
Bromus tectorum	--	H	H
Wheat	--	H	H*

H= Plants dead two weeks after treatment; M= Reduced growth two weeks after treatment; L= Treatments did not affect plant growth two weeks after treatment

* Synergistic effects were observed

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OXADIARGYL A NOVEL HERBICIDE FOR SUNFLOWER AND VEGETABLES

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ABSTRACT

Oxadiargyl, a new pre-emergence herbicide, has been developed primarily for the control of broad-leaved weeds and grasses in rice and sugarcane; In addition, extensive experiments in Europe and Middle-East have shown that 300-400 g a.i. / ha oxadiargyl are well tolerated by sunflower and transplanted vegetables when applied pre-emergence or pre-transplanting. Applied at suggested dose rates, oxadiargyl controls a wide range of important dicotyledons (e.g. *Amaranthus* spp, *Chenopodium* spp, *Polygonum* spp and *Solanum nigrum*) and exhibits a good activity on annual grasses. Weed control is not dependant from soil type or texture but can be reduced under non adequat soil moisture. Oxadiargyl is of particular interest for weed control in transplanted vegetables which, usually, are irrigated. Transplanted vegetables (tomato, artichoke, asparagus, cabbage, eggplant, pepper and celery) tolerate dose rates ranging from 400 to 800 g a.i./ha.

INTRODUCTION

Oxadiargyl, a member of the oxadiazole chemistry group, is a novel pre-emergence herbicide discovered by Rhône-Poulenc Agrochimie. Its toxicological, ecotoxicological and environment properties represent a significant advance in this area of chemistry (Dickmann *et al*, 1997). Its biological properties have been investigated by Rhône-Poulenc Agrochimie (in-house research farm trials) for many years and by national crop protection organisations for registration purposes. Sunflower and vegetables were identified as important target crops for development.

MATERIAL AND METHODS

During 1994, 1995 and 1996, a total of more than 100 small plots efficacy and selectivity trials were carried in sunflower and in transplanted vegetables in Europe (France, Italy and Spain) and Israel (transplanted vegetables only). For all the trials, oxadiargyl was formulated as a suspension concentrate containing 400 g a.i./l oxadiargyl (code EXP 03316). In all trials in sunflower, oxadiargyl was applied as a pre-emergence spray. No land cultivation or incorporation techniques were made after the application.

In transplanted vegetables, treatments were generally applied either in pre-transplanting (2-3 days) or in early pre-transplanting (20-60 days) depending upon the crop tolerance or cultivation practises.

Efficacy trials were designed to include an untreated control adjacent to the treated plot with two replicates or with a randomised block (four replicates). Herbicidal performance was assessed visually or by quadrat counts of surviving plants in comparison with untreated control plants. The weed control data given in Tables 1 and 3 represent the mean values calculated from all occurences of each species. Crop tolerance was also assessed visually at intervals following emergence. Selectivity trials carried out in France were established in naturally weed-free fields in order to avoid any interactions (i.e., efficacy-phytotoxicity).

RESULTS AND DISCUSSION

Sunflower

Applied pre-emergence to sunflower, 200 g a.i./ha oxadiargyl are particularly effective on some very susceptible key broad leaf weeds such as: *Chenopodium* species, *M. chamomilla*, *S. nigrum* and *V. tricolor* (Table 2). Field trials also indicate that oxadiargyl, when applied at rates of 400 g a.i./ha, controls many other dicotyledons (e.g. *A. theophrasti*, *A. retroflexus*, *A. blitoides*, and *Polygonum* spp*)*. It also gives adequat control of grass weeds, in particular *D. sanguinalis* and *S. glauca*. However, efficacy against grass weeds is water dependent, and the activity may be not sufficient against *Echinochloa* spp and some *Setaria* spp, when limited rainfalls follows the application of oxadiargyl.

As for most of the pre-emergence herbicides, rainfall after the application is an important factor for both efficacy and selectivity. In particular, heavy rainfall after the application may reduce crop selectivity. Oxadiargyl at 400 g a.i./ha proved to be as selective as the reference compounds, aclonifen (2700 g a.i./ha) and flurochloridone (750 g a.i./ha), at their normal and double dose rates (Table 1).

Table 1. Means of yield assessments corrected to 9% moisture as a percentage of untreated control. (Selectivity trials - France 1994 and 1995)

	Oxadiargyl		Flurochloridone		Aclonifen		*Control*
Dose rate g a.i./ha	360	720	750	1500	2700	5400	*t/ha*
Means of 14 trials	100	99	100	101	102	106	*3.09*

Table 2. Efficacy of oxadiargyl on grasses and broad-leaved weeds in sunflower (Summary of the efficacy trials in France, Italy and Spain in 1994/95/96)

	Oxadiargyl		Aclonifen	Flurochloridone
Dose g a.i./ha	200	360 - 400	2700	750
Abutilon theophrasti	MR-MS	S	S	-
Amaranthus blitoides	-	S	-	-
Amaranthus retroflexus	S	S	S	S
Ambrosia artemisiifolia	MS	MS	MR-MS	MR-MS
Ammi majus	MR-MS	MS	MR	MR-MS
Capsella bursa-pastoris	MS	MS	S	S
Chenopodium album	S	S	S	S
Chenopodium polyspermum	S	S	S	S
Digitaria sanguinalis	MS	S	MS	S
Fallopia convolvolus	MS	S	MS	MR-MS
Matricaria chamomilla	S	S	S	S
Mercurialis annua	MS	S	S	S
Polygonum aviculare	MS	S	S	S
Polygonum lapathifolium	MS	S	S	S
Polygonum persicaria	-	S	MS	-
Raphanus raphanistrum	MS	S	S	S
Reseda spp.	MS	S	S	S
Senecio vulgaris	MS	S	MS	MS
Setaria glauca	MR-MS	S	S	S
Setaria verticillata	MS	MS	S	MS
Sinapis arvensis	MR-MS	MS	S	S
Solanum nigrum	S	S	MR	S
Sonchus arvensis	MR-MS	S	S	-
Viola tricolor	S	S	MS	MR-MS

Table key :

	S	=	susceptible, > 90% control
	MS	=	moderatly susceptible, 75% - 90% control
	MR-MS	=	moderatly tolerant, 50% - 75% control
	R	=	tolerant, < 50% control

Vegetables

In transplanted vegetables, 400 g a.i./ha oxadiargyl, applied pre-transplanting selectively control annual grasses and a wide range of broad-leaved weeds, excepted *O. oxyptera* and *F. convolvulus.*

Table 3. Means of efficacy trials in Europe and Middle-East

	Oxadiargyl		
Dose rate g a.i./ha	300	400	500
Abutilon theophrasti	MS	S	
Ageratum spp		S	S
Amaranthus deflexus		S	S
Amaranthus retroflexus	S	S	
Amaranthus viridis		S	S
Bidens pilosa		MS	S
Chenopodium album	S	S	
Datura stramonium	MS	S	S
Digitaria horizontalis		S	S
Digitaria sanguinalis	S	S	
Echinochloa crus-galli	S	S	
Fallopia convolvulus	MR	MS	
Galinsoga parviflora		MS	S
Oxalis oxyptera		MR-MS	MR-MS
Panicum miliaceum		S	S
Polygonum persicaria	S	S	
Portulaca oleracea		S	S
Solanum nigrum	S	S	

Table key : S = susceptible, > 90% control
MS = moderatly susceptible, 75% - 90% control
MR-MS = moderatly tolerant, 50% - 75% control
R = tolerant, < 50% control

Artichoke, cabbage, cauliflower and broccoli tolerated up to 800 g a.i./ha oxadiargyl applied pre-planting, while eggplant, pepper and celery tolerated up to 600 g a.i./ha and tomato, tobacco and onion up to 400 g a.i./ha. Good selectivity also was observed in early post-emergence applications (1 true leaf) on onions with oxadiargyl at 200 g a.i./ha. Applications made later, at the 2-3 leaf stage, were more selective and no phytotoxicity symptoms were observed with 300 g a.i./ha. Lettuce is less tolerant and tolerated only 200 g a.i./ha applied pre-transplanting. Watermelon was more susceptible to oxadiargyl than other crops. In Israel (trials conducted in 1996), oxadiargyl 800 g a.i./ha was selective only when applied 2 months prior to planting and the soil covered with plastic.

Preleminary data indicate that no adverse effect may be anticipated on following crops; a shallow tillage being sufficient to eliminate the biological activity. This point is of particular importance in the management of vegetable crops where several cycles of different crops follow over a growing period.

CONCLUSION

Oxadiargyl is a novel multi-crop herbicide, with favourable toxicological and ecotoxicological profiles. It shows good activity in pre-emergence or pre-transplanting against a wide weed spectrum, and it could contribute to the effective control of weeds not well controlled by current comercial standards herbicides (e.g. *A. majus, S. nigrum)*. Its mode of action, which is typical of the oxadiazole chemical family, can be a useful tool, in combination with partner herbicides, to avoid cross resistance problems. For vegetable crops, oxadiargyl offers considerable flexibility in terms of methods and timing of treatments without impacting crop safety or producing any residual effect on following crops.

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REDUCED HERBICIDE DOSES IN CARROT PRODUCTION

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ABSTRACT

The consequences of dose reduction of aclonifen and linuron were studied in carrot production in Finland. The efficacy of 25%, 50%, 75% and 100% dose was screened to obtain the dose response curves of herbicides. The efficacy obtained with reduced doses of herbicides was relatively good in terms of % kill. However, the yield responses of carrot revealed the need of very high efficacy which was seldom achieved with reduced herbicide doses. Linuron was more effective than aclonifen which suffered from poor efficacy particularly against *Galeopsis* spp.. It appeared feasible to reduce the recommended application rate of linuron at least by 25% if it was applied at the early growth stages of weeds. The recommended doses of aclonifen should be followed.

INTRODUCTION

Political Action Plans stipulate the reduction of pesticide use in the Nordic countries. In addition, both environmental and economic reasons pressure the farmers to reduce the use of herbicides. Consequently, intensive research efforts have been launched to optimize the use of herbicides in crop production. Most of the research has focused on herbicide use in field crops, mainly cereals, which contribute the major use of herbicides. However, some research is going on to optimise herbicide use in vegetables. This is more challenging than in cereals, since the competitive ability of most vegetables is far too low to out-compete weeds which remain after insufficient weed control. Consequently, the yield losses in weed-infested vegetable fields are an order of magnitude greater than in cereals.

Weeds are recognised to be the most important constraint in field vegetable production in Finland. Herbicides are frequently and efficiently used to solve the weed problems. Carrot is one of the main field vegetables, grown on 2 000 hectares in Finland. The objective of this study was to evaluate the possibilities to reduce application rates of aclonifen and linuron in carrot production.

MATERIALS AND METHODS

The weed control trials in carrot were located in loamy sand soils in Southern Finland in 1994-1996. Herbicide formulations of aclonifen (600 g a.i./litre, 'Fenix') and linuron (450 g a.i/litre, 'Afalon') were screened with 25%, 50%, 75% and 100% of the recommended dose. The 100% dose for Fenix was 2.0 litres/ha and that for Afalon 1.0 litre/ha applied twice. Thus, the total dose of aclonifen was 2.4 kg a.i/ha and that of linuron 0.9 kg a.i./ha.

Herbicides were applied with a portable 'van der Weij' propane sprayer fitted with flat fan nozzles (Hardi 4110) delivering 400 litres/ha (200 litres/ha in 1996) spray solution. The first application in 1994 and 1995 was 3-4 days prior to the carrot emergence with the second at the 2-leaf stage of carrot. In 1996, the first application was at the cotyledon stage and the second application time at 2-3 leaf stage of carrot. Each trial included untreated and hand-weeded plots. Treatments were arranged as a randomised complete block design with four replicates. Irrigation was used as necessary to maintain soil moisture.

The most abundant weed species in the trials were *Chenopodium album, Galeopsis tetrahit, Stellaria media*, *Viola arvensis* and, in 1996, *Matricaria matricarioides*. The efficacy of herbicides was assessed in two 0.50 m^2 quadrats by counting the number of weeds and weighing their air-dry biomass 3-4 weeks after the second treatment. Visual scoring of herbicide phytotoxicity on carrot was made 1-2 weeks after the herbicide applications.

The dry weights of weeds were fitted to the following logistic model (Streibig *et al.*, 1993):

$$U=C+(D-C)/(1+\exp(2b(\log10(ED50)-\log10(z))))$$

where D and C denote the upper and lower limit of the dose-response curve at zero and large doses, respectively. ED50 and similarly estimated ED90 denote the herbicide dose required to achieve 50% and 90% control. The parameter b is proportional to the slope around ED50.

RESULTS

Linuron proved to be more efficient than aclonifen against the prevalent weed flora in the trials. Even the high efficacy level of 90% was reached with application rates substantially lower than the recommended 100% dose (Table 1).

Table 1. Herbicide doses (ED) in litres/ha of product for the 50% and 90% control

Herbicide Year	ED50 (SEM)	ED90 (SEM)
Aclonifen		
1994	1.10 (0.55)	not estimated
1995	0.26 (0.24)	2.33 (5.70)
1996	0.87 (0.12)	3.17 (0.63)
Linuron		
1994	0.44 (0.11)	1.41 (0.21)
1995	0.12 (0.65)	0.35 (0.45)
1996	0.35 (0.07)	0.67 (0.10)

Although the efficacy of herbicides was good in terms of control percentages, the amount of remaining weed biomass was quite high even in the treated plots, particularly with aclonifen (Fig. 1). The yield level of hand-weeded plots was reached only with linuron, sometimes even with reduced doses (Fig 2).

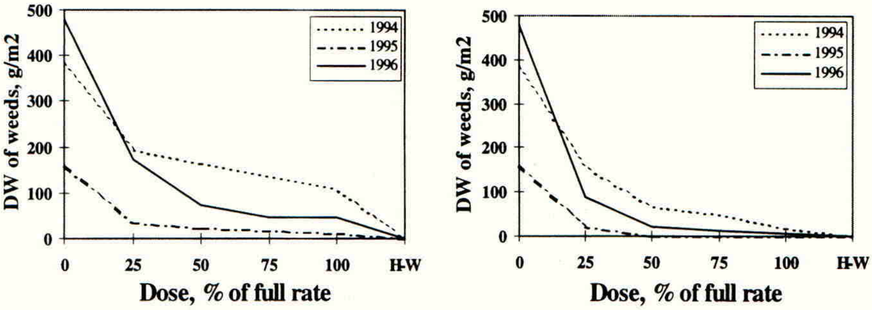

Fig. 1. Dose response of herbicides (left: aclonifen, right: linuron) on weed dry weight in carrot. H-W at the X axis denotes for 'Hand-weeded'.

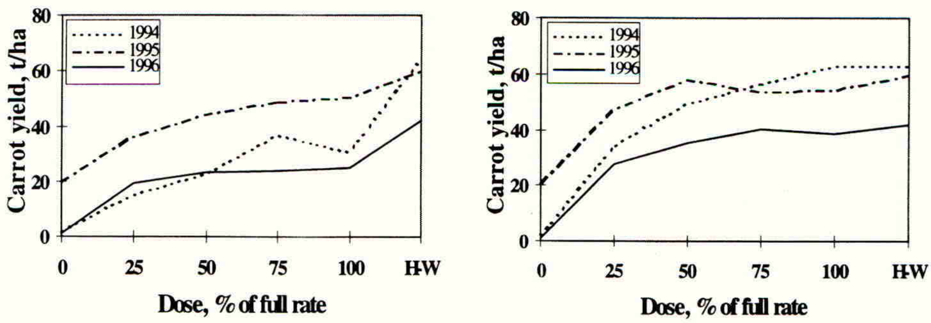

Fig 2. Yield response of carrot to weed control with aclonifen (left) and linuron (right). H-W at the X axis denotes for 'Hand-weeded'.

Both herbicides controlled *C. album* well even at reduced application rates. The required dose of aclonifen increased in the following order *C. album* < *S. media* < *V. arvensis* < *M. matricarioides* < *G. tetrahit*. In addition, the reduced doses of linuron were weak against *M. matricarioides*.

Aclonifen was more phytotoxic than linuron on the crop, particularly at the cotyledon stage of carrot. The damages reached the level of 20-30% at the scale of 0-100%.

DISCUSSION

In general, reduced doses of aclonifen and linuron controlled high percentage of weeds. However, the weed infestation in the carrot fields was so high that 90% kill would seldom satisfy farmers. Even the remaining 10% weed biomass caused considerable yield losses.

The present study proved that the use of herbicides can, to some extent, be minimized by using lower application rates than recommended on the product label. Particularly, doses of linuron can be reduced at least by 25% if the weed populations consist of the most typical weed species in Finland, like *C. album*, *Galeopsis* spp., *V. arvensis*, *S. media* and *Brassicaceae* species like *Thlaspi arvense* and *Capsella bursa-pastoris*.

Split application of herbicides enables the timing of sprays to the early growth stages of weeds. Wijnands & Bauman (1991) recommended only 25% application rates of linuron+additive when the weeds were sprayed at their cotyledon stage. However, this calls for more than two sprays and means higher application costs. Netland (1993) suggested that the common pre-emergence application of linuron is often superfluous in a control programme which consists of split applications. The number of applications depends e.g. on weather conditions and on crop growth.

Aclonifen has recently been registered for the Finnish market. It appears feasible to follow the dose recommendation for aclonifen taking into consideration the prevalent weed floras in Finland. For carrot the label recommendation of aclonifen is 0.9-1.2 kg a.i./ha pre-emergence and 0.9 kg a.i./ha at the 2-leaf stage. In addition, there is a general recommendation to mix or combine aclonifen with other herbicides in the control programme.

ACKNOWLEDGEMENTS

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