Session 7C

Weed Control in Non-cereal Crops

Session Organisers	Mr M J May and Mr D V Clay
Poster Papers	7C-1 to 7C-18

POST-EMERGENCE BROAD-LEAVED WEED CONTROL IN SUGAR BEET WITH TRIFLUSULFURON IN THE UK 1993-1994

S J FISHER
British Sugar plc, Holmewood Hall, Holme, Peterborough, Cambs., PE7 3PG

M J MAY
Morley Research Centre, Morley, Wymondham, Norfolk, NR18 9DB

G DICKINSON
DuPont Agricultural Products, Wedgwood Way, Stevenage, Herts., SG1 4QN

ABSTRACT

In 1993 and 1994, 33 experiments using common protocols were conducted in the UK to examine weed control efficacy and crop safety of post-emergence applications of triflusulfuron in mixture with other herbicides. All treatments were applied at least twice, but mainly as three or four-spray programmes. The first applications were applied at the early cotyledon stage of weed growth. Addition of mineral oil to triflusulfuron had a greater influence on weed control than non-ionic wetters. The spectrum of weeds controlled was increased by the addition of phenmedipham or a phenmedipham:desmedipham:ethofumesate co-formulation to triflusulfuron. Four-way mixes of triflusulfuron + phenmedipham + metamitron or lenacil + mineral oil gave acceptable control of most species. There was some indication of antagonism between chloridazon and triflusulfuron which resulted in poor control of *Polygonum aviculare*. Substitution of the phenmedipham + desmedipham + ethofumesate co-formulation for phenmedipham in the mixtures with lenacil or metamitron resulted in faster kill of weeds. All treatments proved to be safe to the crop with no undue reductions in plant numbers or vigour recorded. At six sites, transient chlorosis was apparent, but this effect was not of a commercially significant level. Triflusulfuron received registration for use on UK sugar beet crops in September 1995.

INTRODUCTION

Triflusulfuron (as DPX66037) was announced at the 1991 Brighton Crop Protection Conference (Peeples *et al*, 1991). Since then it has been registered in a number of European countries and in the USA. UK registration was gained during the summer of 1995. Since 1992 many field trials have been conducted to establish efficacy and crop safety of a number of chemical mixtures with triflusulfuron under UK conditions. This paper covers the common protocol trials conducted in 1993 and 1994 by DuPont (UK) Ltd, British Sugar plc and Morley Research Centre.

MATERIALS AND METHOD

Field trials were conducted on 20 sites throughout the beet growing area in 1993 and 13 in 1994. Common protocols were used for all the trials in each individual year. The treatments (chemical details are in Table 1) changed from 1993 to 1994 to include a greater number and to drop those that had not performed well in 1993 (see Table 2).

A randomised block design with three replicates was used. All treatments were applied post-emergence in the absence of a pre-emergence herbicide spray. The first application was applied to weeds at the cotyledon stage of growth. Subsequent applications were applied when the next weed flush emerged or 7-14 days after the first flush. Assessments of broad-leaved weed control and crop safety were made at all sites.

Table 1. Details of test substances for 1993 and 1994.

Abbreviation used in following tables	Trade or code name	Chemical name	g a.i. l^{-1} or %	Formulation
trifl'on	Debut (DPX66037)	triflusulfuron	50 %	DF
non-ion a	Citowett	non-ionic wetter	100 %	Liquid
non-ion b	KG691	non-ionic wetter	100 %	Liquid
oil	Cropspray 11E	mineral oil	99 %	Liquid
phen.	Betanal E	phenmedipham	114 g a.i. l^{-1}	EC
phen.	Betanal Progress	phenmedipham	62 g a.i. l^{-1}	EC
des.		desmedipham	16 g a.i. l^{-1}	
etho.		ethofumesate	128 g a.i. l^{-1}	
metam.	Goltix WG	metamitron	70 %	WG
chlorid.	Pyramin DF	chloridazon	65 %	DF
lenacil	Venzar	lenacil	80 %	WP

In 1993 and 1994, triflusulfuron treatments were compared with an untreated control and a conventional mixture without triflusulfuron (treatment 23, see Table 2). In 1993, ten mixtures (Table 2) were applied three times and in 1994 twelve were applied three or four times. In 1994 two additional sequences (treatments 21 and 22, see Table 2) were included. Treatments 1-3 were included in 1993 for registration purposes only.

RESULTS

The results for weed control efficacy in each year have been averaged and compiled into Tables 3 and 4. These show average weed control for each treatment on a selected range of species. Of the three adjuvants tested in 1993, the mineral oil was found to be

Table 2. Treatments and doses in 1993 and 1994.

	Treatments	Rate (g a.i. ha^{-1})	Year of use
1	trifl'on + non-ion. a	15+0.05 %	1993
2	trifl'on + non-ion. b	15+0.05 %	1993
3	trifl'on + oil	15+1000	1993
4	trifl'on + phen.	15+171	1993/1994
5	trifl'on + phen. + non-ion b	15+171+0.05 %	1993
6	trifl'on + phen.	15+228	1993
7	trifl'on + phen. + metam.	15+171+350	1993/1994
8	trifl'on + phen. + chlorid.	15+171+260	1993
9	trifl'on + metam. + oil	15+350+1000	1993
10	trifl'on + metam. + oil	15+700+1000	1993
11	trifl'on + phen. + lenacil.	15+171+200	1994
12	trifl'on + phen. + oil	15+114+1000	1994
13	trifl'on + phen. + lenacil + oil	15+114+200+1000	1994
14	trifl'on + phen. + metam. + oil	15+114+350+1000	1994
15	trifl'on + phen./des./etho.	15+31/8/64	1994
16	trifl'on + phen./des./etho. + lenacil	15+31/8/64+200	1994
17	trifl'on + phen./des./etho. + metam.	15+31/8/64+350	1994
18	trifl'on + phen./des./etho.	15+62/16/128	1994
19	trifl'on + phen./des./etho. + lenacil	15+62/16/128+200	1994
20	trifl'on + phen./des./etho. + metam.	15+62/16/128+350	1994
21	trifl'on + metam. + oil (T1) followed by treatment 13 at subsequent applications	15+350+1000	1994
22	trifl'on + lenacil + oil (T1) followed by treatment 13 at subsequent applications	15+200+1000	1994
23	phen. + metam.	285+1050	1993/1994
24	untreated	nil	1993/1994

the most effective; giving superior control of *Chenopodium album* and *Polygonum aviculare* in particular.

The addition of phenmedipham (treatment 4) greatly increased the weed spectrum controlled, giving acceptable control of most species. Increasing the dose of phenmedipham (treatment 6) or adding non-ionic wetter b (treatment 5) gave more consistent control of *P. aviculare* and *C. album*. The three-way mixes of triflusulfuron + phenmedipham + metamitron (treatment 7) gave good control of most species. Substituting metamitron with chloridazon (treatment 8) also controlled most species, but antagonism was recorded on *P. aviculare* and to a lesser extent on *Galium aparine*. Weed kill from mixtures of triflusulfuron + metamitron + mineral oil (treatment 9) gave slow, but effective control of most species. There was little or no improvement from increasing the dose of metamitron (treatment 10).

Table 3. % Average final weed control in 1993.

	C. album	*G. aparine*	*P. aviculare*	*Brassica napus*	*Matricaria* spp.	*Fallopia convolvulus*
Sites:	7	6	7	3	5	5
1	52	81	65	88	99	38
2	45	75	75	91	99	33
3	67	80	85	92	99	39
4	83	86	84	94	100	84
5	82	89	97	93	100	92
6	90	85	93	95	100	82
7	92	85	89	93	100	86
8	83	76	63	91	100	91
9	79	75	76	95	100	38
10	82	76	83	94	100	43
23	98	74	99	94	100	90
24	0	0	0	0	0	0

Table 4. % Average final weed control in 1994.

	C. album	*P. aviculare*	*Matricaria* spp.	*F. convolvulus*	*Urtica urens*	*Viola arvensis*
Sites	7	3	1	8	3	4
4	87	71	93	90	98	94
7	95	71	100	96	98	95
11	94	78	94	95	98	95
12	90	75	97	96	99	98
13	93	77	96	98	98	99
14	97	79	99	93	99	98
15	90	77	91	89	98	96
16	93	77	100	94	98	96
17	93	76	100	90	98	95
18	94	81	100	96	99	97
19	96	82	99	98	99	98
20	97	80	100	97	98	98
21	94	84	100	95	99	98
22	93	81	94	98	98	97
23	97	87	100	95	99	99
24	0	0	0	0	0	0

Four-way mixes of triflusulfuron + phenmedipham + lenacil or metamitron + mineral oil (treatments 13 and 14) gave good control of a wide range of weed species.

Table 5. % Crop chlorosis in 1994.

Site code*	502		LA		501			601	600	HD	
DAT1	28	47	9	24	26	42	55	50	28	9	21
4	5	0	3	7	3	3	0	3	3	0	0
7	1	0	3	7	3	0	0	2	0	0	3
11	5	0	3	8	5	2	0	7	0	0	7
12	8	0	5	18	5	4	0	4	0	0	13
13	5	0	7	20	5	4	0	4	0	3	8
14	4	0	7	10	6	3	0	4	0	3	17
15	4	0	5	10	5	3	0	4	0	7	2
16	4	0	7	10	6	0	0	4	0	0	10
17	1	0	0	10	5	0	0	1	3	0	0
18	6	0	8	10	5	4	0	4	5	0	3
19	3	0	7	13	5	2	0	4	7	0	13
20	2	0	0	10	5	1	0	5	2	0	10
21	6	0	2	10	5	8	0	6	1	0	17
22	6	0	7	8	5	9	0	6	5	0	21
23	0	0	3	8	5	0	0	1	1	0	3
24	0	0	0	0	0	0	0	2	0	0	0

* site code for the organisation carrying out the experiment.

In 1994, the use of the co-formulation of phenmedipham + desmedipham + ethofumesate proved to be very effective. Control was noticeably faster than that with phenmedipham alone. The higher dose of phenmedipham:desmedipham:ethofumesate (treatment 18) improved control of *P. aviculare* compared to treatment 15, but had little additional effect on other species. In 1994 (after the poorer treatments used in 1993 had been discarded), most treatments gave acceptable control that was equal to or better than the standard phenmedipham + metamitron (treatment 23). Triflusulfuron gave effective control of the high populations of *Urtica urens* and *Matricaria* spp., that occurred at some sites.

In 1993, all treatments proved safe to the crop with no undue reductions in crop biomass or plant numbers (data not presented). No treatment had a significantly greater effect than the phenmedipham + metamitron standard (treatment 23) which gave a maximum 8 % average reduction in biomass between 7 and 10 DAT1. In 1994, slightly higher crop biomass reductions were recorded (up to 16 % average maximum on treatment 13 7-10 DAT1). The inclusion of mineral oil tended to cause the greatest reductions, but these were generally small and were outgrown by 47 DAT1. This was particularly evident after the first two applications and remained visible until some time after the third application on some sites. The standard (treatment 23) recorded a maximum average reduction of 7 %, 26-40 DAT1.

Crop chlorosis was recorded in both years but not on all sites. The results for 1994 are shown in Table 5. Effects were transient and only affected the leaves that were sprayed.

Leaves emerging after spraying were unaffected. However, 6 out of 33 sites were noticeably yellow for a short period of time after treatment. The symptoms were cosmetic and not of a commercially significant level.

No problems were encountered with the mixing or application of any of the treatments tested.

DISCUSSION

These experiments show that triflusulfuron can be used in a number of mixtures with sugar beet herbicides or additives to control a wide spectrum of weeds. The most effective mixtures contained a residual component (triflusulfuron has only a very short residual life in soil or sugar beet (Peeples *et al.*, 1991)) to control late germinating weeds such as *C. album*. However, an additional application of a non-residual mixture may have been sufficient to achieve longer term weed control in such situations.

The addition of mineral oil to triflusulfuron + phenmedipham mixtures, with or without a residual herbicide, decreased crop biomass. The reductions, although clearly visible, were not severe and no yield reductions were recorded in those experiments that were taken to yield. However, as with other beet herbicides, it would be prudent to avoid the use of oil on cotyledon beet and/or those suffering from stress.

The observed chlorosis was similar, but not identical, to manganese deficiency symptoms and appears to be a particular, transient effect of triflusulfuron under certain conditions (IIRB Weed Control Study Group, pers. comm.). It did not occur at every site nor after every application, but could become very apparent particularly on larger beet receiving their last spray of the programme. It is an effect that new users will need to be aware of in order to avoid undue concern.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the help of the many colleagues from DuPont (UK) Ltd, British Sugar Plc and Morley Research Centre who worked on these trials.

REFERENCES

Peeples, K A; Moon, M P; Lichtner, F T; Wittenbach, V A; Carski, T H; Woodward, M D; Graham, K; Reinke, H (1991) DPX66037 - a new low-rate sulfonylurea for post-emergence weed control in sugar beet and fodder beet. *Brighton Crop Protection Conference - Weeds*, 25-30.

THE INTEGRATION OF MECHANICAL WEED CONTROL INTO A LOW DOSE HERBICIDE SYSTEM IN SUGAR BEET

J D A WEVERS
Institute of Sugar Beet Research, P.O. Box 32, 4600 AA Bergen op Zoom, The Netherlands.

ABSTRACT

The present weed control system in The Netherlands using low doses of herbicides is described. To reduce the area which has to be treated, sometimes band spraying is used, accompanied by hoeing. To decrease the number of herbicide treatments, experiments have been carried substituting them with harrowing. Harrows offer a good possibility for weed control from the 4-6 leaf stage of the sugar beet. Weed stage should not exceed the cotyledon stage to achieve the same weed control as with herbicides in low dose systems. Some disadvantages of mechanical weed control are discussed.

INTRODUCTION

Both political and economical reasons lead to efforts to reduce herbicide consumption in arable farming. In the last decade, a system of low herbicide dosage has been developed and introduced in sugar-beet growing in The Netherlands and some other countries (May & Cleal, 1993; Wevers *et al.*, 1994). These low dose systems resulted in a reduction of the total amount of herbicides applied to sugar beet. Whilst the low dose system was being developed, hoeing was also being studied and promoted to reduce the area that required treatment with herbicides (Wevers *et al.*, 1993). Band spraying and hoeing resulted in a reduction in herbicide use of 50 to 60%, but the labour requirement increased.

From 1993 to 1995, experiments were carried out to reduce the number of low dose herbicide applications by replacing them with harrowing. In this contribution some results of the experiments are be presented. Also some of the restrictions met with the introduction of mechanical weed-control systems are discussed.

MATERIALS AND METHODS

In close co-operation with the Institute for Arable Farming at Lelystad, PAGV, two experiments were layed out per year, one on sandy soil at Vredepeel and one on clay soil at Nagele. At Vredepeel, weed density is normally high e.g. 105 plants m^{-2} in 1994, while in Nagele weed density is low with only about 12 plants m^{-2}. In these experiments a standard low dose weed-control system was applied consisting of:

a. no pre-emergence herbicides,

b. three (on clay) to five (on sand) applications at intervals of 7-12 days, of a low dose system consisting of a four way mixture of 0.5 l or kg of product resulting in:

phenmedipham	80 g a.i.ha^{-1}		(Betanal EC 157 g.l^{-1})
metamitron	350 g "	"	(Goltix WG 70%)
ethofumesate	100 g "	"	(Tramat EC 200 g.l^{-1})
mineral oil	425 g "	"	(Schering 11E 850 g.l^{-1})

In this low dosage combination metamitron could be replaced by chloridazon at 325 g a.i.ha^{-1}, (Pyramin WG 65%) depending on the weed species to be controlled. In commercial situations, if weather delayed application the dose could be adjusted. In these experiments this was not the case. In this paper the low dosage system is presented as LDS. For historical reasons on clay soil the herbicides were applied as a band spray application, but the dose was reduced in the same ratio as for the overall treated area.

Earlier studies at PAGV showed that the optimal weed stage for harrowing was the same as the optimal timing for an application of LDS, being the cotyledon stage (Van der Weide & Wijnands, 1993).

On sandy soils the treatments for the experiments were as follows:

A. 5 x LDS
B. 4 x LDS, harrowing at last LDS application date
C. 3 x LDS, harrowing at the last two LDS dates
D. 2 x LDS, harrowing at the last three LDS dates

On clay soils the treatments were:

A. 3 x LDS
B. 3 x LDS, plus harrowing at 6 leaves stage
C. 2 x LDS, harrowing at last LDS application date
D. 1 x LDS, harrowing at the last two LDS dates[1)]
E. no LDS, harrowing at all LDS dates (in 1993 only)

[1)] In 1994 LDS had to be applied twice before harrowing could be started.

On clay soils LDS was applied as a band spray and this was always accompanied by hoeing to control the weeds between the rows. The number of LDS applications on clay soil is also lower than on sandy soils because of the lower weed density and the higher residual effect of the herbicides.

All the experiments were designed as completely randomized blocks in four replications.

For harrowing, different implements were used based on the Einböck and Hatzenbichler type of machine with varying working widths between 6 and 12 m. The harrows were adjusted to a light pressure as earlier results showed that the number of plants which were removed was too high when harrowing was done very intensively (Wevers *et al.*, 1994).

The data collected included the number of sugar-beet plants, sugar-beet yield, rate of weed control and the amount of herbicides applied.

RESULTS

The influence of harrowing on the number of plants is presented in Table 1.

Table 1. Loss of plants as % of untreated plots after harrowing in 1993 and 1994 on different soil types and crop stage at the first harrowing operation.

Crop stage at first harrowing	Treatment sand	Treatment clay	1993 clay	1994 sand	1994 clay
at emergence	-	E	70.5	-	-
2 leaves	D	D	13.7	15.7	13.1
4 leaves	C	C	5.2	4.8	2.8
6 leaves	B	B	2.8	2.6	0.7

Harrowing for weed control in sugar beet damaged the crop when carried out at stages earlier than the four true leaves stage. The treatment with the greatest plant loss in 1993 was not harvested. The influence of plant loss on yield is shown in Table 2.

Table 2. Sugar yield ($t.ha^{-1}$) after harrowing in 1993 and 1994 on different soil types and crop stage at the first harrowing operation.

Crop stage at first harrowing	Treatment sand	Treatment clay	1993 clay	1994 sand	1994 clay
at emergence	-	E	n.d.[1)]	-	-
2 leaves	D	D	12.0	11.5	11.2
4 leaves	C	C	12.5	11.4	11.9
6 leaves	B	B	12.5	11.8	11.3
LSD 95%			0.59	1.97	0.69

[1)] not determined

The differences between the data presented in Table 2 are not statistically significant.

In the experiments the differences in the level of weed control were also not statistically significant with one exception. In 1993 on clay soil, the first harrowing took place at a weed stage which was too early. The interval before the second harrowing was too long and the rate of control was < 70%. The actual weed density on this field was only 11.5 plants m^{-2}, so that this poor weed control had no effect on the crop (see also Table 2).

The reduction in the amount of herbicides used, when replacing LDS by harrowing differed very much for the two experimental locations. The earlier studies showed that at least two applications of herbicides were needed to allow the sugar beet to grow to a sufficient size to allow harrowing. Therefore the number of LDS applications on clay soil which can be substituted by harrowing is restricted to only one, while the reduction in the number on sandy soils is three out of five. On clay soils at Nagele this meant a reduction of 33% of the total amount of herbicides used. If treated overall, the standard amount would have been three applications of 0.955 g a.i.ha^{-1} each. The saving of 33% is then 0.955 g a.i.ha^{-1}. However, because of band spraying, the absolute amount of herbicides saved is only about half of that quantity i.e. 0.5 g a.i.ha^{-1}.

On sandy soil at Vredepeel the total amount applied was five times 0.955 = 4.775 g a.i.ha^{-1}. Replacing three LDS applications by harrowing meant a reduction of 60% or 2.765 g a.i.ha^{-1}.

DISCUSSION

If applied from the 4 to 6 true leaves stage of the sugar beet onwards, harrowing was a form of mechanical weed control which hardly affected the number of sugar beet plants. Not more than 5%, but mostly less than 3% of the plants were lost. Most of the plants which were pulled out of the soil were small with poor rooting systems. This was probably the reason that yield was not affected by harrowing.

Weed control with harrowing can be as good as with chemical treatments. It is very important to treat the weeds in the same stage as with LDS. Weeds larger than the cotyledon stage are difficult to control. In 1994 after a period of rain, two treatments with a harrow were needed immediately after each other on weeds with true leaves appearing, in order to achieve adequate control.

On sandy soils, the amount of herbicides that can be saved by the introduction of harrowing is reasonably high. On clay soils it is much less. If band spraying and hoeing are integral parts of a weed-control system, the amount of herbicides saved is very restricted. Although savings in herbicides can be achieved, the extra cost in machinery and labour have to be paid. From questionnaires to farmers by the sugar industry it has become clear that following introduction of low dose herbicide systems, the use of band spraying and hoeing decreased. This was the result of the small savings in herbicide costs not warranting the expenditure on hoeing or band spraying. The same was true in the UK (McClean & May, 1986). The same problem has also risen when introducing harrows. The additional costs of machinery and labour is hardly compensated for by the savings in costs of herbicides.
If other disadvantages of mechanical weed control appear, farmers will tend to stay with more traditional systems. Some of the disadvantages are:

- Increase in vulnerability to wind erosion of sandy soils and to water erosion for all soil types.
- Problems with the treatment of mechanical weed control when cover crops are (or have been) grown.
- For Dutch conditions, volunteer potatoes should be controlled by wiping with glyphosate. Mechanical weed control should be omitted until volunteer potatoes

have been controlled.
- Overall sprayers are present on almost all farms. If a band sprayer and hoe has to be purchased for the first two applications of herbicides in sugar beet and a harrow for the rest of the weed control, the total investments will be high.
- Although this does not apply to harrows of 18 m width which have been introduced recently, most mechanical operations require more labour than chemical weed control. Compared to overall spraying with a boom of 18 m wide, a harrow with the same width will lead to a saving of labour provided the working speed is about the same. Sprayers require filling time.
- The dependency of the weather conditions is higher for mechanical than for chemical weed control. In a LDS system, a delay in application time can, within limits, be compensated by an increase in herbicide dose. With harrowing such a compensation is only possible by repeating the operation within hours, with the danger for plant loss.

Because the situation on every farm is different with respect to vulnerability to erosion, the growing of cover crops, the presence of machinery, farm size and labour availability, every farmer has to decide for his own farm which is the best weed control system for him. From research institutes many possibilities have been developed.

ACKNOWLEDGEMENTS

The author wishes to thank R.Y. van der Weide and C.E. Westerdijk of PAGV for the pleasant co-operation with the experiments.

REFERENCES

May, M J; Cleal, R A E (1993) Possibilities for low dose herbicide mixtures for weed control in sugar beet. *Brighton Crop Protection Conference - Weeds.* 431-436.

McClean, S P; May, M J (1986) A comparison of overall herbicide application with band-spraying and inter-row cultivation for weed control in sugar beet. *IIRB Winter Congress.* Brussels. 345-354.

Weide, R Y van der; Wijnands, F G (1993) Strategieën voor duurzame onkruidbestrijding. In: *Themadag Duurzame onkruidbestrijding.* eds R Y van der Weide *et al.*. pp. 6-14.

Wevers, J D A; Westerdijk, C.E.; Zande, J.C. van de (1993) Onkruidbestrijding in suikerbieten. In: *Themadag Duurzame onkruidbestrijding.* eds R Y van der Weide *et al.*. pp. 47-51.

Wevers, J D A; Hermann, O; Wauters, A (1994) Integrated crop protection, *IIRB Winter Congress.* Brussels. 43-62.

INVESTIGATION INTO USING CROP GROWTH STAGE TO ACHIEVE TWO SPRAY BROAD-LEAVED WEED CONTROL IN SUGAR BEET

P M BEE, S T HOPKINSON, P J JARVIS,
British Sugar plc., Holmewood Hall, Holme, Peterborough, Cambs., PE7 3PG

ABSTRACT

Work by British Sugar's Agricultural R&D Department has indicated that beet growth stage might be used to time post-emergence herbicide applications in sugar beet. During the years 1992-94, experiments investigated the feasibility of delaying the timing of herbicides such that weeds might be controlled at a much larger growth stage than current commercial practice.

The trials were situated on a number of sites, to cover a range of weed species, weed populations and soil types. The optimum timing to achieve the greatest effect from a single herbicide application was identified as 2-4 true leaf stage of the crop. The optimum timing for the second application seems to be less critical and is being investigated further.

The results suggest that it might be possible to achieve a greater flexibility of spray timings by using beet crop growth stage. This may enable a simpler system for the management of herbicide applications to the beet crop. The only prerequisite is that the herbicides selected are of a high contact activity and specific to the weed species present. A relationship between speed of beet growth and herbicide damage to the beet crop has been identified from this work and requires further investigation.

INTRODUCTION

Weed control in sugar beet has changed little over the last twenty years. Weeds emerge and are killed using low dose, low volume sprays, before they reach much beyond the cotyledon growth stage. The speed and frequency of weed flushes can be erratic and prolonged. Up to five applications of herbicides may be required on some soil types, each critically timed (Anon. 1994). The industry would like to achieve savings in uses of active ingredient, management, labour and machinery and therefore the new approach reported here was investigated.

A possible solution appeared when investigating the problems of volunteer oilseed rape control in sugar beet (Anon. 1993). The cotyledons of oilseed rape are very waxy and this may reduce efficiency of herbicides. The work carried out by British Sugar suggested that if oilseed rape were at the first true leaves stage, the sprays were more effective. These findings coincided with the testing of 'hot mix' or 'high contact' herbicide treatments (Anon. 1992). These latter trials showed a good level of weed control with the spray programme initiated at a late stage.

The research programme reported here was set up to exploit the potential use of delayed applications to maximise the effect of herbicides. The objectives were to test the possibilities of extending the period between applications and reduce the number of sprays. The benefits would be reductions in use of spray machinery, in crop management and, possibly, active ingredient used.

The objectives of this project have been met by two experimental programmes of work, using timing trials and randomised block experiments. The former investigating the optimum application timings, the latter to test on a wider scale the results of the timing trials.

MATERIALS AND METHODS

Timing trials years, 1992 - 1994

Over the course of the three years, eleven blocks of application timing trials were laid down, using herbicide mixtures and doses selected for their high level of contact activity on larger weeds (Table 1). The objective was to examine the optimum stage of weed and crop growth at which to apply one and or two herbicide mixtures for prolonged and maximum efficacy. A single herbicide mixture was applied at 2-3 day intervals on 8 different occasions to 3 m^2 plots, beginning at the expanded cotyledon stage of sugar beet growth. Each plot received two applications at right angles overlaying each other, to give each and every combination of spray timings.

Treatments were applied by hand held AZO sprayer using Lurmark F-110 - 01 nozzles at 2.5 bar pressure producing 80 litres ha $^{-1}$ water volume.

Table 1. Treatments applied in 1992-1994.

Location	Chemical mix	Year	Replicates
Southorpe	pmp.(399g) + lenacil (176g)	1992	1
Southorpe	pmp.(399g) + lenacil (176g)+mineral oil (1.0 l)	1992	1
Blackbush 1	pmp.(399g) + tri-allate (600g)	1993	2
Blackbush 2	pmp.(399g) + tri-allate (600g)	1993	1
Nth. Lopham	pmp.(331g) + chloridazon/ethofumesate (275/170g) mineral oil (1.0 l)	1993	2
Chatteris	pmp.(399g) + lenacil (176g) + mineral oil (1.0 l)	1994	2
Whittlesey	pmp.(399g) + lenacil (176g) + mineral oil (1.0 l)	1994	2

pmp. = phenmedipham   Doses are in grammes or litres of active ingredient ha^{-1}

Weed and crop percentage biomass compared to untreated control was scored 7 DAT and at 50 % crop cover. In 1993 and 1994, at each spray date, 5 beets were randomly selected from an untreated area of experiments at Blackbush, Nth. Lopham, Chatteris and Whittlessey and weighed to measure the rate of fresh weight growth.

Randomised block trials 1995

In 1995, trials were set up on four sites each with four randomised blocks. Two, two-spray programmes were compared with a conventional three-spray programme (Table 2). The timings for the two sprays were those identified as the optimum for one spray from the timing trials results and a best estimate for a following second spray.

Table 2. Treatments applied in 1995

Application timings	Chemical mix g or ml ha^{-1}
1) Untreated control	
2) SD1 beet at 2-4 TL	pmp.(331) + chloridazon/ethofumesate (275/170) + mineral oil (1000)
SD2 beet at 4-6 TL	pmp.(331) + chloridazon/ethofumesate (275/170) + mineral oil (1000)
3) SD1 beet at 2-4 TL	pmp.(399) + lenacil (176) + mineral oil (1000)
SD2 beet at 4-6 TL	pmp.(399) + lenacil (176) + mineral oil (1000)
4) SD1 beet at cotyledon	pmp.(330) + metamitron (875)
SD2 beet at 2 TL	pmp./ethofumesate (160/200) + metamitron (700)
SD3 beet at 4 TL	pmp.(331) + chloridazon/ethofumesate (275/170) + mineral oil (1000)

TL = True Leaves   Doses are in grammes or litres of active ingredient ha^{-1}

Total weed numbers and percentage of each species in the control plots were recorded at commencement of the experiment. Weed and crop biomass were assessed, relative to the control plots (being 100 %), 7 DAT. Crop and weed biomass were assessed at 50 % crop cover and commercial weed control (i.e. season long) assessed in early July.

RESULTS

Timing trial 1992-1994

Figure 1. Weed biomass measured 7 DAT of a single treatment.

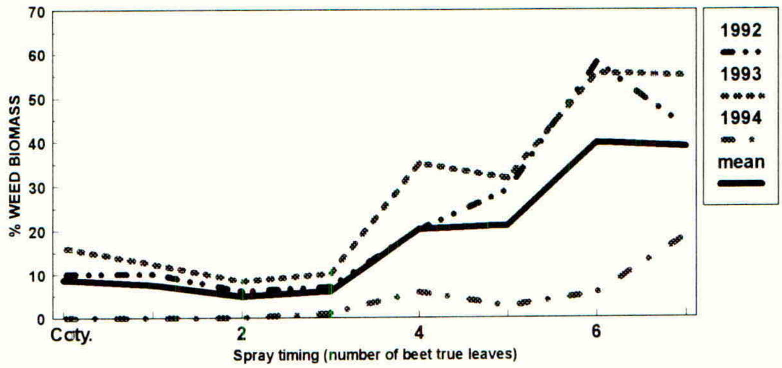
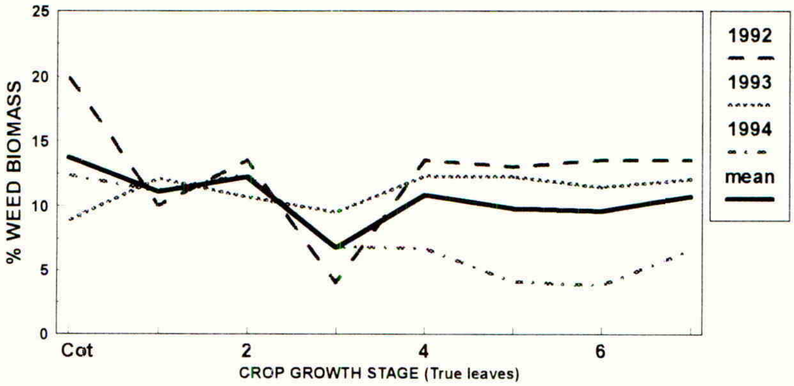


Figure 1 shows a consistent reduction in weed biomass, from the applications up to and including those timed at 2-4 true leaves of beet, when assessed 7 DAT. After this time in two of the three years control declined dramatically. In the third year, however, weed control did not decline until applications were beyond the six true leaf stage of beet.

The results for two sprays (Figure 2) are expressed as the meaned score from all plots receiving a spray at the spray date identified by the (x) axis and a second spray on another date.

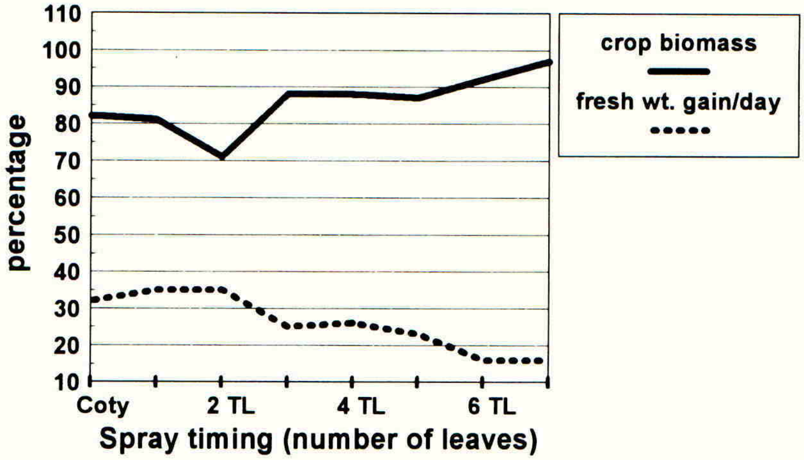
Figure 2. Effect of two applications on weed biomass assessed at 50% crop cover.



There was a reasonably consistent effect from the timing of the sprays on weed biomass in 1992 and 1993. A trend for good weed control was noted when first treatments were applied at the 2-4 leaves of the crop. However, in 1994 this trend differed slightly in that control did not fall until the six true leaf stage of the crop. Sequences started at the cotyledon stage of the crop gave the most variable weed control.

Figure 3 shows the effects of a single herbicide application on crop biomass 7 DAT as a mean of the four sites measured and the corresponding rates of fresh weight gain per day on untreated crop.

Figure 3. Effect of a single herbicide spray on crop biomass and rate of crop growth.



When the sites were averaged, rapid crop growth and retardation of crop by a single herbicide application occurred simultaneously. When rate of growth of the beet was slow, the extent of herbicide damage was small and vice versa.

<u>Replicated block trials 1995</u>

Table 3. Summary of weed control achieved at all sites in July 1995

Treatment	% Plots with commercially acceptable weed control	Control acceptability score (7=commercially acceptable)
1	0	0
2	25	5.6
3	25	5.1
4	56	6.6
LSD @ 5 %		0.82

None of the treatments, when combining all sites, produced commercially acceptable weed control. However, 25 % of all two-spray plots and 56 % of the standard three-spray plots were commercially clean at the end of July.

DISCUSSION

It would appear that 2-4 true leaves of the crop was the latest timing that these mixtures would control weeds with one application. After this, weed control fell rapidly. Where weed numbers were low (1994), weed control continued to be successful up to the six true leaves of the crop, with most single sprayed plots commercially clean at the end of the season. These results suggest that in some situations, one timely spray was sufficient to control weeds throughout the growing season.

Plots scored at 50 % crop cover, after receiving two applications of herbicide, still showed a slight increase in weed control where they received an application at 2-4 true leaves compared to cotyledon stage of the crop. Applications at cotyledon stage showed variable weed control from year to year, almost certainly owing to low weed emergence at the time of application. The level of commercial control was not shown, as this was difficult to indicate when combining all sites and years on charts as used here. However, all sites in all years had some commercially clean plots at the end of the season, including the 1993 fen sites. The meaned crop biomass at 7 DAT, indicated a critical period around two true leaves of the crop when crop biomass was adversely affected by herbicide applications. This coincided with a period when crop growth was rapid, (up to 40 % fresh weight gain/day).

The randomised block trials in 1995 did not achieve consistent weed control. These were carried out in a very difficult season for weed control, early season temperatures were cold and conditions dry. Neither the conventional standard of the three-spray programme nor the two-spray programmes gave consistent acceptable control over all sites. It is likely that a more 'weed species specific' choice of chemical mix may have improved the control in this season.

Future work will concentrate on evaluating the technique over more sites and weed control situations. Where the technique has not worked, it has highlighted the requirement of more careful selection of herbicides as compared to the more usual programme of three-sprays. More work is required to identify the optimum timing for the second spray.

REFERENCES

Anon. (1992) Control of larger broad-leaved weeds using 'hot' tank-mixes of herbicide and adjuvant oil. *SBREC British Sugar plc Agricultural Research & Development Department Annual Report*, 58-62.

Anon. (1993) Control of Volunteer Oilseed Rape: Effect of timing of treatments. *SBREC British Sugar plc Agricultural Research & Development Department Annual Report*, 57-62.

Anon. (1994) Specific field survey. British Sugar plc, Peterborough, pp. 49.

EFFECT OF WHEAT AND BARLEY RESIDUES ON BRANCHED BROOMRAPE (Orobanche ramosa) GROWTH AND DEVELOPMENT IN POTATOES

M A HAIDAR, W BIBI, N ABDEL-KHALEK
Department of Crop Production and Protection, Faculty of Agricultural and Food Sciences, American University of Beirut. Beirut, Lebanon.

ABSTRACT

A Field study was conducted to investigate the effect of wheat and barley straw on *Orobanche ramosa* growth and development in potatoes. Surface and preplant incorporated mulches of wheat and barley straw were applied at four different rates: 0, 6000, 9000, and 12000 kg.ha^{-1} each. Results indicated that wheat and barley residues at different rates significantly reduced *Orobanche* shoot number, height and dry weight. Preplant incorporated residues of both crops were more effective than surface applied residues in reducing *Orobanche* growth and infestation. All tested treatments delayed *Orobanche* shoot emergence above the soil surface and reduced the *Orobanche* dry weight. High levels of both types of straw had no effect on the potato yield, but affected the vegetation growth of potatoes as compared to control.

INTRODUCTION

Orobanche ramosa, commonly called branched broomrape, is a noxious root holoparasitic higher plant. It is widely distributed in disturbed habitats, colonizing diverse ecosystems throughout semi-arid regions of the world. Grasses are not attacked, but a wide range of herbaceous dicots are parasitized by *Orobanche* (Janudi, 1982; Parker and Riches 1993). It is a serious agricultural problem and in Lebanon, potatoes and tomatoes are the primary commercial crops it parasitizes. It is especially troublesome in potatoes, where it causes severe economic losses by reducing yield quantity and quality (Saghir, *et al.*, 1982). Quantitative data on losses caused by *Orobanche* species are scarce and not precise, but yield losses of around 34 % across all species have been suggested by Linke *et al.*(1989).

O. ramosa reproduces primarily by producing thousands of seeds. One plant can generate up to 500,000 seeds, and one gram of seed contains around 150,000 (Zimdahl, 1993). Some seeds germinate in the next growing season, while others remain dormant in the soil for up to ten years. Germination is stimulated by secretions from the host's root. Upon germination, a germ tube "root like structure" moves positively toward the root of the host. Once it strikes the root, it immediately forms an appressorium. If no host attachment occurs, the germ tube loses its ability to parasitize within a few days (Linke *et al.*, 1989).

An important aspect of *Orobanche* is our present inability to control it. A lot of research on its control has been published, including cultural, biological, mechanical and chemical methods (Linke *et al.*, 1989; Parker and Riches, 1993; Saghir *et al.*, 1982). Yet none of these methods has been successful, effective and economic. In Lebanon control measures are limited to fumigation and hand pulling which is expensive and injurious to the host plants (Janudi, 1982). Thus research on an alternative control method such as using crop residues is necessary.

The concept of crop residues such as wheat and barley straw had not been tested on parasitic weeds. It is well documented that wheat and barley straw affect germination, growth, and development of several weeds. Putnum *et al.*(1983) indicated that residues of wheat and barley reduce the density and biomass of several weed species. Residues of wheat have been found to reduce the fresh weight of *Aegilops cylendrica* by 70 to 85 % (Anderson, 1993). The main objective of this study was to determine if the use of surface-applied or incorporated wheat and barley straw reduces *O. ramosa* growth and population in potato.

MATERIALS AND METHODS

Seed source

Seeds of *O. ramosa* were obtained from plants parasitizing potato in the Beqa'a plain of Lebanon in 1993. Seeds were stored in darkness at room temperature until used for experimental purposes.

Field experiment

A naturally infested field with *O. ramosa* was selected at the Agricultural Research and Education Centre (AREC) in the Beqa'a plain, Lebanon on June 28, 1994. The AREC is located in the northern central Beqa'a plain, Lebanon at an elevation of 1000m. The soil is silty clay loam with a pH of 7.68, organic matter 1.86 % and E.C. of 0.39 mmhocm^{-1}. The field was tilled and disked twice and then shaped into furrows 75 cm wide.

In all experiments, residues of local wheat cv."Nessr" and barley cv. "Rihan", consisting mainly of stems and leaves (straw) were collected from AREC in June 1994, and stored in dry conditions until study initiation. Certified potato seed "Mondial" were used. The experimental area received uniform application of 2500 kg.ha^{-1} of NPK (15:15:15), one week before sowing, followed by shallow tillage. No further nitrogen was supplied.

Wheat and barley residues each at four levels (0, 6000, 9000 and 12000 Kg.ha^{-1}) were applied. These levels were based on the amount of straw left in the field from previous wheat and barley crops. The amounts left in the fields were found to vary from 7000-9000 kg.ha^{-1} for both mulches. Residues were either soil-incorporated one day prior to planting potato seeds or applied as cover mulch (surface-applied) one day after sowing potato. To eliminate weeds, the herbicide metribuzin (Sencor^{R}) was applied at a rate of 0.75 kg a.i.ha^{-1} after the addition of mulch.

Potato data included the number of shoots 3 m^{-1}, crop height, and potato yield of the two middle rows, trimmed to 3 m in the centre. The height of five potato plants per replicate were measured at random, 90 days after planting. *Orobanche* shoot emergence, number of shoots 2 m^{-2} (twice/season), shoot height and dry weight of *Orobanche* shoots 2 m^{-2} were recorded. *Orobanche* shoot height was measured on ten shoots per replicate chosen at random one day before potato harvesting. Experiments were arranged as a randomized complete block design with four replications. Plots were 6 m long and 3 m wide.

RESULTS AND DISCUSSION

Both incorporated and surface-applied crop residues reduced significantly *Orobanche* growth and development (Table 1). *Orobanche* shoot number (1st assessment) and dry weight were significantly reduced by all treatments in comparison with the control. The treatments reduced *Orobanche* shoot number early in season by 73 % to an average of 81 % compared to 300 shoots 2 m^{-2} in the control. However, late in the season, all treatments, except for incorporated wheat at 12000 kg.ha^{-1} and barley at all levels, were without an effect (2nd assessment). The highest reduction in Orobanche shoot number was obtained with surface-applied barley at 12000 kg.ha^{-1}.

All treatments delayed the appearance of *Orobanche* shoots and reduced the incidence of its emergence as compared to the control (unpublished data). This suggests that *Orobanche* germination and growth slowed down at early stages of potato growth. The results also indicate that the incorporated mulches at all levels reduced significantly *Orobanche* shoot height in comparison to surface-applied ones and the parasite-control. Surface-applied mulch of wheat at 6000 and barley at 6000 and 9000 kg.ha^{-1}, were the only effective treatments in reducing *Orobanche* shoot height.

All treatments reduced significantly *Orobanche* dry weight and incorporated mulch of both crops were more effective than surface-applied ones. Incorporated mulches of both crops reduced *Orobanche* dry weight by an average of 70 % compared to 55 % by the surface-applied. The highest reduction of *Orobanche* dry weight was obtained with incorporated mulch of either crop at 12000 kg.ha^{-1}. Dry weight was reduced by 87 and 80 % in incorporated wheat and barley mulch respectively when compared to the control (Table 1).

Patrick *et al.* (1963) indicated that the location of wheat residues with respect to the plant roots had a direct effect on root growth. Plant residues caused injury if the residues were in contact with or in the vicinity of plant roots. Kimber (1973), indicated that surface-applied wheat straw depressed seed germination of many weeds. Our results show that incorporated residues are more effective in reducing *Orobanche* growth than surface-applied mulch. Both crop residues significantly reduced *Orobanche* growth and development early in the growing season. Thus placement of residues with respect to *Orobanche* is critical.

Its well known that the intensity of *Orobanche* infestation is affected by several factors including, soil moisture, pH, and soil fertility (Parker and Riches, 1993). Crop residues conserve moisture in the soil, lower the soil temperature and reduce the nitrogen level. Several local farmers indicated that high soil moisture could curb the growth of *O. ramosa* in potatoes. Parker and Riches (1993) indicated that *Orobanche* growth is reduced under wet conditions.

Table 1. Effect of wheat and barley residues on the shoot number, shoot height, shoot dry weight of *Orobanche*.

Treatment	Rate ($kg.ha^{-1}$)	Shoot no. (1st)	Shoot no. (2nd)	Shoot height (cm)	Shoot dry wt. (g)
Control-parasite	0	0 g	0 e	0 c	0 f
Control+parasite	0	300 a	452 a	17 a	82 a
Soil-incorporated mulch					
Wheat	6000	153 b	373 abc	13 b	24 cde
	9000	136 bc	342 a-d	13 b	39 bcd
	12000	84 cde	276 bcd	11 b	10 ef
Barley	6000	65 def	184 d	13 b	23 cde
	9000	84 cde	249 bcd	12 b	33 bcd
	12000	69 def	230 cd	12 b	17 def
Surface-applied mulch					
Wheat	6000	43 efg	298 a-d	15 ab	52 b
	9000	69 def	344 abc	12 b	34 bcd
	12000	100 b-e	305 a-d	13 b	40 bcd
Barley	6000	111 bcd	399 ab	15 ab	45 bc
	9000	43 efg	349 abc	14 ab	30 cde
	12000	14 fg	30 e	12 b	23 cde

Means followed by same letter do not significantly differ (Duncan's MRT, P=0.05).

Extent research indicates that crop residues reduce nitrogen level in soil. Nitrogen has been found to enhance *Orobanche* seed germination (Rakesh and Foy, 1992), but inhibits the parasitic growth of Orobanche (Abu-Irmaileh, 1981). Thus it is likely that nitrogen immobilization in soil due to the application of crop residues delays *Orobanche* seed germination and seedling emergence above the soil and reduces its infestation. In addition, other factors such as physical and chemical effects of the residues and the effect of their breakdown products (allelochemicals) could affect *Orobanche* growth and development. Several scientists reported that wheat and barley residues produce allelochemicals that inhibit the growth of many crops and weeds (Guenzi and McCalla, 1966; Guenzi *et al.*, 1967; Putnum *et al.*, 1983).

Results in Table 2 indicate that none of the mulch treatments were phytotoxic to potato plants. The number of plants, height and yield was not affected by the addition of crop mulches. In fact, a significant increase in the potato yield was observed in most of treatments. This increase besides being a result of the significant *Orobanche* control, may also be due to the indirect effect of the treatment such as high level of organic matter, low soil temperature and high soil moisture. However, high levels of soil-incorporated mulches affected the vegetation growth of potatoes compared to the parasite free-control. Chlorosis was observed later in the season with high levels of incorporated mulches, but yield was not affected.

Table 2. Effect of wheat and barley residues on the plant number, height and yield of potato.

Treatment	Rate ($kg.ha^{-1}$)	Plant no. 3 m^{-1} length	Crop height (cm)	Tuber fresh wt.(kg)
Control-parasite	0	17 a	94.7 a	1.30 c
Control+parasite	0	20 a	88.0 ab	1.10 c
Soil-incorporated mulch				
Wheat	6000	21 a	81.7 ab	2.33 ab
	9000	18 a	68.0 ab	1.13 c
	12000	19 a	84.0 ab	1.24 c
Barley	6000	15 a	85.3 ab	2.30 ab
	9000	17 a	60.3 b	1.82 bc
	12000	18 a	81.7 ab	1.76 bc
Surface-applied mulch				
Wheat	6000	18 a	88.0 ab	2.25 ab
	9000	23 a	96.7 a	2.13 ab
	12000	25 a	85.0 ab	1.78 bc
Barley	6000	19 a	81.0 ab	1.57 bc
	9000	23 a	97.7 a	2.75 a
	12000	15 a	82.0 ab	1.63 bc

Means followed by same letter do not significantly differ (Duncan's MRT, $P=0.05$).

The degree of variation in this experiment was extremely high. The nature of the host-parasite relationship is very delicate and is mediated by several factors such as soil moisture, soil microorganisms, soil temperature and nutrient levels in soil (Parker and Riches, 1993). All these factors varied during the growing season and between weeks of the growing season. Furthermore, being a naturally infested field there were three main constraints, including the difficulty of creating plots free of the parasite, the random distribution of the parasite and the emergence of *Orobanche* shoots over an extended period.

Our results have led to the conclusion that *Orobanche* growth and development can be suppressed with residues of mature cereals, both incorporated and surface-applied wheat and barley residues inhibited the growth of *Orobanche* under the condition of our test, soil-incorporated residues were more effective than surface-applied ones in reducing *Orobanche* infestation and the severity of *Orobanche* growth inhibition depends on the residue concentration and the location of the residue with respect to the *Orobanche* seeds and seedlings. Further greenhouse and laboratory studies should be conducted in greater detail to verify these results.

REFERENCES

Abu-Irmaileh, B E (1981) Response of hemp broomrape (*Orobanche ramosa*) infestation to some nitrogenous compounds. *Weed Science*. **29**,8-10.

Anderson, R L (1993) Crop residue reduces Jointed Goatgrass (0U*Aegilopylendrica*) seedling growth. *Weed Technology*. 7,717-722.

Guenzi, W D; McCalla T M (1966) Phenolic acids in oat, wheat, sorghum, and corn residues and their phytotoxicity. *Agronomy Journal*. **58**,303-304.

Guenzi, W D; McCalla T M; Norstadt F A (1967) Research and persistence of phytotoxic substances in wheat, oat, corn, and sorghum residues. *Agronomy Journal*. **59**,163-165.

Kimber, R W L (1973) Phytotoxicity from plant residues. III. The relative effect of toxins and nitrogen immobilization on the germination and growth of wheat. *Plant Soil*. **38**,543-555.

Janudi, A K (1982) Comparative studies on GR-24 and herbicides for *Orobanche ramosa* control in tomato. M.Sc. thesis. American University of Beirut. 66 pp.

Linke K H; Sauerborn J; Saxena M C (1989) *Orobanche* field guide. University of Hohenheim and ICARDA. 42 pp.

Parker, C & Riches C R (1993) Parasitic weeds of the world: Biology and Control. CAB International, UK, pp. 111-164.

Patrick, Z A; Toussoun T A; Snyder W Y (1963) Phytotoxic substances in arable soils associated with decomposition of plant residues. *Phytopathology*. 53,152-161.

Putnaum, A R; Defrank J; Barnes J P (1983) Use of phytotoxic plant residues for selective weed control. *Crop Protection*. **2(2)**,173-181.

Rakesh, J & Foy C L (1992) Nutrient effects on parasitism and germination of Egyptian Broomrape (*Orobanche aegyptiaca*). *Weed Technology*. **6**,269-275.

Saghir, A R; Kurban M; Budayr B (1982) Studies on the control of *Orobanche* in Lebanon. *Tropical Pest Management*. **26(1)**,51-55.

Zimdahl, R (1993) Fundamentals of weed science. Academic Press Inc. New York, 499 pp.

A COMPARISON OF THE COMPETITIVE EFFECTS OF ELEVEN WEED SPECIES ON THE GROWTH AND YIELD OF WINTER OILSEED RAPE

P J W LUTMAN
IACR Rothamsted, Harpenden, Herts., AL5 2JQ

P BOWERMAN
ADAS Boxworth, Boxworth, Cambridgeshire, CB3 8NN

G M PALMER
Morley Research Centre, Wymondham, Norfolk, NR18 9DB

G P WHYTOCK
Scottish Agricultural College, 581 King St., Aberdeen, AB9 1UD

ABSTRACT

Four experiments in the season 1993/94 investigated the relative competitive effects of 11 annual weeds in winter oilseed rape. By integrating infestation levels with the reductions in crop growth caused by the weeds it has been possible to produce a tentative index of their competitive abilities. *Galium aparine* was most competitive followed by *Papaver rhoeas*, *Stellaria media*, and *Sinapis arvensis*. *Lamium purpureum*, *Veronica persica*, *Matricaria perforata* and *Poa annua* were intermediate, whilst *Capsella bursa-pastoris* and *Fumaria officinalis* were only weakly competitive. *Viola arvensis* was least competitive.

INTRODUCTION

The techniques used in the production of oilseed rape have been evolving over the last ten years as a result of economic pressures, legislative requirements, technical progress and changes in EU support for arable agriculture. The profitability of winter oilseed rape has declined during this period, encouraging reductions in fertiliser and pesticide usage. This means that the use of herbicides has to be clearly justified.

The experiments reported in this paper are part of a larger programme which has the primary aim of identifying the benefits arising from the control of broad-leaved weeds in winter oilseed rape. Earlier research on the effects of these weeds was limited and, because much of the data was from mixed infestations, it was not possible to identify the critical species (Bowerman, 1989; Davies *et al.*, 1989). The overall impression was that there was not often an economic yield benefit resulting from their control (Wahmhoff, 1990; Lutman, 1991). Research in Germany has begun to identify the competitive effects of some broad-leaved species (eg Munzel *et al.*, 1992), ranking species according to their competitiveness. They concluded that *Stellaria media* was their most competitive broad-leaved weed followed by *Matricaria* spp. and then *Lamium purpureum*, *Viola arvensis*, *Myosotis arvensis* and *Capsella bursa-pastoris*. Similar data were not available in the UK. An earlier paper (Lutman *et al.*, 1993) reviewed the competitive effects of *S. media*, *Galium aparine* and *Matricaria perforata*, from experiments in 1992 and 1993. This paper provides information on a wider range of species from experiments completed in 1994.

MATERIALS AND METHODS

The experiments described were done on the research farms of the four authors: IACR Rothamsted, ADAS-Boxworth, Morley Research Centre - Stonham farm, SAC Aberdeen - Tillycorthie farm. Details of cropping and assessments are given in Table 1. Each experiment was of a randomised block design with three replicates and included 5-7 weed species chosen from the following: *Sinapis arvensis*, *S. media*, *G. aparine*, *Veronica persica*, *Fumaria officinalis*, *V. arvensis*, *Papaver rhoeas*, *L. purpureum*, *M. perforata*, *C. bursa-pastoris* and *Poa annua*. Each species was sown at two appropriate densities and each experiment included a weed-free treatment. Species studied and the densities established in each experiment are presented in Tables 2 and 3. Indigenous weeds were controlled when necessary with appropriate herbicides or by hand weeding. Samples (0.25 - 1.0 m^2) were taken in December/January and in April. Crop and weed dry weights were determined. Rape yields (t ha^{-1} at 9% moisture) were recorded at maturity.

Table 1. Details of experiment sites

Details	Aberdeen	Boxworth	Morley	Rothamsted
Soil type	sandy loam	clay	sandy clay loam	silty clay loam
Rape cultivar	Rocket	Bristol	Apex	Falcon
Sowing date	30 August	7 Sept.	7 Sept.	7 Sept.
Plot size	2.1 x 20 m	2.25 x 20 m	2.25 x 10 m	3 x 14 m
Rape plants m^{-2}	80	83	64	78
Nitrogen (kg ha^{-1} N)	180	190	201	175
Assessment date 1	16 Dec.	11 Jan.	14 Jan.	15 Dec.
Assessment date 2	21 April	25 April	1 April	7 April
Harvest date	31 August	18 July	29 July	29 July

RESULTS AND DISCUSSION

Details of the December/January harvest are not given in the paper but can be found in the full report of this project (Lutman *et al.*, 1995). The vigour of the crops and weeds varied between the four sites, the crop at Boxworth being of particularly poor vigour in the winter, resulting in a low yield. As it was not possible to establish identical populations of weeds at all sites, comparisons between sites are partially confounded. However, it is still possible to establish some overall conclusions as to the relative competitive effects of the studied species. The relative behaviour of the species tended to be similar at all sites. Complete suppression of the indigenous weeds was not always achieved but in most plots the survivors did not have a marked effect on yields.

G. aparine

This weed was only tested at Rothamsted. Growth of the plants was slow until June, as

Table 2. The effect of competition from two densities of seven weed species in Aberdeen (a) and five species at Boxworth (b) on the weight of rape and weeds in April and on rape yields (figures in bold are significantly different from the weed free (P=0.05)).

a) Aberdeen

Weed species	Weed density (plants m^{-2})	Sample dry weights (April) (g m^{-2})			Rape seed yields (t ha^{-1})
		Rape	Sown weed	Total weed	
S.media	152	43.7	**527**	**642**	**1.89** (59.5)[+]
	320	**20.4**	**350**	**396**	**1.77** (62.1)
M.perforata	3	75.0	1	83	3.47 (25.7)
	50	164	12	119	3.59 (23.1)
V.persica	160	96.3	76	103	3.95 (15.4)
	728	35.3	**312**	**356**	**2.16** (53.7)
V.arvensis	179	78.2	6	144	**2.56** (45.2)
	748	82.3	76	180	**2.89** (38.1)
F.officinalis	35	179	1	50	4.47 (4.3)
	124	56.1	14	110	3.00 (35.8)
C.bursa-pastoris	33	97.3	1	78	4.40 (5.8)
	265	96.8	30	106	3.35 (28.3)
P.annua	292	148	46	156	3.40 (27.2)
	773	67.0	**194**	214	**2.87** (38.5)
Weed free	0	119		30	4.67
SED		49.4	52.0	120	0.778 (16.7)

b) Boxworth

S.media	132	251	**337**	**338**	**0.81** (59.5)[+]
	350	153	**364**	**366**	**0.40** (62.1)
V.persica	55	246	**154**	199	**0.92** (38.3)
	494	146	**347**	**353**	**0.57** (61.7)
S.arvensis	17.7	115	**290**	**328**	1.10[x] (26.2)
	66.4	**84**	**432**	**466**	1.19[x] (20.1)
L.purpureum	14.4	317	31	112	1.40 (6.0)
	134	194	106	187	**0.90** (39.6)
P.rhoeas	3.3	290	46	120	1.06 (28.9)
	35.1	202	66	125	**0.60** (59.7)
Weed free	0	241		88	1.49
SED		65.5	53.2	68.7	0.221 (14.8)

\+ figures in parentheses = % yield loss

x rape yields on *S.arvensis* plots contain approximately 11 % of *S.arvensis* seeds

Table 3. The effect of competition from two densities of six weed species at Morley (a) and Rothamsted (b) on the weight of rape and weeds and April and on rape yields (figures in bold are significantly different from the weed free ($P=0.05$)).

a) Morley

Weed species	Weed density (plants m^{-2})	Sample dry weights (April) (g m^{-2}) Rape	Sown weeds	Total weeds	Rape seed yields (t ha^{-1})
S.media	155	**92**		**443***	**2.70** (30.6)
	620	**127**		**464**	**2.37** (39.1)
M.perforata	56	350		50	4.17 (-7.2)
	156	255		**227**	3.20 (17.8)
V.persica	96	**230**		113	4.11 (-5.7)
	795	**191**		**142**	3.45 (11.3)
S.arvensis	123	**221**		83	3.52[x] (9.5)
	276	**72**		77	3.21[x] (17.5)
L.purpureum	104	**248**		**130**	3.77 (3.1)
	542	**170**		**296**	**3.07** (21.1)
P.rhoeas	205	**165**		**160**	**3.07** (21.1)
	496	**254**		**259**	**3.17** (18.5)
Weed free	0	378		82	3.89
SED		47.5		56.9	0.317 (8.23)

b) Rothamsted

Weed species	Weed density (plants m^{-2})	Rape	Sown weeds	Total weeds	Rape seed yields (t ha^{-1})
S.media	59	**185**	**175**	**183**	**3.19** (20.4)[+]
	328	**142**	**183**	**193**	3.45 (14.0)
G.aparine	1.4	249	6	58	3.72 (7.2)
	6.3	270	7	63	**2.42** (39.7)
M.perforata	59	261	27	65	3.94 (1.7)
	210	208	58	113	4.08 (-1.7)
V.arvensis	84	284	12	58	4.02 (-0.2)
	666	295	26	57	3.89 (3.0)
S.arvensis	16	**159**	**131**	**165**	**2.25** (43.9)
	124	**70**	**264**	**303**	**0.83** (79.3)
L.purpureum	42	233	26	80	3.99 (0.5)
	294	**165**	**163**	**197**	**3.42** (14.7)
Weed free	0	269		73	4.01
SED		27.1	27.9	25.3	0.239 (6.00)

\+ Figures in parentheses = % yield loss

x Rape yields of *S.arvensis* plots contain an unknown % of *S.arvensis* seeds

* Weed weights at Morley = sown weeds + indigenous species

it had been in the previous experiments (Lutman *et al.*, 1993), but the density of only 6.3 plants m^{-2} reduced yield by nearly 40% (Table 3), making it the most competitive weed at this site. The main reason for the yield loss was the difficulty caused by the weed at harvest. In addition, this density caused 26% contamination of the harvested grain.

<u>Prostrate species (*S. media, V. persica, L. purpureum*)</u>

S. media grew very vigorously during the autumn and winter, significantly reducing crop weight in April at all sites except Boxworth (Tables 2 & 3) At three sites, densities of 132-155 plants m^{-2} the previous autumn reduced yields by 30 - 60% and at the fourth site (Rothamsted) by c. 20%. The effects of intra-specific competition were clearly seen at this site because of similar yield losses recorded at densities of 59 and 328 plants m^{-2}. The generally high level of yield loss agrees with the experiments carried out in 1992 and 1993. *V. persica* at high densities, like *S. media*, produced a large weight of plant by the end of the winter and at Morley it also significantly reduced crop weight. However, as it tended to senesce very early in the summer, yield losses were not as great as those recorded for *S. media*. *L. purpureum* has a similar phenology to the other two species, growing vigorously in autumn and winter. It reduced rape weights in April at two of the three sites. Significant yield losses (15 - 40%) were recorded on all three sites. It appeared slightly less competitive than *S. media*, but similar to *V. persica*.

<u>Erect species (*S. arvensis, M. perforata, P. rhoeas*)</u>

The behaviour of *S. arvensis* was different at the three sites. It grew vigorously in the autumn, so that in December/January it was almost as abundant as the *S. media* and caused marked reductions in rape weights. During the following three months it was almost killed by the frost at Morley and was partially damaged at Boxworth but was unaffected at Rothamsted. Consequently, in April the *S. arvensis* was extremely vigorous at Rothamsted and was nearly absent at Morley. Yields reflected these effects, as less than 20 plants m^{-2} reduced yields by 44% and 26% at Rothamsted and Boxworth, respectively, whilst an autumn density of 276 plants m^{-2} at Morley only lowered yields by 17%. *S. arvensis* contaminated the harvested grain and so the yields at Morley, may be a slight overestimate. Analysis of the harvested seeds suggested it caused up to 15.5% contamination at Rothamsted and *c.* 11% at Boxworth. In contrast to the *S. arvensis*, *M. perforata* was not very competitive, as had been shown in the earlier experiments. Low, but non-significant, yield losses in the region of 20% were recorded from c. 150 plants m^{-2} at Aberdeen and Morley. Similar densities at Rothamsted had no effect on yields. Over 200 *P. rhoeas* plants m^{-2} at Morley reduced crop growth in April and lowered yields by c. 20%. At Boxworth, where densities were lower, it had little effect on crop growth in April but still reduced yields by 60%.

<u>*C. bursa pastoris, F. officinalis, P. annua*</u>

These three species were only studied at Aberdeen, as they were particularly relevant to Scottish conditions. Only *P. annua* had a significant effect on the crop, reducing yields by 38%. At the studied densities, the other two species may have had some effects, especially *C. bursa pastoris*, but because of the patchy distribution of the weeds and resulting high standard errors, their effects were not statistically detectable.

CONCLUSIONS

From these four trials it is possible to produce a tentative ranking of competitive abilities of the 11 studied species:

Very highly competitive: *G. aparine*
Highly competitive: *P. rhoeas, S. media, (S. arvensis)*
L. purpureum, M. perforata, V. persica, P. annua, (*S. arvensis*)
Poorly competitive: *C. bursa pastoris, F. officinalis*
Very poorly competitive: *V. arvensis*

The position of *S. arvensis* depends on whether it survives the winter. More work would be needed to confirm these relative effects, but research elsewhere (eg Munzel *et al.*, 1992) gives a similar order of competitiveness for some of these species. Thus farmers should be most concerned about the presence of *G. aparine*, *P. rhoeas*, *S. media* and *S. arvensis* in their rape crops, and should target herbicide treatments at these species.

ACKNOWLEDGEMENTS

We would like to thank the Home-Grown Cereals Authority, MAFF, and Scottish Agricultural College for financial support for this work. IACR Rothamsted receives grant-aided support from the Biotechnology and Biological Sciences Research Council of the United Kingdom.

REFERENCES

Bowerman, P (1989) Weed control in winter oilseed rape - a review of ADAS trials 1985-87. *Aspects of Applied Biology 23, Production and Protection of Oilseed Rape and other Brassica Crops,* 219 - 226.

Davies, D H K; Walker, K C; Whytock, G P (1989) Herbicide use and yield response in winter oilseed rape in Scotland. *Aspects of Applied Biology 23, Production and Protection of Oilseed Rape and other Brassica Crops,* 227 - 235.

Lutman, P J W (1991) Weeds in oilseed crops. *HGCA Oilseeds Research Review,* **OS2,** 70pp.

Lutman P J W; Bowerman, P; Palmer, G M; Whytock, G P (1993) The competitive effects of broad-leaved weeds in winter oilseed rape. *Proceedings 1993 Brighton Crop Protection Conference - Weeds*, 1023-1028.

Lutman P J W; Bowerman, P; Palmer, G M; Andrews, F; Whytock, G P (1995) Cost-effective weed control in winter oilseed rape. *Home-Grown Cereals Authority Research Project Report,* **OS15**, pp53.

Munzel, L; Wahmhoff, W; & Heitefuss, R (1992) Überprüfung und Weiterentwicklung eines Schadenschwellen-modells zur gezielten Unkrautbekämpfung im Winterraps (*Brassica napus*). *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, Sonderh.* **XIII**, 205 - 214.

Wahmhoff, W (1990) Unkrautbekämpfung im Winterraps - Auswertung von Herbizid versuchen aus den Jahren 1971 bis 1988. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz, Sonderh.* **XII**, 329 - 338.

DEVELOPING COST-EFFECTIVE STRATEGIES FOR WEED CONTROL IN WINTER OILSEED RAPE

G P WHYTOCK, I J BINGHAM
Crop Biology Department, SAC, 581 King Street, Aberdeen, AB9 1UD

R E L NAYLOR
Department of Agriculture, University of Aberdeen, 581 King Street, Aberdeen, AB9 1UD

ABSTRACT

Field trials over two seasons investigated the potential for reducing the dose of metazachlor in winter oilseed rape and the influence of initial chickweed density and crop sowing date on the efficacy of reduced doses. Metazachlor applied early post-emergence gave good weed control at half dose in a vigorous crop in a good growing season, and even quarter dose was sufficient to prevent yield loss due to weed competition. However, in a less vigorous crop, full dose was necessary to prevent yield loss, and, where application of the herbicide was delayed, weed control was not visually acceptable. The results of these trials confirm the variability in yield response of oilseed rape to broad-leaved weed control and suggest that a semi-prophylactic approach based on an early treatment is a good basis for a cost-effective weed control strategy.

INTRODUCTION

Farmers are under increasing pressure to reduce agrochemical inputs for financial and environmental reasons. In winter oilseed rape the costs of weed control represent a substantial 15-27% of the total variable costs of production (Anon., 1993, 1994a). Several authors have reported yield responses to control of broad-leaved weeds in herbicide trials to be low (less than 6%; Davies, 1987; Bowerman, 1989) or variable (negative to greater than 20%; Davies *et al.*, 1989; Walker *et al.*, 1990). In many cases, yield response was not related to the level of weed control achieved. Recent weed competition work has confirmed that yield losses from broad-leaved weeds in oilseed rape are dependant on site and season (Lutman *et al.*, 1993).

The high costs of weed control in relation to the often small effects of weed competition on yield suggests that herbicides are a good target for reducing the costs of inputs in oilseed rape It also emphasises the need to develop an advisory strategy for cost-effective weed control in this crop. However, the variability in yield response makes it very difficult to predict the requirement for herbicides and to develop weed thresholds to aid decision making in oilseed rape. One potential approach is to adopt the use of routine reduced or 'appropriate' dose herbicide sequences, as advocated by Proven *et al.* (1991) for winter cereals. However, the successful use of the appropriate dose approach requires an understanding of the factors influencing the efficacy of reduced doses in the field.

Previous work on the timing of weed control in oilseed rape suggested that late-sown crops are more sensitive to weed competition and yield loss may not always be prevented if weed control is delayed beyond the early post-emergence stage of the crop (G.P. Whytock, unpublished data). Thus, an early treatment would be a useful basis for herbicide programmes designed to achieve acceptable weed control with reduced inputs. The aim of the trials reported here was to evaluate the potential for reducing herbicide doses and to investigate the effect of initial weed density and crop sowing date on the need for herbicides and the efficacy of reduced doses.

MATERIALS & METHODS

Field trials were carried out over two seasons, 1991-92 (Experiment 1) and 1992-93 (Experiment 2), at Tillycorthie Farm, Udny, Aberdeenshire on a freely drained sandy loam soil. In Experiment 1, oilseed rape, cv. Samourai, was sown with an Oyjord plot drill on 28 August. Chickweed (*Stellaria media*) seed was sown at two target densities, 125 and 500 plants m^{-2} (low and high respectively). In Experiment 2, oilseed rape, cv. Rocket, was sown on 26 August, 3 September and 9 September. On each occasion, chickweed seed was sown at a target density of 200 plants m^{-2}.. In both experiments the crop seed rate was 6 kg ha^{-1} and chickweed seed was broadcast by hand before sowing the crop. Four herbicide treatments were imposed within each chickweed density in Experiment 1 and within each sowing date in Experiment 2. In both seasons, the herbicide treatments were metazachlor (Butisan S; BASF plc; 500 g a.i. litre^{-1}) at 750, 375 and 188 g a.i. ha^{-1} and an untreated control. The treatments were applied early post-emergence at crop GS 1,0-1,1. All treatments were applied with an Azo propane small plot sprayer fitted with TeeJet 11002 'low-drift' nozzle tips and calibrated to deliver 200 l ha^{-1} at a pressure of 2.5 bars. Harvested plot size was 1.95 m x 18 m and there were four replicates in a randomised block design in Experiment 1 and four replicates in a split plot design with sowing date as main plot in Experiment 2. Percent weed ground cover was scored visually by species on a whole plot basis on 3 October 1991 and 23 January, 17 March and 26 April 1992 in Experiment 1 and on 15 December 1992 and 10 February, 18 March and 26 April 1993 in Experiment 2. The plots were swathed with a Haldrup plot swather. In Experiment 2, the three sowing dates were swathed separately as each reached the correct stage of maturity. Plots were harvested on 6 August and on 1 September (all sowing dates) in Experiments 1 and 2 respectively with a Deutz Fahr 660 plot combine fitted with an electronic balance. A seed sample of approximately 1 kg was taken from each plot and a sub-sample of 100 g dried at 80^{o}C for 48 hrs to determine dry matter content. A further sub-sample of 100 g was cleaned by sieving, aspiration and hand picking to determine 'clean seed content'. Clean seed yield was expressed in t ha^{-1}at 91 % d.m.

RESULTS

The crop in Experiment 1 was sown at the end of August when soil temperatures were high; rain fell within a few days of sowing which ensured good establishment. Warm sunny weather in September encouraged rapid growth resulting in a vigorous crop which overwintered well. The sown chickweed established better than expected, especially at the lower density (272 m^{-2} vs 125 m^{-2} target at the low density, compared to 555 m^{-2} vs 500 m^{-2} target at the high density). The development of chickweed ground cover (mean of two densities) over the season is summarised in Figure 1. In October, all herbicide treatments significantly reduced chickweed ground cover compared to untreated but there was no difference between doses. Chickweed ground cover in untreated plots increased from a mean of 12 % in October to 52 % in January. Despite this, full dose herbicide reduced mean chickweed ground cover to less than 2 % and half dose to 4.9 % in January. Remaining chickweed ground cover at quarter dose was significantly greater than either of the higher doses at 12.6 %, but still significantly less than the untreated (Figure 1). Chickweed ground cover peaked at a mean of 68 % in untreated plots in mid-March, while weed ground cover scores in the treated plots remained very similar to those in January. There was no effect of sown weed density on final yield (Table 1); failure to control weeds, however, significantly reduced the mean yield of the two sowing dates by 10 % compared to full dose herbicide. Despite the visually poorer weed control at quarter dose noted throughout the season (Figure 1), this rate of application was sufficient to prevent yield loss due to chickweed competition (Table 1).

Table 1. The effect of chickweed density and herbicide dose on seed yield, t ha^{-1} at 91 % d.m. in Experiment 1.

Target chickweed density	Herbicide dose: Full	Half	Quarter	Nil	Mean
Low	3.89	3.76	3.79	3.40	3.71
High	3.80	3.86	4.00	3.50	3.80
Mean	3.85	3.81	3.90	3.45	3.75

LSD (P<0.05): Sowing date NS; Herbicide dose 0.240; Means in body of table NS

During the establishment of Experiment 2 the mean soil temperature in autumn was approximately 2°C below average. The crop was sown into moist soils, but low temperatures delayed establishment, and growth slowed further when soil temperatures dropped in October and November. As a result, the crop was small going into winter and slow to grow away in spring. Sown chickweed established bettter than anticipated in the first sowing (363 plants m^{-2} vs 200 m^{-2} target), close to the target density in the second sowing (208 m^{-2}) and below target in the third (149 m^{-2}). The development of chickweed ground cover in plots either treated with full dose herbicide or left untreated is shown in Figure 2 for the three sowing dates. For simplicity, the data for half and quarter doses are not presented. Throughout the season, across all three sowings, chickweed ground cover was always significantly less in plots treated with full dose herbicide than in untreated plots. However, the efficacy of the herbicide differed between the sowing dates. Plots treated with full dose herbicide had consistently greater chickweed ground cover at the early compared to the two later sowing dates, up until March (compare 23.8 % ground cover in the 26 August sowing with 3.7 % and 0.0 % in the 3 and 9 September sowings respectively). Chickweed

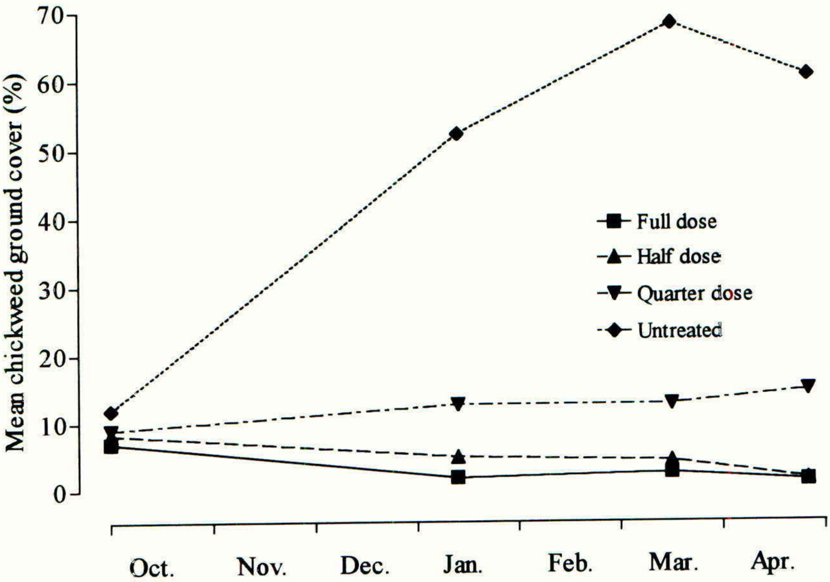


Figure 1. The effect of herbicide dose on the development of chickweed ground cover (mean of two target chickweed densities) in Experiment 1.

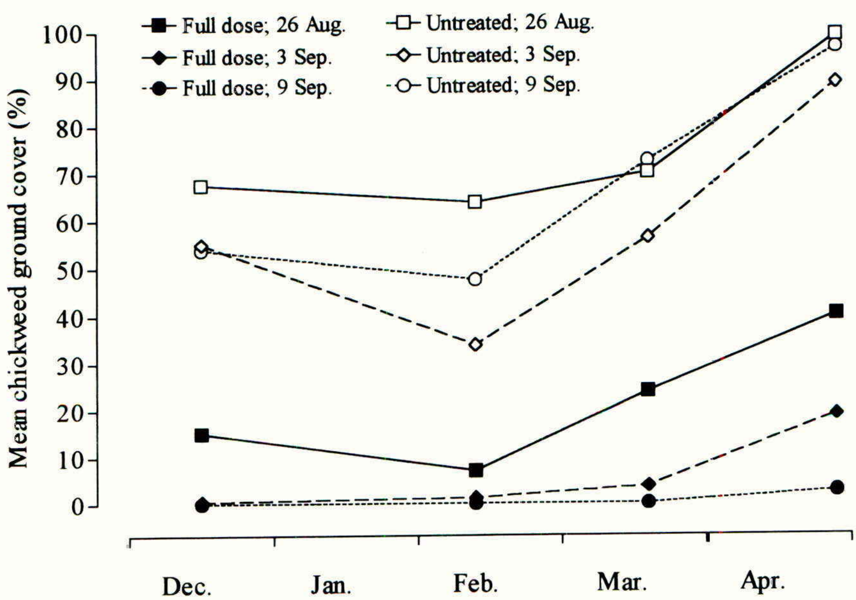


Figure 2. The effect of sowing date and full dose herbicide on the development of chickweed ground cover in Experiment 2.

ground cover increased substantially between March and April in all sowing dates (Figure 2). As a result of the poor growing season, seed yields were low compared to the previous year (mean 1.53 compared to 3.75 t ha^{-1} in 1992). Sowing date had no significant effect on seed yield overall, perhaps because the effect of delayed sowing was masked by considerable variation within sowing date. However, failure to control weeds substantially reduced yield (Table 2); untreated plots yielded on average 55 % less than those treated with full dose herbicide, and all treated plots yielded significantly more than the untreated. Yield declined sharply as herbicide dose was reduced.

Table 2. The effect of sowing date and herbicide dose on seed yield, t ha^{-1} at 91% d.m. in Experiment 2.

	Herbicide dose				
Sowing date	Full	Half	Quarter	Nil	Mean
26 August	2.01	1.82	1.69	1.11	1.66
3 September	1.79	1.51	1.16	0.93	1.35
9 September	2.31	1.99	1.28	0.76	1.58
Mean	2.04	1.78	1.37	0.93	1.53

LSD (P<0.05): Sowing date NS; Dose 0.353; Means in body of table NS

DISCUSSION

The results of these trials confirmed the variability in the yield response of oilseed rape to broad-leaved weed control (Lutman *et al.*, 1993) and demonstrated the role of crop vigour and seasonal weather patterns in influencing these responses.

Metazachlor gave visually acceptable weed control at full and half doses in a vigorous crop in Experiment 1. Although weed control was poorer at quarter dose, the amount of chickweed remaining was not sufficient to compete with the crop and reduce yield. Therefore it could be argued that weed control was acceptable. There was no evidence to suggest that initial chickweed density influenced the efficacy of the herbicide, though this would not necessarily have been the case in a less vigorous crop.

By contrast, in Experiment 2, where crop vigour was poor, even full dose herbicide failed to give visually acceptable weed control in the early sowing. However, weed control was good until March in the later sowings. This may be because application of the herbicide in the first sowing was delayed by slow crop establishment and windy weather and the chickweed had reached the 4-6 leaves stage by the time of spraying. Treatment was more timely in the later sowing dates: none of the chickweed had more than 2-4 leaves and therefore it would have been more susceptible to the herbicide, especially at low doses. It is worth noting that the 'full' dose used here, although the standard dose used in Scotland, is, in fact, only 60% of the maximum dose on the label (Anon., 1994b). Given the late application in the first sowing, perhaps a higher dose should have been used in this case. Full dose herbicide was necessary to prevent yield loss due to weed competition irrespective of crop sowing date.

The contrasting results of these two trials highlight the difficulties of attempting to predict the responses of oilseed rape to weed control and strengthen the case for adopting a semi-prophylactic approach to the control of broad-leaved weeds. In vigorous crops in good growing conditions, a reduced dose of metazachlor applied early post-emergence may be all that is required. In less vigorous crops, the use of such an early treatment offers the flexibility of following up with a low dose post-emergence herbicide such as benazolin + clopyralid or cyanazine later in the autumn, if the dose of metazachlor required is underestimated. This approach is a sound basis for a cost-effective weed control strategy and need not entail any extra application costs, at least in Scotland, where most crops are sprayed with a fungicide in autumn to control light leaf spot (*Cylindrosporium concentricum*) (Sutherland *et al.*, 1994)

REFERENCES

Anon. (1993). Weed control in winter oilseed rape. *SAC Technical Note T 52 (Revised)*, 5 pp. The Scottish Agricultural College, Edinburgh.

Anon. (1994a). *SAC Farm Management Handbook 1994/95, 15th Edn*, 478 pp. The Scottish Agricultural College, Edinburgh.

Anon. (1994b). *BASF Product Manual 1994.* BASF plc, Ipswich.

Bowerman, P (1989). Weed control in winter oilseed rape - review of ADAS trials 1985-87. *Aspects of Applied Biology 23, Production and Protection of Oilseed Rape and Other Brassica Crops*, 219-226.

Davies, D H K (1987). Effect of herbicides on weed control and crop yield in winter oilseed rape in south-east Scotland. *Proceedings British Crop Protection Conference - Weeds*, 815-820.

Davies, D H K; Walker, K C; Whytock, G P (1989). Herbicide use and yield response in winter oilseed rape in Scotland. *Aspects of Applied Biology 23, Production and Protection of Oilseed Rape and Other Brassica Crops*, 227-236.

Lutman P J W; Bowerman, P; Palmer, M; Whytock, G P (1993). The competitive effects of broad-leaved weeds in winter oilseed rape. *Proceedings Brighton Crop Protection Conference - Weeds*, 1023-1028.

Proven, M J; Courtney, A; Picton, J; Davies, D H K; Whiting, A J (1991). Cost-effectiveness of weed control in cereals - systems based on thresholds and reduced rates. *Proceedings 1991 Brighton Crop Protection Conference - Weeds*, 1201-1208.

Sutherland, K G; Griffin-Walker, V; Oxley, S J P (1994). Resistance of light leaf spot (*Pyrenopeziza brassicae*) of winter oilseed rape to MBC fungicides. *Proceedings 1994 Brighton Crop Protection Conference - Pests and Diseases*, 463-468.

Walker, K C; Whytock, G P; Davies, D H K (1990). Evaluation of yield response and financial benefits from weed control in oilseed rape in Scotland. *Proceedings Crop Protection in Northern Britain 1990*, 301-306.

CONTROL OF VOLUNTEER OILSEED RAPE IN PEAS

C M KNOTT
Processors & Growers Research Organisation, The Research Station, Great North Road, Thornhaugh, Peterborough, PE8 6HJ

ABSTRACT

Pre- and post-emergence herbicides were compared to assess efficacy on oilseed rape volunteers sown shallowly at 0-10 mm, or deep at 60 mm depth, in peas. Pre-emergence pendimethalin/prometryn and fomesafen/terbutryn were effective in 1993 and 1994 when shallow sown rape was more easily controlled but, under dry soil conditions, were inadequate in 1995. Post-emergence tank-mixes terbuthylazine/isoxaben + bentazone (315/56 + 480 g a.i. ha^{-1}), pendimethalin + bentazone (800 + 750 g a.i. ha^{-1}) (not registered in the UK) and half a dose of bentazone/MCPB + cyanazine (400/400 + 100 g a.i. ha^{-1}) performed best. This latter treatment and MCPB at 1680 g a.i. ha^{-1} were the least expensive. In 1993, desiccants were compared, the addition of wetter improved speed of action of diquat; glufosinate ammonium was slow to desiccate oilseed rape volunteers.

INTRODUCTION

Oilseed rape volunteers (*Brassica napus*) frequently occur in peas where both crops are grown in the same rotation. A survey of 17.7 thousand ha of vining peas in England in 1992 (Knott, 1993) showed that 24.8 % were infested with rape volunteers which can cause a weedy contaminant problem. In peas harvested dry, oilseed rape can cause severe combine harvesting difficulties and treatment with a desiccant adds to production costs. Farmer experience suggests that rape seed persists in the soil for five years or more and research on this topic is being carried out by Lutman (1993). Garrett and Orson (1989) found that emergence of oilseed rape from seed sown in pots at 75 mm depth was good, but seven days later than shallow sown rape, but only 8 % of seed sown at 100 mm depth emerged. In the field, pre-emergence herbicides may not control seed germinating from depth and a prolonged period of emergence presents a problem for the timing of post-emergence sprays.

The objectives of the experiments in field (combining) peas reported here were: to identify the most effective herbicide treatments; the optimum dose and timing of application relative to growth stage of crop and volunteer, and in 1993 and 1994 to assess control of oilseed rape sown at different depths. In 1993 desiccation of oilseed rape volunteers was also studied. The experiments were funded by PGRO pulse levy.

MATERIALS AND METHODS

The experiments were sited on sandy loam soil at Thornhaugh, Cambridgeshire. In March, peas, cv. Solara in 1993 and 1994, cv. Grafila in 1995, were sown 50 mm deep and oilseed rape cv. Libravo was sown in rows between the peas. In 1993 and 1994, rape was shallow sown just on the soil surface at 0-10 mm or deep sown at 60 mm, and in 1995 at 50 mm only. The plots were rolled with a Cambridge roll after sowing.

The experiment was of randomised block design for herbicide treatments and with four (1993) or three (1994 and 1995) replications. Plot area was 4 m x 10 m with plots split for shallow or deep sown oilseed rape, except in 1995 where the area was 2 m x 10 m.

Dates of emergence of peas and oilseed rape were noted and growth stages recorded at each application timing (Table 1). The peas were tested for leaf wax using crystal (methyl) violet dye before each herbicide application timing and wax cover was good on all occasions. In 1993 and 1994, oilseed rape was also tested for leaf wax.

Table 1. Herbicide application dates and growth stages of peas and oilseed rape deep (D) or shallow (S) sown for experiments from 1993 - 1995.

Timing	Application date	Growth stages Peas	Oilseed rape D	 S
1993 experiment sown 9 March				
T0	16 March	pre-em	pre-em	pre-em
T1	16 April	1-2 node	cot-1 TL	2 TL
T2	20 April	2-3 node	2 TL	3 TL
T3	29 April	4-5 node	4-6 TL	5-6 TL
T4	3 May	5 node	5-6 TL	6TL
1994 experiment sown 23 March				
T0	21 April	pre-em	pre-em	pre-em
T1	27 April	1-2 node	cot-1 TL	2 TL
T2	2 May	2-3 node	cot-2 TL	2 TL-4 TL
T3	10 May	4-5 node	3-4 TL	4-5 TL
T4#	27 May	7 node	7 TL	7 TL
1995 experiment sown 19 March				
T0	30 March			
T1	13 April	< 2 node	cot	
T2	21 April	2 node	cot-1 TL	
T3	28 April	3 node	2 TL	
T4	3 May	4 node	2-3 TL	

treatment T4 delayed because of adverse weather

Applications of herbicides and desiccants were made with an Azo plot sprayer delivering 200 litre ha^{-1} through Lurmark flat fan nozzles 02F110 at 200 kPa pressure to give fine spray quality.

The herbicides evaluated were pendimethalin/prometryn (Monarch; 264/170 g a.i. $litre^{-1}$ SC), fomesafen/terbutryn (Reflex T; 80/400 g a.i. $litre^{-1}$ SC), terbuthylazine/isoxaben (Skirmish 495 SC; 420/75 g a.i. $litre^{-1}$ SC), terbutryn/terbuthylazine (Opogard 500 SC; 350/150 g a.i. $litre^{-1}$ SC), pendimethalin (Stomp 400; 400 g a.i. $litre^{-1}$ SC), bentazone (Basagran; 480 g a.i. $litre^{-1}$ SL), cyanazine (Fortrol; 500 g a.i. litre^{-1} SC), MCPB/MCPA (Trifolex-Tra; 216/34 g a.i. litre^{-1} SL), MCPB (Tropotox; 400 g a.i. litre^{-1} SL) and bentazone/MCPB (Pulsar; 200/200 g a.i./litre^{-1} SL). Pre-emergence herbicides were applied at rates recommended for the light soil type, except for those containing pendimethalin where the same rate is used for all soils. Post-emergence herbicide treatments were applied either at the full dose recommended on the product label, or at half doses at an earlier timing than recommended. A post-emergence tank-mix of pendimethalin plus bentazone was included, although it is not registered for use in the UK but it is widely used in peas in France as Vulkan T. Programmes of pre- and post- emergence herbicides were also assessed. In 1993, desiccants diquat (Reglone; 200 g a.i. litre^{-1} SL) alone or with non-ionic wetter (Agral) and glufosinate-ammonium (Challenge; 150 g a.i. litre^{-1} SL) were applied on 2 August at normal desiccation stage for peas GS 301 (Knott, 1987) when most of the crop was yellow, lower pods dry and brown, upper pods green and wrinkled and pea seed moisture content about 40%. At this timing the oilseed rape was in flower, several pods were set and the leaves green.

Counts of oilseed rape plants in three random one metre lengths of row per plot were made at appropriate intervals after spraying. Some treatments severely stunted but did not kill the rape and therefore final assessments were made at dry harvest stage for the peas. Analysis of variance was carried out. The effect of desiccants was assessed as percentage area of leaf, pod and stem desiccated at intervals after treatment.

RESULTS AND DISCUSSION

In the 1993 and 1994 experiments, there was rainfall after sowing and good emergence of both shallow and deep sown oilseed rape with only 4 % and 14 % reduction in emergence respectively. Deep sown rape emerged about 10 days later than shallow sown rape in both years. Crystal violet tests showed that oilseed rape at cotyledon and one true leaf (1 TL) stage had virtually no leaf wax with almost 100 % dye retention. At later stages wax appeared dependent on weather conditions (it was greater after a warm dry period), and also on pest and disease attack. Rape leaves at 2-3 TL stage retained 10-50 % dye and wax was unexpectedly poor at the later stages in both years.

Pre-emergence herbicide treatments (Table 2)

In all experiments there was almost 100 % emergence of oilseed rape plants on plots treated with pendimethalin or pendimethalin/prometryn. However, most remained at cotyledon stage, assumed a purple colouration and subsequently died in the 1993 experiment. In 1994, some survived during a wet April, although the plants were stunted at harvest. The other pre-emergence herbicides reduced emergence.

In 1993 and 1994, pre-emergence herbicides in most cases achieved better control of shallow sown than deep sown rape. Fomesafen/terbutryn and pendimethalin /prometryn were the most effective pre-emergence treatments in two years but, for the 1995 experiment, rainfall following application was negligible and consequently residual activity was very poor. Terbuthylazine/isoxaben was less reliable and terbutryn/terbuthylazine was ineffective in all three years.

Post-emergence herbicide treatments (Table 2)

At post-emergence timings, deep sown oilseed rape was at a less advanced growth

Table 2. Percentage control of 'volunteer' oilseed rape deep (D) or shallow (S) sown in peas, with herbicide treatments at timings (see Table 3), for experiments from 1993-1995.

Herbicide	Dose (g a.i. ha^{-1})	Application timing	Oilseed rape control (%) 1993 D	1993 S	1993 Mean	1994 D	1994 S	1994 Mean	1995 D
pendimethalin/prometryn	1320/850	T1	89.4	95.5	92.5	67.3	75.6	71.7	48.3
fomesafen/terbutryn	200/1000	T0	73.8	88.2	81.1	97.4	97.5	97.5	49.2
terbuthylazine/isoxaben	420/75	T0	53.3	49.3	51.3	84.9	89.3	87.3	-
terbutryn/terbuthylazine	805/345	T0	45.4	57.7	51.6	(40.2	48.4	44.3)~	27.1
terbuthylazine/isoxaben	420/75	T1	77.3	76.7	77.0	83.1	71.5	76.8	-
terbuthylazine/isoxaben + cyanazine	315/56 + 750	T2	68.6	65.0	66.8	54.0	45.1	47.6	-
terbuthylazine/isoxaben + bentazone	315/56 + 240	T1	-	-	-	-	-	-	90.8
terbuthylazine/isoxaben + bentazone	315/56 + 480	T1	100	100	100	100	100	100	96.8
pendimethalin + bentazone	800 + 750	T2	-	-	-	98.9	99.7	99.3	95.3
bentazone/MCPB + cyanazine	400/400 + 100	T2	96.7	98.0	97.3	99.6	98.1	98.8	95.6
bentazone/MCPB + cyanazine	800/800 + 200	T3	100	99.1	99.5	96.0	93.7	94.8	100
cyanazine + MCPB/MCPA split dose	500 + 216/34 & 500 + 216/34	T2 & T4/T3	100	99.2	99.6	75.7	75.6	75.6	-
cyanazine + MCPB/MCPA	1000 + 432/68	T3/T4	86.6	65.1	75.8	66.9	67.1	67.0	97.8
MCPB	840	T2	-	-	-	76.1	68.3	71.9	85.5
MCPB	1680	T3/T4	100	95.3	97.6	82.6	78.1	83.1	95.0
pendimethalin & bentazone/MCPB + cyanazine	1000 & 400/400 + 100	T0 & T3	-	-	-	100	100	100	-
fomesafen/terbutryn & terbuthylazine/isoxaben + bentazone	200/1000 & 315/56 + 480	T0 & T1	-	-	-	-	-	-	99.4
fomesafen/terbutryn & bentazone/MCPB + cyanazine	200/1000 & 400/400 + 100	T0 & T2	-	-	-	-	-	-	98.4
fomesafen/terbutryn & MCPB	200/1000 & 840	T0 & T2	-	-	-	-	-	-	84.9
Mean numbers oilseed rape plants/m^2 on untreated			173	180		100	117	106	
Significance @ P=0.05			SD	SD	SD	SD	SD	SD	SD
LSD			11.27	11.55	9.60	9.99	9.33	8.40	9.48
CV%			10.1	10.4	8.6	7.5	7.2	6.4	7.3

()~ data not analysed single plot; - treatment not included in this year stage than shallow sown rape and hence better control was achieved. Terbuthylazine/isoxaben alone or at a lower dose plus cyanazine were inadequate. MCPB at 840 g a.i. ha^{-1} did not perform as well as the normal dose. Control with MCPB, or cyanazine + MCPB/MCPA, which rely on hormone herbicide activity, was superior in the dry season of 1995 but many rape plants recovered during wet weather in 1994. Both treatments were slow to act, causing distortion of the growing points and the leaves remained green for about 30 days before plants died completely.

Early application with tank-mixes of terbuthylazine/isoxaben + bentazone at (315/56 + 480) g a.i. ha^{-1}, low doses of bentazone/MCPB + cyanazine at (400/400 + 100) g a.i. ha^{-1} and pendimethalin + bentazone (800 + 750) g a.i. ha^{-1} applied to rape at cotyledon -2 TL gave excellent control, causing severe scorch and complete necrosis within a few days. Later applications with the full dose of bentazone/MCPB + cyanazine (800/800 + 200) g a.i. ha^{-1} also gave very effective control of rape at 4-6 TL stage, particularly when applied in ideal conditions of warm sunny weather in 1993, but was less effective in 1994 even though the rape was smaller 3-5 TL.

In 1995, the oilseed rape germinated over a long period in dry weather and possibly a few emerged after the T1 and T2 timings, hence these early treatments were slightly less effective than in previous trials. The higher dose of 480 g a.i. ha^{-1} bentazone in tank-mix with terbuthylazine/isoxaben improved control.

The programme of pendimethalin pre-emergence followed by bentazone/MCPB + cyanazine in 1994 gave complete control. In 1995, because of poor residual activity in dry conditions, pre-emergence application of fomesafen/terbutryn used in programmes did not significantly improve control compared with post-emergence treatments alone.

Desiccants (Table 3)

In 1993 and 1994, the oilseed rape was vigorous, growing through Solara peas, and a desiccant would have been required to avoid harvesting problems. In contrast, under the drought conditions of 1995 the rape was suppressed by the taller cv. Grafila.

Table 3. Effect of desiccants on volunteer oilseed rape in 1993, expressed as percentage leaf area desiccated, visual assessment DAT.

Desiccant	Dose g a.i. ha^{-1}	DAT	% area desiccated leaf	pods	stem
diquat	600	2	80	50	0
		5	100	100	0
diquat + non-ionic wetter	600 + 0.1% final volume	2	100	100	0
glufosinate ammonium	450	2	little effect		
		7	100	10	0
		10	100	100	0

At the time of desiccant application, the oilseed rape was flowering, leaves, pods and stem were green and dry hot weather followed. Results show that the addition of wetter to diquat speeded up desiccation and this treatment had the most rapid effect. Glufosinate-ammonium had very slow action. Desiccants had little effect on the thick rape stems.

CONCLUSIONS

The experiments demonstrated that volunteer oilseed rape control with pre-emergence herbicides may be unreliable, particularly if no rain follows application. Oilseed rape often emerges after treatment with pendimethalin/prometryn and some may survive under good growing conditions. The dilemma for the farmer is to decide at an early stage whether a follow-up herbicide application is worthwhile.

Consistent and nearly complete control of rape volunteers was achieved with: very early applications to small rape of terbuthylazine/isoxaben + bentazone; pendimethalin + bentazone which is not registered in the UK and the half dose of bentazone/MCPB + cyanazine when the peas were at 2 node stage, earlier than label recommendations. Further data on crop tolerance is needed for the last two treatments, but varietal tolerance screens in one year at Processors and Growers Research Organisation suggest that safety margins may be adequate.

Under CAP reform, UK peas are now sold at world market prices and the most economic treatments are sought. The cheapest, most effective, treatment was the half dose of bentazone/MCPB + cyanazine. The full dose of MCPB was also inexpensive. If, as a last resort, desiccants are needed, diquat + non-ionic wetter had the quickest action, but desiccation may not overcome difficulties of cutting through thick rape stems with the combine cutter-bar at harvest.

REFERENCES

Garrett, H J; Orson J H (1989) Depth and date of emergence of volunteer oilseed rape (*Brassica napus* L) and its control with herbicides used in peas, beans, potatoes and sugar beet. *Brighton Crop Protection Conference - Weeds*, **3**, 811-816.

Knott, C M (1993) Volunteer crops in legumes for processing. *Aspects of Applied Biology*. **35**, *Volunteer crops as weeds*. 207-213.

Knott, C M (1987) A key for stages of development of the pea (*Pisum sativum*). *Annals of Applied Biology*. **111**, 233-244.

Lutman, P J W (1993) The occurence and persistence of volunteer oilseed rape (*Brassica napus*). *Aspects of Applied Biology*. **35**, *Volunteer crops as weeds*. 29-36

INTERACTION BETWEEN ANNUAL GRASS WEED POPULATION AND THE TIMING OF WEED REMOVAL ON THE YIELD OF COMBINING PEAS AND SPRING FIELD BEANS

S E WILSON
Zeneca Crop Protection, Fernhurst, Haslemere, Surrey, GU27 3JE

ABSTRACT

Two trials in each of spring field beans and combining peas were conducted at the Processors and Growers Research Organisation to determine the effects of annual grass weed population and timing of weed removal on yield. Grass weed infestations were simulated by sowing winter barley at various densities. These were removed by application of fluazifop-P-butyl at two timings. Significant yield reductions occurred at low weed populations in the absence of control. In general, there was a greater yield response to early weed removal at the 2-3 leaf pair/node stage than to later removal.

INTRODUCTION

It has long been understood that combining peas, and to a lesser extent field beans, compete poorly with weeds. Both crops are regularly treated with herbicides in the UK for grass and broad-leaved control with up to three applications being made in a season.

The efficacy and robustness of post-emergence graminicides allows growers to be flexible in their approach to grass weed control (Knott, 1985). This encourages a 'wait and see' approach to control which is sensible when the extent of grass weed infestation or emergence is not known. It is perceived by some growers and advisers that recent product introductions have further increased this flexibility by having later harvest intervals and, in the absence of contrary information to advise otherwise, there is a tendency for graminicide applications to occur later year by year. Furthermore, there has been little study of the effect of grass weed populations on the yield of combining peas and field beans (Lutman *et al.*, 1994) or populations that justify herbicide treatment.

The purpose of the work described here was to assess both the effect of different grass weed populations and the effect of timing of weed removal on yield.

MATERIALS AND METHODS

Two trials in each of field beans and combining peas were conducted at the PGRO in the spring/summer of 1994. The trial design was a randomised block arrangement with four replicates. Plots were 2 m x 15 m.

Winter barley cv. Marinka was used as the representative grass weed (the most common grass weeds in spring sown peas and beans are cereal volunteers) and was broadcast by hand at the required density and then incorporated with a rotary cultivator. 95% germination of the barley was achieved. Crops were then drilled two days later except site 2 of the field beans which was drilled on the same day.

Weed control was achieved using fluazifop-P-butyl (as 'Fusilade' 250EW) at 187.5 g a.i.ha^{-1} together with non-ionic surfactant at 0.1% of spray volume in 200l/ha of water. Applications were made with a plot sprayer pressurised with propane gas, using 110 degree flat fan nozzles, delivering a fine spray quality at 2 bar pressure.

Table 1. Treatments and timings.

	Weed control	Weed density(pl m^{-2})	Timing
1.	Untreated	0	-
2.	Untreated	5	-
3.	Untreated	20	-
4.	Untreated	50	-
5.	Untreated	100	-
6.	Untreated	200	-
7.	Complete removal	0	T1 (2-3 nodes)
8.	Complete removal	5	T1 (2-3 nodes)
9.	Complete removal	20	T1 (2-3 nodes)
10.	Complete removal	50	T1 (2-3 nodes)
11.	Complete removal	100	T1 (2-3 nodes)
12.	Complete removal	200	T1 (2-3 nodes)
13.	Complete removal	0	T2 (T1+4weeks)
14.	Complete removal	5	T2 (T1+4weeks)
15.	Complete removal	20	T2 (T1+4weeks)
16.	Complete removal	50	T2 (T1+4weeks)
17.	Complete removal	100	T2 (T1+4weeks)
18.	Complete removal	200	T2 (T1+4weeks)

Table 2. Site details.

Site 1.	Cottagers Piece, Thornhaugh	Soil type SL over gravel
Site 2.	Big Meadow, Thornhaugh	Soil type ZCL

Site	Crop	Cv	Sowing date	Population (pl m^{-2})
1.	Peas	Solara	10 March	72
	Beans	Victor	10 March	42
2.	Peas	Grafila	20 March	66
	Beans	Maris Bead	25 April*	38

* 1st sowing destroyed by rooks

Table 3. Treatment details.

Site	crop	Weed removal	Crop GS	Barley GS	Harvest date
1.	Peas	T1 25 April	2-3 node	13,21-22	27 July
		T2 23 May	bud enclosed	31	27 July
	Beans	T1 25 April	2 node	13,21	15 August
		T2 23 May	6 node	31	15 August
2.	Peas	T1 10 May	4 node	13,22	2 August
		T2 2 June	bud enclosed	31	2 August
	Beans	T1 23 May	2 node	13,21-22	26 August
		T2 17 June	7-8 node	31	26 August

Weather summary

The spring was very wet with rainfall higher than the 20 year average for February (136%), March (170%), and April (148%). There was very little rain from 25 May until 24 July. June rainfall was only 30% of the 20 year average with higher than average temperatures.

RESULTS

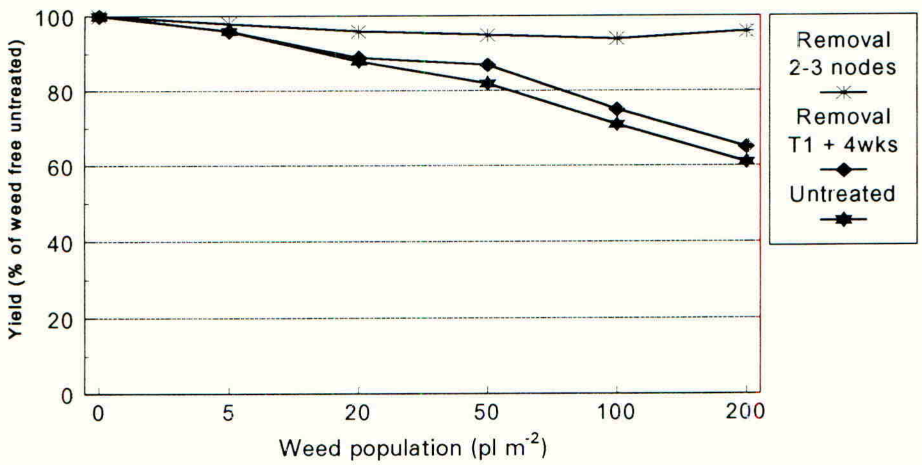
Although the experimental design was a full factorial, inspection of the data shows a clear interaction between the use of fluazifop-P-buty and barley density making factorial analysis inappropriate. Furthermore, because the factor of barley density forms an ordered progression, use of multiple comparison procedures does not give the most appropriate analysis for comparison of one barley density with another. Thus interpretation should be based on the overall trends which are clearly apparent in the graphical presentation of the results.

Table 4. Combining pea yields.

	Weed control	Target weed density(pl m^{-2})	Yield - t ha^{-1} at 15% m.c. (% of treatment 1) Site 1	Site 2
1.	Untreated	0	4.19 (100)	3.31 (100)
2.	-	5	4.03 (96)	3.14 (95)
3.	-	20	3.64 (86)	2.97 (90)
4.	-	50	3.32 (79)	2.83 (85)
5.	-	100	2.68 (64)	2.59 (78)
6.	-	200	2.44 (58)	2.10 (64)
7.	Early removal	0	4.20 (100)	3.55 (107)
8.	-	5	4.17 (99)	3.20 (97)
9.	-	20	4.08 (98)	3.10 (94)
10.	-	50	3.80 (91)	3.24 (99)
11.	-	100	3.65 (87)	3.35 (101)

Weed control	Target weed density(pl m^{-2})	Yield - t ha^{-1} at 15% m.c. (% of treatment 1) Site 1	Site 2
12. -	200	3.81 (91)	3.33 (101)
13. Late removal	0	4.09 (98)	3.50 (106)
14. -	5	3.86 (92)	3.30 (100)
15. -	20	3.48 (83)	3.16 (95)
16. -	50	3.29 (79)	3.14 (95)
17. -	100	2.71 (65)	2.78 (84)
18. -	200	2.11 (50)	2.64 (80)
LSD (5%)		0.374 (8.93)	0.310 (9.35)

Figure 1. Effect of weed population and timing of removal on the yield of combining peas (mean of two trials).

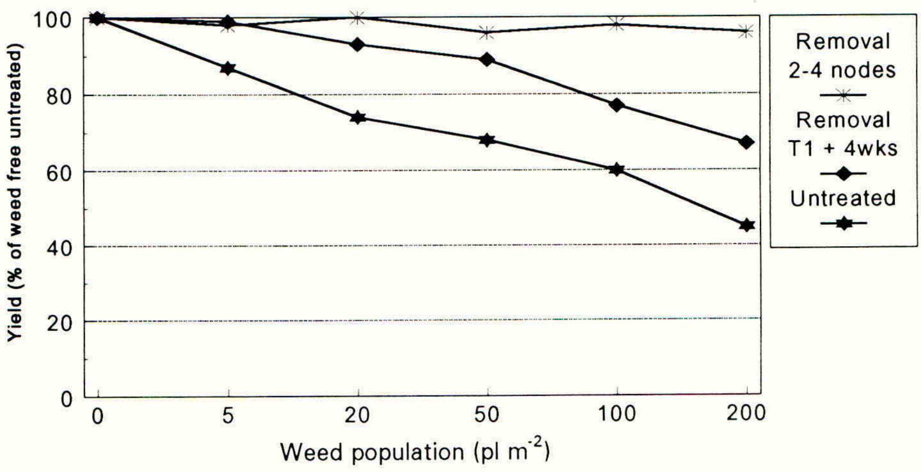


The effect of weed competition in peas was greater on the short strawed cv. Solara than on Grafila. The former suffered particularly acute drought stress during June and was visibly wilted on occasions. In untreated plots in both trials weed populations of 20 pl m^{-2} clearly reduced the yield of the peas. Early weed removal when the Peas were at the 2-3 node stage prevented yield loss at site 2, but significant loss had already been caused by this stage at site 1. There was significant yield gained by the later application at site 2 at the higher weed populations over the untreated, but not at site 1.

Table 5. Field bean yields.

Weed control	Target weed density(pl m^{-2})	Yield - t ha^{-1} at 15% m.c. (% of treatment 1) Site 1	Site 2
1. Untreated	0	4.45 (100)	2.11 (100)
2. -	5	4.12 (93)	1.72 (81)
3. -	20	3.64 (82)	1.40 (66)
4. -	50	3.46 (78)	1.22 (58)
5. -	100	2.93 (66)	1.13 (54)
6. -	200	2.19 (49)	0.86 (41)
7. Early removal	0	4.44 (100)	2.13 (101)
8. -	5	4.37 (98)	2.06 (98)
9. -	20	4.37 (98)	2.14 (102)
10. -	50	4.33 (97)	2.00 (95)
11. -	100	4.28 (96)	2.10 (100)
12. -	200	4.34 (97)	2.00 (95)
13. Late removal	0	4.45 (100)	2.10 (100)
14. -	5	4.45 (99)	2.10 (100)
15. -	20	4.27 (96)	1.97 (93)
16. -	50	4.18 (94)	1.75 (83)
17. -	100	3.69 (83)	1.47 (70)
18. -	200	3.16 (71)	1.33 (63)
LSD (5%)		0.387 (8.69)	0.292 (13.84)

Figure 2. Effect of weed population and timing of removal on the yield of field beans (mean of two trials).



The results from this work suggest that under some conditions field beans can be as susceptible to weed competition as combining peas. Cereal volunteers at 5 pl m^{-2} gave a significant reduction in yield at site 2. It should be remembered that this crop was late drilled, but would be representative of field situations where emergence was delayed or redrilling occurred. Almost all the potential yield loss from weed competition was recouped from herbicide applications at the 2-3 node stage whilst later application was still worthwhile, although some yield loss occurred.

DISCUSSION

Although there was some variability in the effect of both weed population and timing of removal on the yield of the pea and bean crops examined, several conclusions are suggested :

1. The yield of both combining peas and field beans were strongly affected by grass weed competition, sometimes by populations as low as 5 pl m^{-2}.

2. Herbicide applications for the removal of grass weeds were best made at or just before the 2-3 node stage of both combining peas and field beans.

3. It would seem that drought stress or susceptibility to drought stress exacerbated the competitive effects of grass weeds. This is not in accord with the findings of Lutman *et al.*(1994) or Babalola *et al.* (1991) who found that grass weed competition increased with greater rainfall. However, this dicotomy may simply be a result of the extreme nature of the drought suffered by the peas at site 1 and the late drilled beans at site 2.

Confidence in these conclusions would be increased by repeating the study for at least one further year.

'Fusilade' is a Registered Trade Mark, the property of Zeneca Limited.

ACKNOWLEDGEMENTS

Processors and Growers Research Organisation who managed the experiments and assisted in the trial design.

REFERENCES

Babalola, A; Froud-Williams, RJ; Drennan DSH (1991) Effects of volunteer barley competition on yield of autumn and spring-sown field beans. *Aspects of Applied Biology*. **27**, Production and protection of legumes 179-182.

Knott, CM (1985) Grass-weed control for broad-leaved crops - The options. *British Crop Protection Conference - Weeds*. **2**. 429-440.

Lutman, PJW; Dixon, FL; Risiott R (1994) The response of four spring-sown combinable arable crops to weed competition. *Weed Research*. **34**, 137-146.

USE OF A SIMPLE MECHANISTIC MODEL TO SIMULATE WEED AND CROP GROWTH

D P AIKMAN, L R BENJAMIN, W BOND, A MEAD.

Horticulture Research International, Wellesbourne, Warwick, Warks., CV35 9EF

ABSTRACT

A simple mechanistic model has been developed to simulate individual plant growth within monocultures. The model allows for environmental factors and for competition for these factors with neighbouring plants. The model parameters can be determined easily by fitting the model to data from pure species stands. With no further adjustment, the model gives good predictions of the growth of each of the component species in mixed-species stands. The model will be used to evaluate the effects of different weed control strategies on crop and weed growth at different crop and weed densities, different relative seedling emergence times and in different environments.

INTRODUCTION

The success of tailoring weeding strategies to crop weed control requirements depends upon the ability to predict the competitive effect of weeds on crops under different environmental conditions. Models to simulate competitive interactions between plants of different species have been developed to quantify the amount of yield loss due to the presence of weeds (Doyle, 1991). Most of the current models are static, empirical and deterministic (Cousens, 1985; Rejmanek *et al.*, 1989; Roush *et al.*, 1989). The predictive ability of these static models can be weak (Martin *et al.*, 1987), as they do not allow for the effect of different climatic conditions on different species or for differences in emergence times and initial plant sizes. Cousens *et al.* (1987) and Kropff and Spitters (1991) allowed for these factors, but their models were still static.

In this paper we demonstrate the ability of a dynamic model to predict growth of weeds and a crop. The model allows for the complex competitive growth interactions between crop and weed. It is also mechanistically based, allowing for the effects of climatic conditions. These relationships are simple compared with those in other mechanistic models, retaining the advantage of static models in having few parameters. For plants that are well fertilised and irrigated, we assume growth is driven by temperature and light. The amount of light intercepted by each plant is determined by the projected area of the shoot crown and the within-crown leaf area index (lai). Plants within a stand are assumed to grow as though isolated until canopy closure. Plant growth following canopy closure depends upon the within-crown lai of the individual plants. If all plants have the same lai, then all will have a lower relative growth rate (rgr) than if isolated, because their crowns cannot expand laterally to their full potential. If, at canopy closure, some plants have a higher lai than others, then the plants of higher lai will continue to grow as though isolated and expand their crowns laterally at the expense of the plants of lesser lai. This inflates the lai of the plants with initially low lai. Consequently, as stand growth proceeds, the difference in lai between plants diminishes. When the lai of all plants are equal, then the rgr of all plants becomes identical and no further disparity between plants in rgr develops, (Aikman & Benjamin, 1994). The model can allow for different shoot canopy structures. Most simply, all plants could have a uniform shoot height. Alternatively some plants may occupy an overstorey, and the others would form an understorey. In each storey, there would be more space for lateral expansion of the crowns, but those in the understorey would suffer shading (Benjamin & Aikman, 1995).

MATERIALS AND METHODS

In experiments 1 - 4, one or more of the species, carrot (cv. Marathon), mayweed (*Matricaria inodora*) and speedwell (*Veronica persica*) were grown in monoculture. In experiment 5, carrot was grown in mixed cultures a) with mayweed, and b) with speedwell.

Experiment 1

Monocultures of carrot, mayweed and speedwell were established on three occasions. Carrots were sown on 23 May, 20 June and 26 July 1994. Mayweed and speedwell were established in compost blocks and transplanted to the field on 22 June, 14 July and 31 August 1994. In the field, the plants were 0.65 m apart in a triangular lattice layout. Between four and ten plants were harvested on five to seven occasions about ten d apart. At harvest the following were determined for each plant:- (i) the area of ground cover by the shoot crown, (ii) the area of the smallest vertically projected circle to encompass all the leaves (iii) the total plant leaf area, and (iv) total weight after drying at 80°C. The areas were determined by image analysis of video captured onto a PC and processed using VISILOG.

Experiment 2

Carrot monocultures were grown in plots containing cells as in experiment 2, but cells were either 0.05, 0.15 or 0.25 m wide. There were two replicates for each of two sowing dates (20-21 May and 3-4 June 1991), and dry weights were determined from six plants in each single age plot 35, 56, 77, 99 and 126 d after the first sowing (Aikman & Benjamin, 1994).

Experiment 3

Two ages of mayweed seedlings were transplanted on 28 July 1992 to plots containing cells either 0.05, 0.07, 0.10 or 0.14 m wide. There were three replicates of each treatment and dry weights were determined on six guarded plants 15, 28, 42, 58 and 69 d after transplanting. Single aged speedwell seedlings were transplanted on 19 August 1992 and harvested 14, 27, 40 and 54 d after transplanting. For this species, there was a single replicate of the spacings used for mayweed and three replicates of plots in which each alternate diagonal row of cells was left empty.

Experiment 4

The experiment was identical to experiment 3, except that speedwell was used and the plants were of the same age at transplanting, on 24 May and 4 June 1993. Harvests were made 27, 46, 62, 81 and 95 d after the second transplanting. Plants from the first transplanting became senescent by 81 d, so the data for these plants at 81 and 95 d were excluded from model fitting.

Experiment 5

In this experiment there were two treatments (i) carrots growing with mayweed and (ii) carrots growing with speedwell. Each plot consisted of an array of cells, each cell being 0.07 m wide. A single plant was grown in each cell. The carrots and the weed occupied alternate diagonal rows of cells, in a chequer board pattern. There were three replicates of each treatment in a randomised block design.

Pre-germinated carrot seeds were sown in each designated cell on 6 June 1994. 'Spare' seedlings were used to replace any carrots that failed to establish within the plots. Mayweed and speedwell were transplanted to their designated cells on 6 July 1994. Harvests were made on 13 and 25 July, 8, 19 and 30 August, 13 September and 3 October. At each harvest six guarded plants were lifted and the total plant weights determined for each species after drying at 80°C.

RESULTS

Using the individual plant data from experiment 1, the general relationships between leaf area, s_L, and plant dry weight (w) was found to be

$$s_L = Fw^{\theta} \qquad (1)$$

and that between projected crown zone area, s_Z, and plant dry weight was

$$s_Z = Aw^{\phi} \qquad (2)$$

The values of F and θ, and of A and ϕ were determined by least squares linear regression of $\log s_L$ on $\log w$, and of $\log s_Z$ on $\log w$, respectively. The ratio of the two areas was used to calculate the within-crown leaf area indices for any plant weight for each species. The extinction coefficient for each species was estimated from the projected crown area, area of ground cover and leaf areas for these isolated plants.

Having directly determined these parameter values, those relating to the conversion of light energy to dry matter (dm) and the linear relation between temperature and d.m. increase were determined heuristically for each species by fitting to the weight data from experiments 3, 4 and 5. The agreement between fitted and observed weights were generally close in all three species and the effects of density were well described (Figures 1, 2 and 3).

The model was then used to predict the weights for the mixed species stands in experiment 5. In this experiment, the stands consisted of 33 % 'original' carrots, 17 % transplanted carrots and 50 % mayweed or speedwell. At canopy closure, as the plant zone areas fill the space, we assume that the carrots and mayweed form a canopy of uniform height. Fixing the allometric

Figure 1. Fitted and observed weights of carrots in experiment 2.

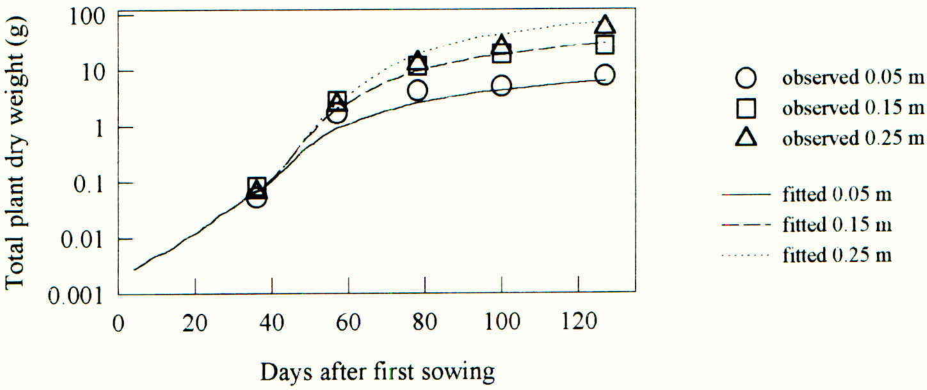


Figure 2. Fitted and observed weights of mayweed in Expt 3.

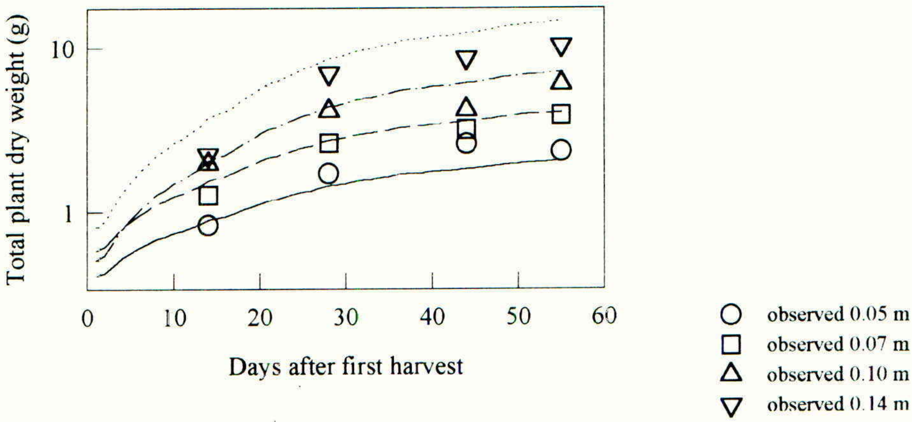


Figure 3. Fitted and observed weights of speedwell in Expt 3.

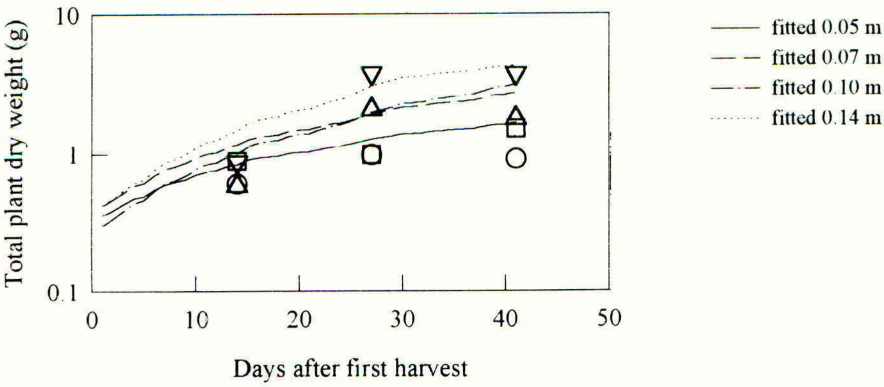
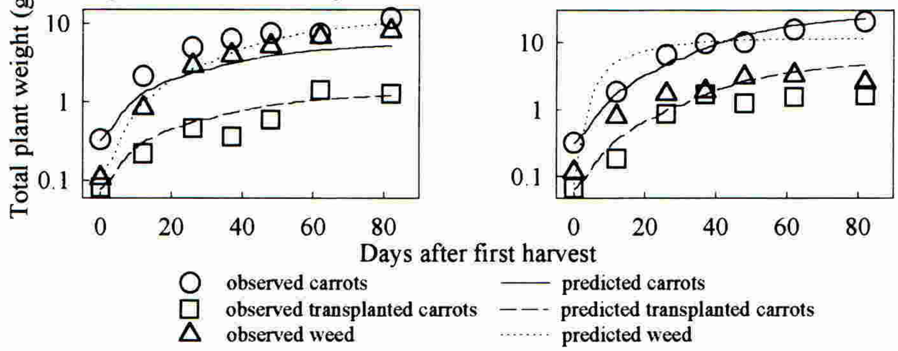


Figure 4. Predicted and observed weights of carrots and mayweed

Figure 5. Predicted and observed weights of carrots and speedwell



and growth parameters at the values determined for experiments 1, 2, 3 and 4 and using the weights observed at the first harvest as starting values, the subsequent growth of the carrots, and mayweed was predicted (Figure 4). The growth of the mayweed was accurately predicted, whereas the growth of the 'original' carrots was underestimated and that of the 'transplanted' carrots was overestimated.

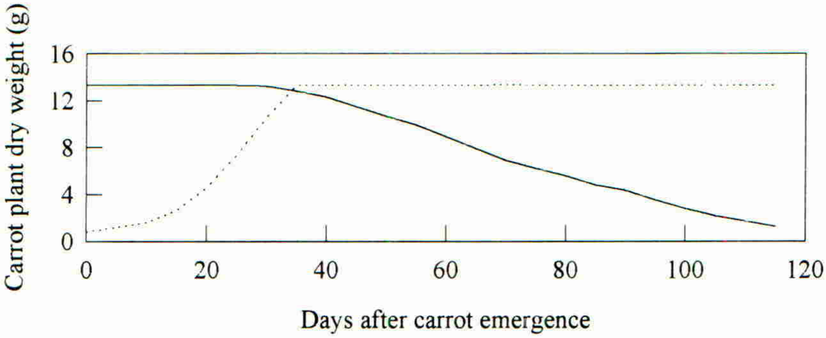
In the other combination, we assumed that the carrots formed an overstorey and the speedwell formed an understorey. This difference between mayweed and speedwell shoot canopies with respect to the carrots was observed in the plant stands. The growth of the carrots was accurately predicted, but the growth of the speedwell was overestimated (Figure 5). For speedwell, the observed and predicted growth virtually ceased about 20 days after the first harvest.

DISCUSSION

We have shown that a relatively simple dynamic mechanistically-based model, when fitted to monocrop data is able to predict the growth of both crop and weed in mixed species stands. Estimates of the parameter values for individual weed species are difficult to obtain because weeds, particularly speedwell, are difficult to establish reliably when grown in pure stands. More accurate predictions of growth in competition with carrots may be obtained when using more extensive data sets for this species have been obtained.

The model can be used to explore the effects of different weed control protocols on crop growth, allowing for different times of crop and weed seedling emergence, different crop and weed densities and varying climatic conditions. For example, the timing and duration of the 'critical period' for weeding can be predicted. Figure 6 shows the simulated plant weight of carrots after 125 d growth at 125 plants m^{-2} with mayweed at 656 plants m^{-2}. The solid line shows carrot weight when mayweed was simulated to emerge at the same time as the carrots and were removed at a given time after emergence. The dotted line shows carrot weight when mayweed was not allowed to emerge until a given time after emergence. Under the above conditions, the model predicts a critical period between 25 and 35 days after carrot emergence during which the crop must be kept free of weeds to prevent yield loss.

Figure 6. Critical period predicted by the competition model for carrot and mayweed



The model can has the potential to allow growers to evaluate different weed control measures under different cropping systems using estimates of likely weed populations from seed bank data.

ACKNOWLEDGEMENTS

We thank the Ministry of Agriculture, Fisheries and Food, UK for financial support, and L. Peach, A Hellemans, B. Auwalu and V. Tenebe for technical assistance.

REFERENCES

Aikman, D P; Benjamin L R (1994) A model for plant and crop growth, allowing for competition for light by the use of potential and restricted projected crown zone areas. *Annals of Botany*. **73**, 185-194.

Benjamin, L R; Aikman D P (1995) Predicting growth in stands of mixed species from that in individual species *Annals of Botany*. **76**, 31-42.

Cousens, R (1985) A simple model relating yield loss to weed density. *Annals of Applied Biology*. **107**, 239-252.

Cousens R; Brain P; O'Donovan J T; O'Sullivan P A (1987) The use of biologically realistic equations to describe the effects of weed density and relative time of emergence on crop yield. *Weed Science*. **35**, 720-725.

Doyle C J (1991) Mathematical models in weed management. *Crop Protection*. **10**, 432-444.

Kropff M J; Spitters C J T (1991) A simple model of crop loss by weed competition from early observations on relative leaf area of the weeds. *Weed Research*. **31**, 97-105.

Martin R J; Cullis B R; McNamara D W (1987) Prediction of wheat yield loss due to competition by wild oats (*Avena spp.*). *Australian Journal Agricultural Research*. **38**, 487-499.

Rejmanek M; Robinson G R; Rejmankova E (1989) Weed - crop competition: experimental designs and models for data analysis. *Weed Science*. **37**, 276-284.

Roush M L; Radosevich S R; Wagner R G; Maxwell B D; Petersen T D (1989) A comparison of methods for measuring effects of density and proportion in plant competition experiments. *Weed Science*. **37**, 268-275.

WEED INTERFERENCE IN AUTUMN-SOWN FIELD BEANS (*Vicia faba* L.)

R C VAN ACKER, P J W LUTMAN
IACR-Rothamsted, Harpenden, Herts, AL5 2JQ

R J FROUD-WILIAMS
Department of Agricultural Botany, School of Plant Sciences, University of Reading, 2 Earley Gate, Reading, RG6 2AU

ABSTRACT

Although field bean (*Vicia faba* L.) is becoming an increasingly popular crop in the U.K., relatively little research has been done on it's response to weed intereference. This is particulary true for the autumn-sown crop. Three experiments were conducted to investigate the influence of autumn-sown barley (*Hordeum vulgare*) and chickweed (*Stellaria media*), and spring-sown oats (*Avena sativa*) and white mustard (*Sinapis alba*), on the yield of autumn-sown field bean. Generally, field bean was resilient to weed interference and maximum yield loss was only 33%. The level of yield loss and the relationship between yield loss and weed density differed among weed species, and for barley, between years. These differences were related to weed phenology and weed dry weight. The results of these experiments suggest that significant expenditure on weed control would rarely be warranted in this crop.

INTRODUCTION

From 1981 to 1992, the area devoted to field bean in the UK rose from 45,000 ha to 130,000 ha. Despite this increase in popularity, relatively little research has been conducted on the effect of weed interference on the yield of field bean and in particular the autumn-sown crop. Autumn-sown beans have been reported to be resilient to weed competition (Knott, 1994) but this claim is relatively untested. Babalola and his colleagues (1991a, 1991b) found that the presence of barley at 200 plants m^{-2} caused a maximum yield loss of 50% in one experiment but only 23% in another. They also found that wild oats (Avena fatua) and chickweed, at densities of 200 plants m^{-2} caused yield losses of 18 and 23% respectively (Babalola *et al.*, 1993). Cook *et al.* (1991) reported no measurable yield loss on autumn-sown field bean, competing with a variety of natural weed populations containing both grass and broad-leaved weed species. From these experiments general conclusions cannot be drawn on weed competitiveness in this crop and more work needs to be done.

The purpose of this project was to investigate the resilience of autumn-sown field bean to interference from four weed species, barley (*Hordeum vulgare*), cultivated oats *(Avena sativa)* and mustard (Sinapis alba) which are erect and, chickweed (*Stellaria media)* which is prostrate. Barley and chickweed were sown in autumn and oats and mustard in spring, thus providing different competitive situations.

MATERIALS AND METHODS

A preliminary experiment was conducted with cultivated oats in autumn-sown field bean (cv. Punch) in 1991/92. Field bean was sown on 24 October, 1991 and the oats (cv. Dula) were sown on 4 March, 1992. Subsequently, field experiments were conducted, one each in 1992/93 and 1993/94. For the first of these, barley and chickweed were sown at the same time as the beans (31 October, 1992) and in the second, barley was sown at the same time as the beans (2 November, 1993) and mustard was sown on 23 February, 1994. For all experiments, weeds were sown randomly by hand at various rates designed to provide four final densities for each weed species (five for oats). Weed counts were done using 1 m^{-2} quadrats early in April of each year, to determine actual seedling densities in each 2.5 m X 10 m plot (Table 1).

Table 1. Target and mean actual weed densities (plants m^{-2}).

Experiment	Weed	Target Density	Weed	Target Density
1991/92	Oats	10 40 120 240 480		
		5 17 80 137 263		
1992/93	Barley	50 100 200 400	Chickweed	50 200 600 1200
		12 29 75 191		14 31 103 322
	Barley	50 100 200 400	Mustard	50 100 200 400
		7 31 77 172		13 34 66 130

In the 1992/93 and the 1993/94 experiments 1 m^2 quadrats were harvested, from each plot, at three or four dates, respectively. Species were separated and dry weights recorded. On the 10 September 1992, 1 September 1993 and 23 August 1994, the bean plants were harvested from 2 m^2 quadrats in each plot, threshed, and the seed cleaned, collected and dried with yields adjusted to 15% moisture content. For the 1992/93 and 1993/94 experiments the number of bean plants m^{-2}, stems per plant and pods per stem were counted, and 1000 seed weights determined.

Regression analysis was used to estimate the relationship between weed density and bean yield, and yield components. Data were fitted to either a simple linear model; $y = \alpha + \beta D$; where y = bean yield, α = weed free yield (y intercept), β = the slope of the line, D= density of weed species, or a general rectangular hyperbola model; $y = A + B/(1 + CD)$; where y = bean yield, A = asymptotic yield, B and C are additional parameters, D = density of weed species. For each data set the model used was that which accounted for the greatest percentage of the variance.

RESULTS AND DISCUSSION

In no case did the weed species cause a large yield loss in the autumn-sown beans (Figure 1), maximum yield loss being only 33%. The level of yield loss was dependent upon the weed species. Maximum yield loss due to oats interference was 33% at densities of up to approximately 300 plants m^{-2}. For barley, it was 14% and 33% in 1993 and 1994, respectively, at densities of up to approximately 200 plants m^{-2}, and with mustard it was 20% at densities up to 180 plants m^{-2}. There was, however, no discernible relationship between bean yield and chickweed density (the grand mean bean yield was 5.06 t ha^{-1}). For barley, the shape of the yield response differed between years. For the 1993 data a rectangular hyperbola appropriately described the response while for the 1994 data a simple linear regression was more suitable (Figure 1). For some data sets, (Figures 1 and 2) the percentage variance accounted for by the models was low. This was due not only to the variability of the data but also to the shallowness of some of the responses.

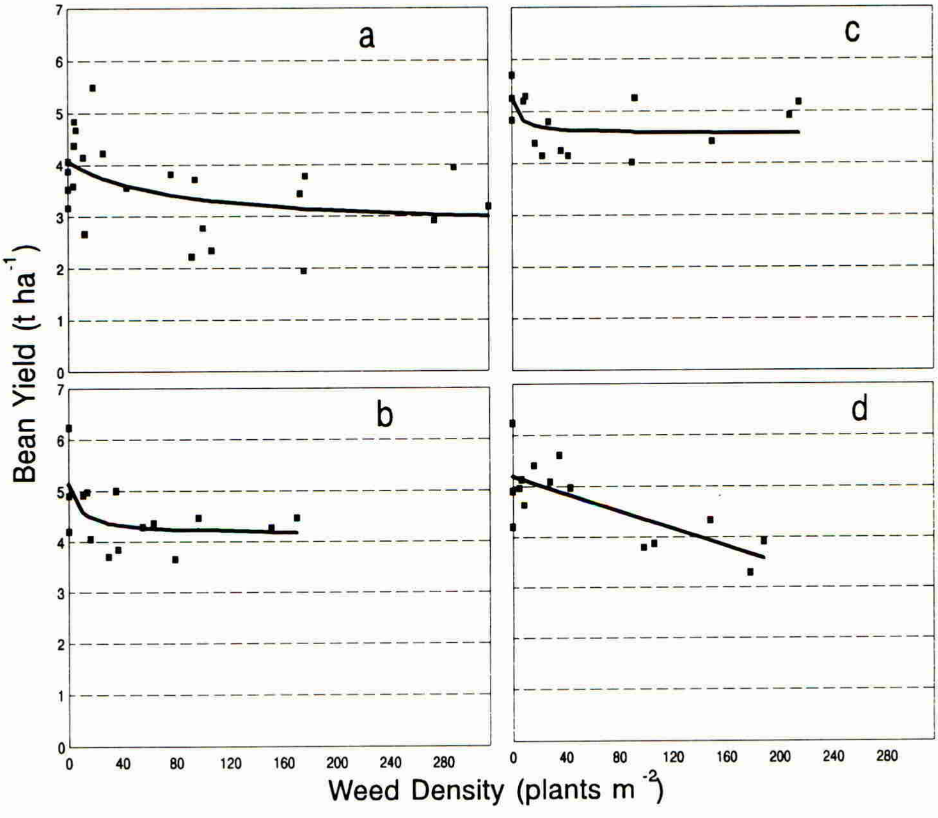


Figure 1. Influence of oats, mustard and barley on the yield of autumn-sown field bean. (a) oats, 1992, $y=2.73+1.345/(1+0.0129D)$,% variance accounted for (%VAF)=0.23, (b) mustard 1994, $y=4.13+1.01/(1+0.11D)$, %VAF=0.29. (c) barley 1993, $y=4.56+0.72/(1+0.19D)$,%VAF=0.26, (d) barley 1994, $y=5.19-0.0086D$,%VAF=0.54,

Bean dry weight differed markedly from dry weight of barley, chickweed or mustard both in terms of quantity and the rate of accumulation (Figure 2). Noting the logarithmic scale in Figure 2, bean dry weight was always much greater than the weed dry weight, particularly that of mustard and chickweed. Judging by the steepness of the lines in Figure 2 it appeared that in both 1993 and 1994 the dry weight accumulation rate of field bean, from mid-May to mid-July, was greater than that of any of the weed species. The rate of dry weight accumulation of braley and mustard decreased after mid-May, while for chickweed it decreased in early June due to senescence.

The level of bean yield loss due to competition from the three weed species can be related to their dry weights (Figure 2). Thus barley had the greater effect, followed by mustard and then chickweed. This ranking could also be related to the rate of dry weight accumulation where barley and mustard, continued to grow (and therefore compete) into summer, while chickweed began to senesce at a time when the beans were still accumulating dry weight at a steep rate.

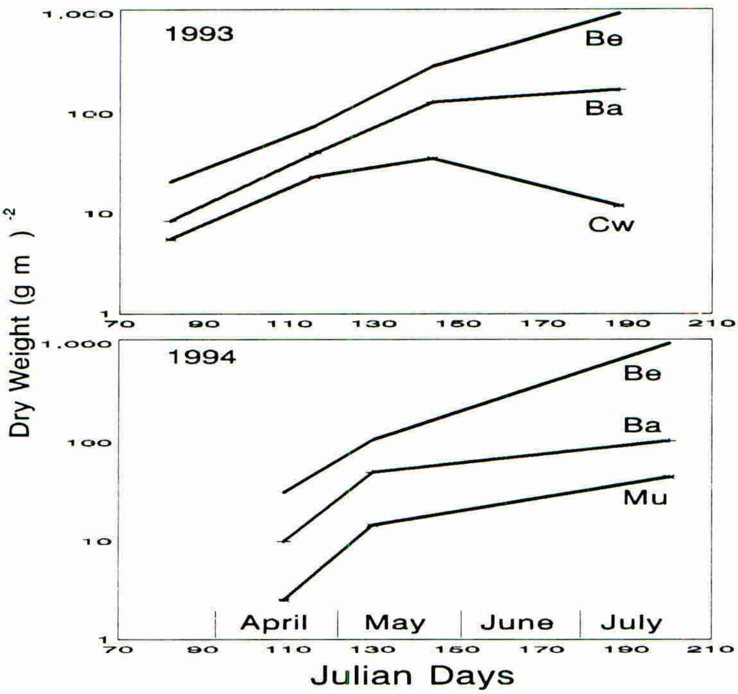


Figure 2. Dry weight of field bean (Be), barley (Ba), chickweed (Cw) and mustard (Mu), over time. Values are grand means of all treatments.

The yield components influenced by weed interference, differed between weed species, and between years for barley. In both 1993 and 1994, the presence of barley caused a measurable decrease in the number of bean stems m^{-2}. In 1994, barley interference also caused a decrease in numbers of bean seeds per pod. Similarly, mustard interference resulted in fewer bean seeds per pod, but had no effect on the number of bean stems m^{-2}. 1000 bean seed weight and numbers of pods per stem, were found to be uninfluenced by weed interference. The effect of barley and mustard interference on the number of bean seeds per pod is unusual since it is reported to be the most stable yield component of field bean and is usually only affected by stress during critical periods, such as full flower (Dantuma & Thompson, 1982). In 1994, the drought during this period (late June and early July) coupled with the stress of weed interference, may explain this result. The fact that the number of bean stems m^{-2} was influenced, in both years, by the presence of barley, suggests that the effect of barley on autumn-sown bean was concentrated early in the season. This coincides with the differences in relative dry weight accumulation rate between beans and barley, noted earlier, where the rate for barley begins to diminish before that for beans. Lutman & Dixon (1991) reported a similar phenomenon with volunteer barley in autumn-sown oilseed rape where reduction of barley growth rates, especially between May and early July, resulted in relatively little rape seed yield loss.

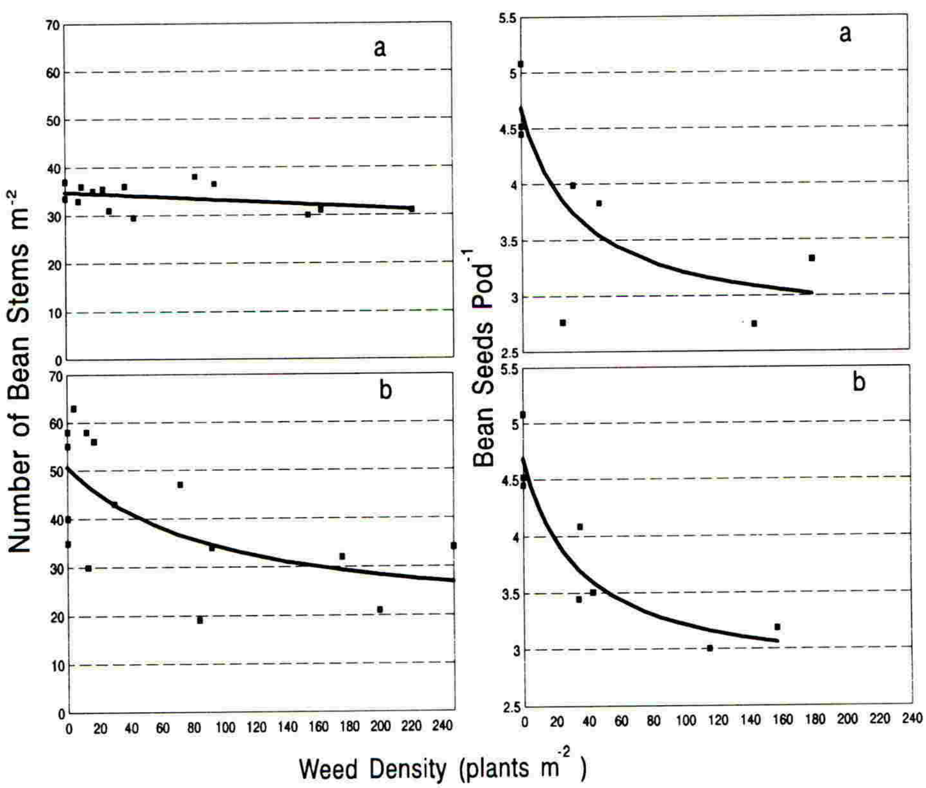


Figure 3. Influence of barley density (D) on the number of bean stems m^{-2}, (a) 1993, y= 34.7-0.017D, %VAF=0.18, (b) 1994, y=17.2+33.4/(1+0.01D), %VAF=0.41; and the influence of (a) barley, y=3.15+1.53/(1+0.15D), %VAF=0.69, and (b) mustard, y=2.69+2.0/(1+0.03D, %VAF=0.81, on number of bean seeds pod^{-1}.

It is surprising that greater yield losses were not achieved in these experiments. Barley at densities of 200 plants m^{-2} has been shown to cause up to 50% yield reductions in autumn-sown field bean (Babalola *et al.*, 1991) and chickweed, at similar densities was reported to cause yield losses ranging between 2% and 71% in autumn-sown oilseed rape (Bowerman *et al.*, 1994). As well, the presence of mustard, at 400 plants m^{-2}, has been found to completely prevent seed yield in spring wheat (Lotz, personal communication). A number of factors could have contributed to the lack of effect of weed interference on field bean yield. The most important of these is likely to be relative size of the crop to the weeds. Unusually cold and wet autumn weather at Rothamsted in 1992 and 1993 seemed to slow the growth of both barley and chickweed more than the beans, giving the beans a size advantage which continued in warmer spring conditions. The beans would have also had a size advantage over oats and mustard since both were spring-sown. It is probable that the difference in competitive effect of chickweed on oilseed rape and autumn-sown beans is due to sowing date, oilseed rape being planted in August/September when warmer and drier conditions allow chickweed to develop a sizeable and competitive canopy before winter.

These experiments offer some evidence that yields in autumn-sown field bean are little affected by the presence of appreciable infestations of weed species of different growth patterns. This is especially true when the weeds emerge after the beans, or under autumn weather conditions which favour the growth of the bean crop. These conclusions need confirmation through further testing, but they do indicate that significant expenditure on weed control in this crop will rarely be warranted.

REFERENCES

Babalola, A; Froud-Williams R J; Drennan D S H (1991a) Varietal competitiveness of autumn and spring-sown field beans (*Vicia faba* L.) with volunteer barley. *Brighton Crop Protection Conference-Weeds*, 635-636.

Babalola, A; Froud-Williams R J; Drennan D S H (1991b) Effects of volunteer barley competition on yield of autumn and spring-sown field beans. *Aspects of Applied Biology* **27**, *Production and Protection of Legumes*, 179-182.

Babalola, A; Froud-Williams R J; Drennan D S H (1993) Effects of time of weed emergence on competition in autumn-sown field beans (*Vicia faba* L.). *8th EWRS Symposium, Quantitative approaches in weed and herbicide research and their practical application, Braunschweig*, 49-54.

Bowerman, P; Lutman P J W; Palmer G M; Whytock G P (1994) Weed control requirements of oilseed rape under reformed CAP. *Aspects of Applied Biology* **40**, *Arable Farming Under CAP Reform*, 361-368.

Cook, S K; Bowerman P; Laverick R M (1991) Control of broad-leaved and grass weeds in winter beans. *Aspects of Applied Biology* **27**, *Production and Protection of Legumes*, 161-166.

Dantuma, G; Thomson R (1982) Whole-crop physiology and yield components. in The Faba Bean (Vicia faba L.), P.D. Hebblethwaite (ed.), Butterworths, London, pp. 143-158.

Knott, C M (1994) Weed control for peas and beans at world market prices. *Aspects of Applied Biology* **40**, *Arable Farming Under CAP*, 351-360.

Lutman, P J W; Dixon F L (1991) The competitive effects of volunteer barley (*Hordeum vulgare*) on the growth of oilseed rape (*Brassica napus*). *Annals of Applied Biology*, **117**, 633-644.

EFFECTS OF SEED CONDITION AND THE HERBICIDE METAZACHLOR ON THE GERMINATION AND ESTABLISHMENT OF SWEDE (*BRASSICA NAPUS*).

I J BINGHAM, J KAY, G P WHYTOCK
Department of Crop Biology, SAC, 581 King Street, Aberdeen AB9 1UD

ABSTRACT

Experiments were conducted on swedes to investigate the effects of seed condition on the sensitivity of germination and seedling growth to metazachlor. Low quality seed was produced by ageing seed artificially at elevated temperature and moisture content. Germination and early shoot growth were insensitive to high concentrations of metazachlor, but root growth was inhibited by concentrations as low as 10^{-9} M. Ageing seed reduced the rate and final percentage of germination, but had no effect on the sensitivity of germination or root growth to metazachlor. In pot experiments, sowing naturally-aged seed led to poor seedling establishment. Application of metazachlor also reduced establishment, but old and new seed were affected equally.

INTRODUCTION

Metazachlor is widely used in Scotland for the control of a range of broad-leaved weeds in Brassica crops, particularly oilseed rape, swedes and turnips. It is known to cause damage to crops of oilseed rape under certain conditions. The most serious damage can occur if the herbicide is applied as the seed is germinating (Stormonth & Woodroffe, 1982). For this reason the label recommendation is that pre-emergence applications be made within 48 h of sowing. In the case of winter oilseed rape metazachlor may also be applied early post-emergence (Anon., 1994). However, slower seedling growth and distorted foliage have been observed even when the herbicide is applied according to these timings (Lutman & Dixon, 1991, Bingham, unpublished results).

Cases of crop damage are not confined to oilseed rape. In recent years we have received reports from farmers that fields of swedes treated with metazachlor have resulted in poorly established or stunted crops. Many of these same farmers had either used old seed or complained of poor seed quality. This raises the question as to whether seed deterioration increases the susceptibility of swedes to herbicide damage. Pathways for the degradation of metazachlor in dicotyledonous species are not well documented, but in the *Graminae* conjugation to glutathione is a major route for metabolism of the chloroacetamide group of herbicides (Lamoureux *et al.*, 1991). Since ageing of seeds during storage can lower their reduced-glutathione content (de Vos, 1994), seedlings emerging from deteriorated seed may be less able to detoxify metazachlor. In this paper we report the results of a series of laboratory and glasshouse experiments whose objective was to investigate the effects of seed ageing on the tolerance of swede (*Brassica napus*) to metazachlor during germination and early seedling growth.

MATERIALS AND METHODS

Germination and growth experiments were conducted on swede seeds (cv. Doon Major) supplied untreated by Sharpes International, Sleaford UK. Seed lots were aged artificially by storing at 45°C and 20% moisture content for 36 h (Matthews & Powell, 1981). Control seeds were unaged. After ageing, seeds were imbibed and germinated in Petri-dishes containing germination paper (Papierfabriek Schut) soaked with 3.5 ml of metazachlor solution at concentrations ranging from 10^{-2} to 10^{-9} M depending on the experiment. These concentrations were achieved by serial dilution of metazachlor ('Butisan S'; 500 g l^{-1} SC; BASF plc) in water. Replicate dishes of 25 seeds were covered in polythene and placed in the dark at 25 $\pm$ 1°C . Dishes were inspected at 12 h intervals to assess germination and the lengths of roots and shoots were measured to the nearest mm at the end of the experiment.

For experiments on seedling establishment, two seed lots (cv. Doon Major) were obtained from a local merchant (N & F Allan, Aberdeen); one lot was new seed produced the same season, the other was old seed that had been stored for 4 years. Both lots were supplied coated with a gamma-HCH + thiram ('Hydraguard'; 615:230 g l^{-1} FS; Agrichem) and iprodione ('Rovral WP' 500 g kg^{-1} WP; RP Agriculture) polymer seed treatment. Seeds were sown in 1.5 litre pots containing sandy loam soil. Prior to sowing, the soil was watered to field capacity. Sixteen seeds were sown per pot to a depth of 15 mm and 24 h later metazachlor was applied to half the pots using a small volume, hand-held mister which delivered the herbicide in a fine spray at an equivalent rate of 0.75 kg ai ha^{-1} in 450 l ha^{-1} of water. The remaining pots received water. Pots were arranged in a randomized block design in an unheated glasshouse. Water loss was monitored by weighing the pots daily and losses replaced by watering the soil surface with the required volume. At the same time, counts of seedling emergence were made .

RESULTS

Germination was recorded as protrusion of the radicle through the testa. For unaged seed lots imbibed in water, germination commenced 24-36 h after imbibition (data not shown). The final germination after 96 h was 98% and of those seeds capable of germination, 50% did so within 32 h (Table 1). Time to 50% germination is a measure of the rate of germination. Thus on the basis of its high rate and final percentage germination, this seed lot can be regarded as being of high vigour. Incubation in metazachlor had no effect on any of these germination parameters up to a concentration of 10^{-3} M. At 10^{-2} M the rate and final percentage germination was reduced marginally (Table 1). Similarly, metazachlor had no appreciable effect on the emergence of cotyledons from the testa up to 10^{-3} M, but at 10^{-2} M the rate of emergence was decreased and the final percentage emergence reduced by nearly a half.

Insensitivity to metazachlor was also observed in measurements of shoot extension. Shoot length 96 h after imbibition was reduced significantly ($P \leq 0.05$) only at concentrations greater than 10^{-3} M (Fig. 1). In contrast, root extension was extremely sensitive to the herbicide, with a 76% reduction in root length occurring at concentrations of 10^{-7} M.

Table 1. Effects of metazachlor on germination (radicle protrusion) and emergence of the cotyledon from unaged seed 96 h after imbibition. Values are means of two replicates of 25 seeds $\pm$ SE.

	Germination		Cotyledon emergence	
Conc. (M)	Time to 50% germ. (h)	Final germination (%)	Time to 50% emerg. (h)	Final emergence (%)
0	32 ± 0.4	98 ± 1.4	66 ± 1.1	98 ± 1.4
10^{-7}	31 ± 0.2	98 ± 1.4	68 ± 1.5	98 ± 1.4
10^{-6}	32 ± 0.4	100 ± 0	70 ± 1.0	94 ± 1.4
10^{-5}	32 ± 0.8	98 ± 1.4	70 ± 1.0	94 ± 1.4
10^{-4}	33 ± 0.8	98 ± 2.8	71 ± 1.5	96 ± 2.8
10^{-3}	33 ± 0.8	98 ± 1.4	72 ± 1.6	92 ± 0
10^{-2}	36 ± 0.2	96 ± 0	88 ± 1.4	54 ± 1.4

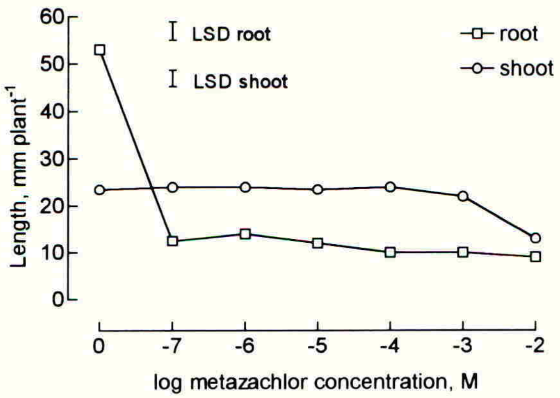


Figure 1. Effects of metazachlor on the length of roots and shoots measured 96 h after imbibition . Values are means of 75 plants. LSD bars are for herbicide concentration P=0.05.

Artificial ageing of seed reduced the final germination by 12% and the rate of germination by nearly a half (Table 2). Similarly, the rate and final percentage of cotyledon emergence was also reduced (data not shown). However, ageing appeared to have no effect on the sensitivity of germination to metazachlor at concentrations of less than 10^{-3} M (Table 2).

The lower range of concentrations used in these later experiments allowed a more complete analysis of the dose-response relationship of metazachlor and root growth to be conducted. (Fig. 2a). Here root length was measured 168 h after imbibition. Fig. 2a illustrates that some inhibition of root extension occurred at concentrations as low as 10^{-9} M. EC_{50} values

Table 2. Effects of metazachlor and seed ageing on germination (radicle protrusion) measured 168 h after imbibition. Values are means of three replicates of 25 seeds $\pm$ SE.

	Unaged		Aged	
Conc. (M)	Time to 50% germ. (h)	Final germ. (%)	Time to 50% germ. (h)	Final germ. (%)
0	34 ± 0.4	100 ± 0	59 ± 0.7	88 ± 4.0
10^{-9}	31 ± 0.1	100 ± 0	56 ± 0.6	92 ± 4.1
10^{-8}	31 ± 0.7	99 ± 1.9	56 ± 0.5	87 ± 3.3
10^{-7}	32 ± 0.3	97 ± 1.9	58 ± 1.7	92 ± 1.9
10^{-6}	33 ± 0.7	97 ± 1.9	61 ± 1.4	88 ± 4.6
10^{-5}	36 ± 1.3	96 ± 3.3	58 ± 0.9	88 ± 4.1
10^{-4}	36 ± 1.8	100 ± 0	58 ± 1.1	91 ± 3.5
10^{-3}	39 ± 0.3	100 ± 0	60 ± 0.8	89 ± 4.1

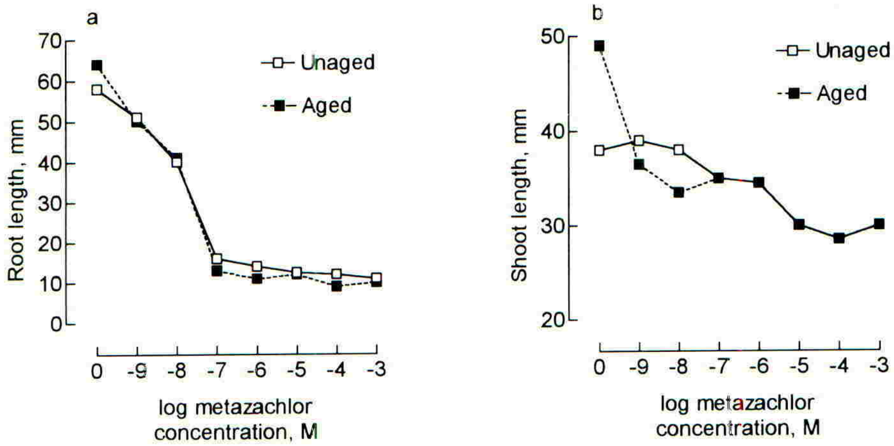


Figure 2. Effects of metazachlor on a) root length and b) shoot length of aged and unaged seed 168 h after imbibition. Values are means of 75 plants. SE omitted for clarity.

(concentration required to give 50% of maximum inhibition) were derived from sigmoidal dose-response curves fitted to the data. Seed ageing had no significant effect on the sensitivity of root growth to metazachlor, with the EC_{50} for aged seed being almost identical to that of unaged (1.17×10^{-8} M and 1.53×10^{-8} M respectively).

The length of the shoot 168 h after imbibition is shown in Fig. 2b. With the exception of lots imbibed in deionised water, the response of aged and unaged seed to metazachlor was comparable with some reduction in length occurring at concentrations of 10^{-8} or 10^{-7} M. Interpretation of these curves is difficult because of the rather surprising increase in length of shoots from aged seed compared to unaged in the absence of herbicide. If this represents a real increase, then it would appear from Fig. 2b that ageing increased the sensitivity of shoot growth to metazachlor. However, if the value is uncharacteristic of the population as a whole, then, since the remainder of the curve is comparable for aged and unaged seed, there may be little or no change in sensitivity.

When sown in soil, old seed that had aged naturally produced seedlings which emerged at a slower rate and resulted in a poorer final establishment than new seed lots (Fig. 3). In each case, application of metazachlor at rates equivalent to the recommended field rate reduced the final percentage seedling emergence. Analysis of variance on the final sample data indicated that the effects of seed lot and herbicide application were significant at $P \leq 0.05$, but there was no significant interaction between the two. Thus, metazachlor reduced establishment from both new and old seed lots equally.

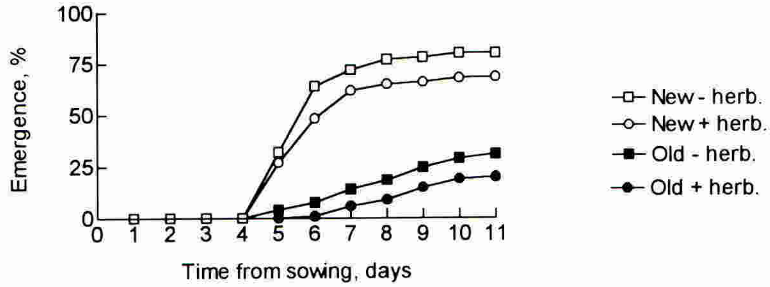


Figure 3. Effects of seed age on the emergence of seedlings from the soil with and without application of metazachlor. Values are means of eight replicate pots, each with 16 seeds.

DISCUSSION

Germination of swede seed is remarkably insensitive to metazachlor. Concentrations greater than 10^{-3} M were required to reduce the rate and extent of germination (Table 1). It is extremely unlikely that seed in the soil would ever experience concentrations of this magnitude. At recommended rates of application the concentration in the spray tank would range from 6×10^{-3} to 1.2×10^{-2} M ai. After further dilution by soil water and adsorption onto organic matter, concentrations in soil solution would be considerably lower. In contrast, post-germination root growth is extremely sensitive to metazachlor (Fig. 2a). These results suggest that tolerance of swede to metazachlor in the field results largely from depth-protection of the roots and that, unlike other species such as soyabean and maize (Lamoureux *et al.*, 1991), the contribution from metabolism of the herbicide may be minimal, at least at this early growth stage. The results are consistent with the herbicide label recommendation to avoid application to Brassica crops during germination (Anon., 1994) as this is a time when the primary root may come into contact with concentrated herbicide prior to its dispersal by soil water.

Up to 96 h after imbibition when shoots were in contact with the herbicide, there was no inhibition of shoot growth by concentrations less than 10^{-3} M, which suggests that there may have been little direct uptake by shoot tissue, as reported for other species (Stormonth & Woodroffe, 1982). Between 96 and 168 h after imbibition, shoots had grown away from the germination paper and were no longer in direct contact with the herbicide. The apparent increase in sensitivity of shoot growth to herbicide over this time (cf. Fig. 1 & Fig. 2b) probably results from a slow translocation of metazachlor from the roots and a gradual accumulation in the shoot during this period.

One of the primary objectives of crop husbandry is the rapid and uniform establishment of crops. Poor establishment can lead to greater susceptibility to pests and diseases and, in some types of crop, irregular sized produce and lower final yield (Matthews & Powell, 1986). Thus, any factor that reduces or delays establishment is undesirable. In the present work, both low seed quality and metazachlor application reduced establishment (Fig. 3), but appeared to operate in different ways. Ageing (natural or artificial) of seed during storage can reduce the rate and final percentage seedling establishment through its effects on germination and early post-germination mortality (Matthews & Powell, 1986). There was no effect of ageing on root extension in swede under laboratory germination conditions (Fig. 2a). In contrast, metazachlor must have reduced establishment through its effects on root growth since germination and early shoot growth were insensitive to the herbicide. Although there was no evidence of any significant influence of seed ageing on the inherent tolerance of swede to metazachlor (Table 2, Fig.2), our results suggest that where metazachlor is used in conjunction with poor quality seed, their independent effects could combine to produce an unacceptable level of crop establishment.

ACKNOWLEDGEMENTS

SAC receives financial support from the Scottish Office Agriculture and Fisheries Department.

REFERENCES

Anon. (1994) Product manual. BASF Agriculture Division.

de Vos, C H R (1994) Thiol oxidation in ageing tomato seeds. In: *Technological Advances in Variety and Seed Research. Book of Abstracts, ISTA/ISHS Symposium*, W J van der Burg & R J Rino (eds), The Netherlands: Wageningen Academic Press, pp. 8.

Lamoureux, G L; Shimabukuro, R H; Frear, D S (1991) Glutathione and glucoside conjugation in herbicide selectivity. In: *Herbicide Resistance in Weeds and Crops*, J C Caseley; G W Cussans; R K Atkin (eds), Oxford: Butterworth-Heinemann Ltd, pp. 227-261.

Lutman, P J W; Dixon, F L (1991) Herbicide tolerance in winter oilseed rape. *Proceedings 1991 Brighton Crop Protection Conference - Weeds*, 195-202.

Matthews, S; Powell, A A (1981) Controlled deterioration test. In: *Handbook of Vigour Test*, D A Perry (ed), Zurich: International Seed Testing Association, pp. 49-56.

Matthews, S; Powell, A A (1986) Environmental and physiological constraints on field performance of seeds. *HortScience*. **21 (5)**, 1125-1128.

Stormonth, D A; Woodroffe, R (1982) The use of metazachlor for the control of weeds in winter oilseed rape. *Proceedings 1982 British Crop Protection Conference - Weeds*, 103-108.

AN ECONOMIC COMPARISON OF CHEMICAL AND LOWER-CHEMICAL INPUT TECHNIQUES FOR WEED CONTROL IN VEGETABLES.

C A EDWARDS, W D SHUSTER, M F HUELSMAN AND E N YARDIM
Environmental Science Program, The Ohio State University, 1735 Neil Avenue, Columbus, Ohio 43210, U.S.A.

ABSTRACT

Since 1990, we have organized a Demonstration Farm, which has made an economic comparison of three minifarm systems of vegetable and small fruit production: (i) conventional chemical, weed, pest, and disease control, with chemical fertility input, system; (ii) integrated lower chemical input system; (iii) organic system with no chemical inputs. Interactions between inputs, e.g. the effects of weed incidence on level of disease and arthropod pest attack are also recorded.

This paper reports an economic comparison of: (i) recommended rates of herbicide use (bensulide, naptalam, trifluralin, and paraquat dichloride) with two alternative methods of non-chemical weed control in tomatoes, peppers, and cucumbers. These are: (ii) use of a cut/blown mulch method of weed control, and (iii) maintaining weeds below threshold levels by minimal cultivation. All chemical, labour, and other inputs were recorded to enable the economic performance of the three systems to be assessed and reported. The mulch system performed best with peppers and tomatoes; there was little difference between the herbicide and threshold cultivation systems.

INTRODUCTION

There is an increasing need for methods of weed control that require lower inputs of herbicides, because these chemicals are relatively expensive, can have environmental side effects on other organisms (Edwards, 1993) and often move into ground water, (Edwards et al., 1992). Many biological and cultural methods of weed control have been tested, and adopted in recent years, as complements to chemical control. Of these techniques, cultivations have long been a traditional method of weed control (Edwards and Regnier; 1989) and are now being used increasingly to minimize herbicide use. The use of living or chopped plant mulches for weed control, has had considerable success in recent years (Madden, 1995). Progressively, the principle of using competitive weed thresholds, in order to assess the number and timing of herbicide application or cultivations, has become increasingly widely-adopted (Oliver, 1988). Such practices have become important components of integrated weed management, as complements to herbicides, in recent years (Gogerty, 1995).

However, although there have been many studies of chemical and non-chemical methods of weed control, and a progressive adoption of these practices into integrated weed management programs, there have been relatively few detailed economic comparisons between conventional and integrated lower chemical input weed management systems. An exception to this was a study by Lybecker et al.(1988) who made comparisons of the economic performance of four weed management systems in a corn, bean, and sugarbeet rotation. They concluded that the intensive use of herbicides, had a much lower risk efficiency than the lower chemical input systems they tested. Temple et al. (1994) compared low-input and organic farming systems, emphasizing weed management, in processing tomatoes, safflower, corn and beans, with tomatoes as the main cash crop. Their results were very variable, but indicated that the lower input systems performed much better after a suitable transition period. Lanini and Le Strange (1991) studied the low-input management of weeds in vegetable fields, including bell peppers and cucumbers, and emphasized the importance of timeliness in weed control by cultivations.

The project described here was part of the program of a university/state government Demonstration Farm which compared the overall economic performance of conventional chemical input, integrated lower chemical input and organic systems of production of arable, fruit and vegetable crops, from 1990 to date. Such detailed economic studies are rare; the first began in 1978 in Germany (El Titi and Landes, 1988) and is still continuing. There are not many other projects, that address in detail, the economic issues of weed management in the context of farming systems.

MATERIALS AND METHODS

This project was part of a larger experiment in 1994 which used a replicated, Latin square design to compare the effects of various weed control methods and fertility inputs on insect populations and disease incidence. In this paper, we discuss the effects of four weed control strategies on the overall economic performance of processing tomatoes (*Lycopersicon eculentum*), cucumbers (*Cucumis sativus*) and peppers (*Capsicum annuum*).

Plots measured 4.5m x 4.5m with four replicates per treatment. Raised beds were used in production of all three crops. Tomatoes and peppers were planted in rows with 37 cm row spacings, and cucumbers were seeded, and thinned subsequently to one plant every 0.9 m, with a 1.5 m bed spacing.

Fertilizer applications were based on spring soil test results, with fertility applied broadcast in a split application, with the remaining nitrogen sidedressed at flowering. No insecticides or fungicides were applied, since insect and disease populations that resulted from fertility or weed control treatments were studied in the larger context of this experiment.

Treatments

1. Control - The control plots function as a check; no weed control measures were used in these plots.

2. Herbicide-treated - Pre-plant herbicides were applied as follows: tomatoes (trifluralin, 0.9 kg a.i./ha), cucumbers (naptalam 2.4 kg a.i./ha and bensulide 7.2 kg a.i./ha), peppers (trifluralin, 0.9 kg a.i./ha). Paraquat dichloride(0.56 kg ai/ha) was applied for post-emergent control in all plots. All sprays were applied using a Durand Wayland W100 boom sprayer at 3.1×10^5 Pa with Tee Jet 8002 flat fan spray tips giving 280 l/ha.

3. Mulch treatment - These plots were treated with a cut ryegrass mulch; the mulch was sown the preceding fall, cut with a forage blower and raked from a wagon onto the mulch plots and spread betweeen the plants rows. The mulch was initially applied at a thickness of 15cm (and reapplied as required through the season) to maintain 100% soil cover.

4. Threshold Cultivation treatment - The threshold cultivation plots were maintained by cultivating all weeds, within 20cm of each plant, whenever a threshold treatment level of weed populations had been reached. Threshold levels were assessed visually and varied with the weed species present and the stage of growth of the crop, i.e. 0-1 highly competitive weeds e.g. Canadian Thistle (*Cirsium arvense*) were tolerated per row early in the season and 3-4 later in the season. Although hand-hoeing was used to avoid disturbing pest entrapment apparatus, a custom built tool bar fitted with Bezzerides Bros. (Orosi, CA, USA) small crop cultivation tools was used to develop accurate production-scale cultivation costs; this cultivator was used several times to check that it was equally as effective as hand-hoeing.

Economic Analyses

Whole plots were harvested, graded and weighed to obtain marketable yields. The *economic analysis* of this experiment was based on a comprehensive list of fixed and variable costs. Variable costs, including costs of fertilizers, seed, transplants, pesticides (where applicable), interest on operating capital and hoeing labour, were recorded. Fixed costs associated with mulch production, spraying, seedbed preparation, planting/transplanting, cultivation, land rental, management, general maintenance and irrigation were estimated from current and previous farm records and production budgets, to determine the most appropriate costing for each implement or activity. Labour was calculated on the basis of a $6.50 hourly wage; labour involved in harvesting and marketing was calculated as a flat-rate commission based on crop yield.

Operating costs associated with equipment were added in on a "per use" basis.All equipment and other durable items were depreciated over reasonable life expectancies. The cost of equipment used was based on a farm size of 32 ha. The market value of the crops and yield data were used to calculate returns on investment; market values were estimated from Ohio state averages based on budgets prepared by Ohio State University Farm Management Extension. When compared with other economic comparisons, some variation in values placed on equipment, labor and market value must be expected. All values were entered on to QuattroPro (ver. 5.0) spreadsheet software. Fixed and variable costs were summed and subtracted from receipts to yield a profit or loss for each treatment. Graphs were derived from these data.

RESULTS

The costs, returns and profit (losses) are summarized for tomatoes in Figure 1, for peppers in Figure 2 and for cucumbers in Figure 3. The yields obtained for each of the crops studied are given in Table 1. The yields for cucumber were abnormally low due to the lack of control of cucumber beetles who transmit the vascular wilt virus.

Figure 1. Comparison of costs, returns and profits for tomatoes: control (CONTRL), herbicide-treated (HERB), mulch-treated (MULCH) and threshold cultivations(THRESH).

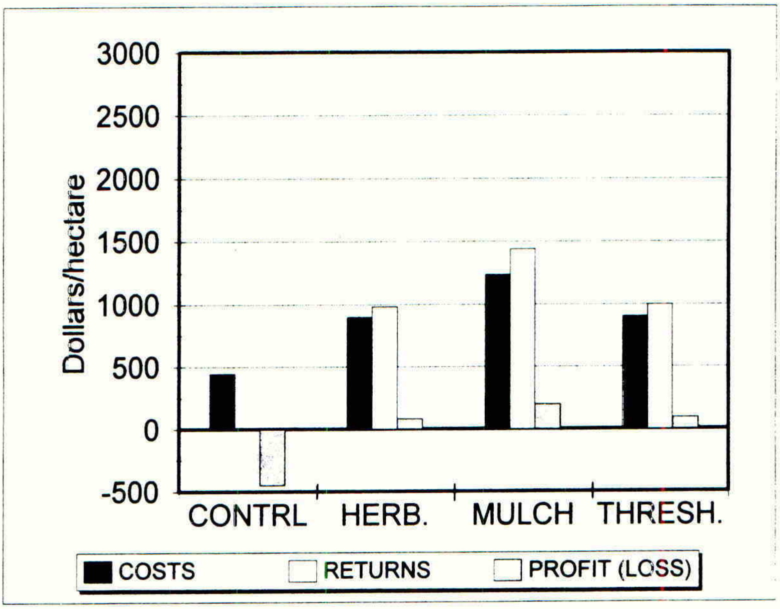


Figure 2. Comparison of costs, returns and profit for peppers: control (CONTRL), herbicide-treated (HERB), mulch-treated (MULCH) and threshold cultivations (THRESH).

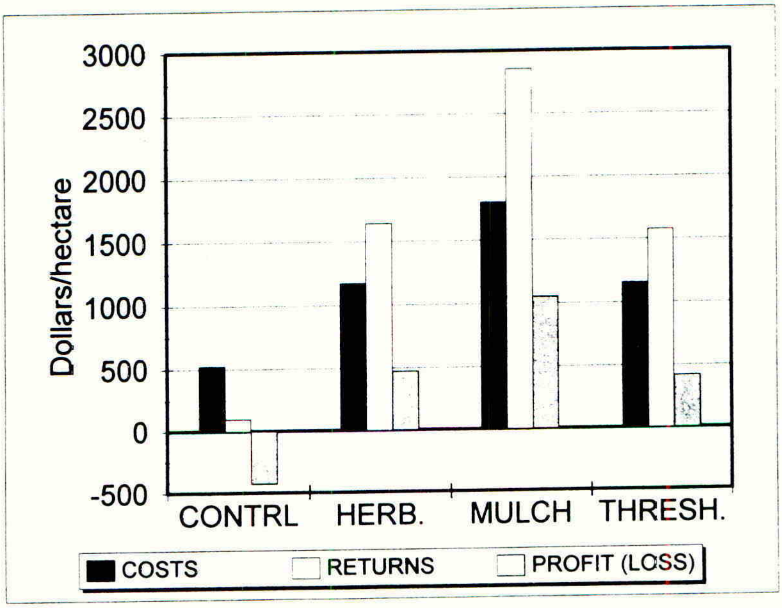


Figure 3. Comparison of costs, returns and profits for cucumbers: control (CONTRL), herbicide-treated (HERB), mulch-treated (MULCH) and threshold cultivations (THRESH).

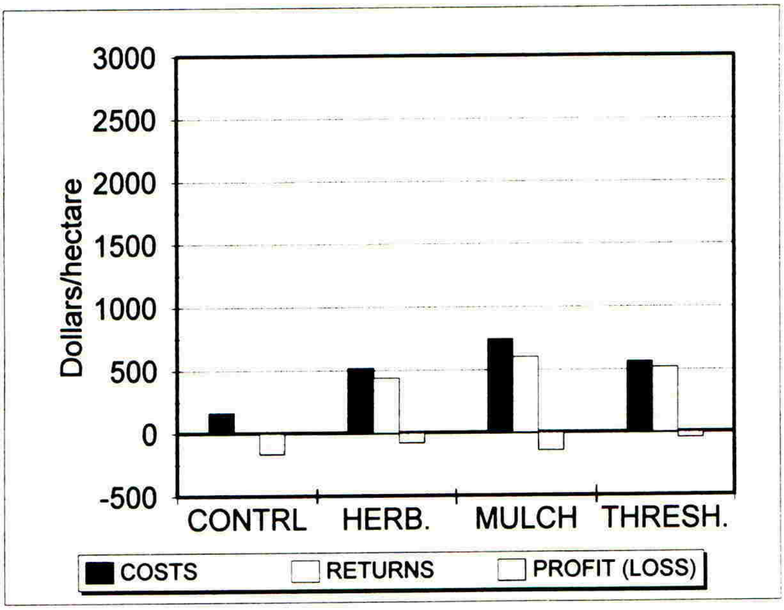


Table 4. Comparison of yields for cucumbers, peppers and tomatoes by treatment

	CUCUMBER(T/ha)	PEPPER(bu/ha)	TOMATO(T/ha)
CNTRL	0.0	12.7	0.0
HERB	2.6	219.1	15.1
MULCH	3.4	380.9	22.1
THRESH	3.0	210.5	15.3

DISCUSSION

The experiment on which this economic study was based used various weed control strategies. Monitoring economic and pest (weed, insect, disease) parameters provides the opportunity for a truly integrated study of the economics of alternative farming systems. For weed management treatments, an evaluation of inputs and returns on investment can help to clarify their relative benefits to farmers. When linked with data on pest and disease incidence, the merits of each weed control treatment can be assessed further to indicate whether the most economically sound treatment may also provide even greater side benefits in pest and disease control. For example, a mulch system of weed control enhances pest predator activity and retains soil moisture.

The overall economic performance of the three vegetables in 1994 differed greatly; peppers were most profitable, followed by tomatoes; cucumbers resulted in a financial loss for all treatments. The untreated plots (CNTRL) resulted in financial losses for all three vegetables. The most expensive weed management system for all three vegetables, was the use of mulch, followed by herbicide use, with threshold cultivation costing least. However, when financial returns were also considered, the mulch system proved to be the most profitable for peppers and tomatoes. Newer technologies in mulch production and use may decrease costs per acre and encourage adoption in larger operations that depend on economy-of-scale operating budgets. There was little difference in profitability between the herbicide and threshold treatments. No conclusions were made on cucumbers since all three treatments cost more than the financial returns for the crops in the 1994 season.

The data presented demonstrate the need for financial analyses in choosing the best weed management strategy. The lack of published data to enable such choices to be made means more economically-based, integrated studies on farming systems management are needed.

REFERENCES

Edwards, C A (1993) Effects of herbicides on soil and surface-inhabiting invertebrates. *Proceedings Brighton Crop Protection Conference-Weeds*, 1993, **3B-3**, 133-138.

Edwards, C A; Edwards, W M; Shipitalo, M J (1992) Earthworm populations under conservation tillage and their effects on transport of pesticides into groundwater. *Proceedings Brighton Crop Protection Conference-Pest and Diseases* **7C-16**, 859-864.

Edwards,C.A; Regnier, E.E. (1989) Designing integrated low-input farming systems to achieve effective weed control. *Proceedings Brighton Crop Protection Conference-Weeds* **6A-7**, 585-590

El Titi A; Landes H (1988) Integrated Farming System of Lautenbach: A Practical Contribution toward Sustainable Agriculture in Europe. In: *Sustainable Agricultural Systems*. C A Edwards, R Lal, P Madden, R H Miller and G House (eds) Soil and Water Conservation Society, Ankeny, Iowa. 265-286.

Gogerty, R (1995) Integrated Weed Management: Coming of Age. *The Furrow*, **May 1995**, 10-13.

Lanini, W T; Le Strange, M (1991) Low-input management of weeds in vegetable fields. *California Agriculture*. **45 (1)**, 11-13.

Lybecker, D W; Schweizer, E E; King, R P (1988) Economic analysis of four weed management systems. *Weed Science*. **36 (6)**, 846-849.

Madden, P (1995) Low Input Tomatoes at A.R.S.. *Report of World Sustainable Agriculture Association*. **4(16)**. 5.

Oliver, L R (1988) Principles of Weed Threshold Research. *Weed Technology*. **2**, 398-403.

Temple, S R; Somasco, O A; Kirk. M; Friedman, D (1994) Conventional, low-input and organic farming systems compared. *California Agriculture*. **48 (5)**, 14-19.

AN ECONOMIC ASSESSMENT OF MULCHES IN FIELD SCALE VEGETABLE CROPS

S R RUNHAM, S J TOWN
ADAS Arthur Rickwood, Mepal, Ely, Cambs CB6 2BA

ABSTRACT

Herbicide availability is increasingly limited in many vegetable crops, with a continual tightening of restrictions on usage. There is interest from the industry in alternative methods of weed control such as the use of mulches (plastic, paper and straw). Mulches could become adopted more widely as a part of an "Integrated Crop Management System" encouraged by some buyers of horticultural produce. Recent MAFF-funded research and private research has shown that mulches can be very effective at suppressing weeds without reducing crop vigour by chemical damage. Mulches incur extra costs either for the material itself or for their application which can be partially recouped in high value vegetables but a premium for the produce may be required.

INTRODUCTION

The past fifteen years has seen an increase in the area of plastic covers and mulches used for the production of horticultural crops. There is a wide range of materials used for mulching such as plastic, paper and straw (Bradley, 1992). Other materials such as living plants, including grass strips, and plant debris other than straw have been evaluated particularly in organic systems of crop production (Millington *et al.*, 1990; Marks, 1993). Mulches may be used for soil moisture conservation, to prevent soil erosion, for crop cleanliness, for soil warming to advance crop earliness and for weed control. This latter role is the focus of this paper although the economic viability of using mulches is affected by all of these potential benefits.

As the costs of developing novel herbicide products increase, or re-registration is not sought for older products, the range of herbicides available to the vegetable grower will diminish (Davies *et al.*, 1993). There is interest in developing systems of food crop production which require little or no herbicides to complement integrated pest management systems of production; these aim to reduce agrochemical use by giving priority to non-chemical methods of pest and disease control. This paper describes a series of experiments carried out in 1991-1994 as part of a research programme on the use of mulches in 'reduced input' systems of vegetable production. The mulches were evaluated on high value vegetables, worth up to £10,000/ha, which are more likely to justify the extra cost of a mulch. These data are discussed in relation to the economic viability of using different types of mulch on a range of vegetable crops.

MATERIALS AND METHODS

The experiments were done at ADAS Arthur Rickwood on a loamy peat soil with 35% organic matter content. Chinese cabbage was grown in 1991 to 1993 and calabrese in 1994.

Trial A. Chinese cabbage in 1991 to 1993

Seeds of chinese cabbage cv. Kasumi were sown into cellular plastic trays on 11 June 1991, 4 June 1992 or 9 June 1993 and were transplanted by hand on 8 July 1991, 3 July 1992 or 30 July 1993 into 1.7 m (1991 and 1992) or 1.8 m (1993) wide beds (approximately 1.3 m inside tractor wheelings) with four rows at 30 cm apart. All plots had 18 plants along the row.

A range of weed control treatments was applied as follows:

(i) Unweeded (1992 and 1993),
(ii) Hand-weeded,
(iii) Standard herbicide regime consisting of two sprays on separate days (one only in 1993) of paraquat (Gramoxone 100, 200 g/l, ICI) at 600 g a.i./ha on 4 July 1991 or 24 June 1992 and propachlor (Ramrod Flo, 480 g/l, Monsanto) at 6.24 kg a.i./ha on 15 July 1991, 10 July 1992 or 23 August 1993,
(iv) Black polythene (38 micron),
(v) Black non-woven film (Agryl P50 weighing 50 g/m²),
(vi) Paper (Hortopaper in 1992 and a creped paper from Patria Paper Co, Austria, in 1993),
(vii) Straw (10 cm depth) in 1992 only.

The crops were harvested when mature, with a firm head weighing over 600 g, from 19-30 August in 1991, 17-30 August in 1992 and 3-8 September in 1993. The data are presented as means of two in-row spacings (30 and 40cm), giving 8 (7 in 1993) or 6 plants/m².

Trial B. Calabrese in 1994

Seeds of calabrese cv. Greenbelt were sown into cellular plastic trays on 11 July 1994 and transplanted by hand on 8 August 1994 with three rows per 1.8 m bed at 50 cm, with 46 cm within the row (4 plants/m²). The weed control treatments comprised:

(i) Unweeded,
(ii) Hand-weeded,
(iii) Standard herbicide regime which was propachlor (Ramrod Flo, 480 g/l, Monsanto) at 6.24 kg a.i./ha on 15 August 1994 and aziprotryne (Brasoran, 500 g/l, Ciba Agric) at 2.25 kg a.i./ha on 23 August 1994,
(iv) Paper mulch (novel product, not commercially available).

Calabrese crowns (>100mm in diameter) were harvested on 21 and 28 November 1994.

All of the herbicides were applied in 250 l/ha water using an Oxford Precision sprayer with F11002 nozzles and operated at 200 kPa pressure. All trial designs were randomized blocks with three replicates for Trial A and six for Trial B. The percentage of the whole plot covered by weeds was recorded on two occasions for all trials. In addition, Trial B had two assessments of weed population based on the whole plot. Crop vigour (0-10, where 0 = dead and 10 = healthy) was recorded once in Trial A in 1992 and 1993 and twice in Trial B in 1994.

RESULTS

Trial A. Chinese Cabbage 1991-1993

All mulches, except the black non-woven film suppressed weeds, to a greater ($P<0.05$) extent than the herbicide regime in 1991 and 1992 (Table 1). In 1993, there were fewer weeds remaining after herbicide treatment, and the black polythene and paper mulches gave similar results. Early crop development (23 days after planting) was more rapid on hand-weeded plots in 1991 compared with other treatments (Table 2). Black non-woven film reduced ($P<0.05$) early crop development in 1991. The effect was not repeated in 1992 and 1993 even though there were fairly high levels of weeds beneath the film in all seasons. Black polythene reduced ($P<0.05$) early crop development in 1991 and 1992 but it did not seem to affect crop growth in 1993. Straw reduced ($P<0.01$) crop vigour in 1992. The number of marketable plants was reduced greatly by weed competition in 1992, but in 1993 the Chinese cabbage competed well with the weeds present (Table 2). All mulch treatments, except the black non-woven film in 1991, gave similar numbers of marketable plants to the standard herbicide regime.

Table 1. Effect of weed control treatment on % of ground covered by weeds in chinese cabbage (Data angularly transformed)

Weed Control Treatment	% ground covered by weeds					
	1991		1992		1993	
	Days after planting					
	23	37	38	47	23	31
Unweeded	-	-	76.3	79.2	13.3	45.8
Hand-weeded	10.6	10.2	0.2	1.7	1.8	4.7
Herbicide	9.1	9.1	20.8	14.5	1.7	2.2
Black polythene	0	0	0.8	0.5	0	0.5
Black non-woven film						
above film #	0	0	0	0.5	0	0.5
below film	11.5	24.2	-	-	16.7	-
Paper	-	-	0.3	0.2	0.2	0.8
Straw	-	-	2.0	4.8	-	-
d.f.	18	18	30	30	26	26
S.E.D.	1.08	2.17	4.51	4.02	1.56	2.40

excluded from the analysis

Table 2. Effect of weed control treatment on chinese cabbage development and number (%) of marketable plants at harvest, weighing at least 600 g per head.
(Data angularly transformed)

Weed Control Treatment	Crop Cover %		Crop Vigour Score		% Marketable plants #		
	1991	1991	1992	1993	1991	1992	1993
	Days after planting						
	23	38	38	34			
Unweeded	-	-	7.0	7.9	-	18.2	76.6
Hand-weeded	68.6	74.6	8.3	8.0	46.2	53.2	75.2
Herbicide	55.2	77.4	7.8	8.2	40.6	52.9	75.2
Black polythene	58.8	76.6	6.8	7.7	36.7	57.9	72.4
Black non-woven film	42.0	56.8	8.7	7.8	28.7	49.0	68.5
Paper	-	-	7.8	8.1	-	53.6	66.4
Straw	-	-	4.3	-	-	50.7	-
d.f.	18	18	30	26	18	30	26
S.E.D.	2.54	4.74	0.52	0.19	5.45	5.63	3.46

From a total number of 216 plants per treatment

Trial B. Calabrese in 1994

The weeds competed vigorously with calabrese and grew above the crop, almost completely covering the unweeded plots (Table 3). Weeds reduced ($P<0.001$) the percentage of marketable plants and returns of the calabrese compared with hand-weeded (Table 4). Herbicides reduced ($P<0.001$) the calabrese vigour and percentage of marketable plants and, in this season, greatly reduced the financial return of the crop. This also occurred in Iceberg lettuce in 1994 (the data are not presented).

Table 3. Effect of mulch on weed control in calabrese in 1994

Weed Control Treatment	Weed Cover %		Weeds/m²	
	5 Sept	2 Nov	5 Sept	2 Nov
Unweeded	14.2	95.5	322	129
Hand-weeded	1.2	5.3	29	56
Herbicide	0.9	18.3	23	39
Paper mulch	0	4.7	0	18
d.f.	-	-	15	15
S.E.D.	-	-	30.8	12.3

Table 4. Effect of mulch on crop vigour, yield and value of calabrese in 1994

Weed Control Treatment	Crop Vigour Score 5 Sept	2 Nov	% Marketable plants	Mean head weight(g)	£/ha crop value
Unweeded	6.7	6.5	35.0	176	1597
Hand-weeded	7.3	7.7	53.3	229	3147
Herbicide	3.2	5.8	28.3	128	939
Paper mulch	6.3	8.3	62.2	203	3274
d.f.	15	15	15	15	
S.E.D.	0.53	0.78	9.07	28.9	

DISCUSSION

The results described here show that there is no economic benefit from using a mulch for the production of chinese cabbage in late summer unless a premium is paid for its production without herbicides in an integrated crop management system or organic production.

Table 5. Cost of weed control in field scale transplanted vegetables *

Vegetable	Weed control £/ha per crop[1+2]	Average price returns to grower per kg of crop(p)[2]	Weed control cost(p) per kg of crop[1+2] without mulch	with plastic mulch	Weed control as % of average returns without mulch	with plastic mulch
Beans (runner)	77	0.54	0.4	2.3	1.7	10.9
Cabbage	53	14.7	1.1	1.2	0.1	8.2
Chinese cabbage	207	38.0	0.5	1.4	1.6	3.6
Calabrese	207	65.0	1.9	4.6	4.5	10.8
Cauliflower	50	30.0	0.3	3.3	1.1	9.7
Celery	291	17.4	0.3	0.5	1.7	2.9
Courgettes	228	54.0	0.9	2.0	1.7	3.7
Leeks	270	47.0	1.1	2.0	2.3	4.3
Lettuce	303	40.8	1.4	2.2	3.4	5.4
Onions	331	12.0	0.7	1.1	5.8	9.2
Sweetcorn	47	50.0	0.5	5.0	1.0	10.0

* Sources 1 ADAS Gross margin budgets, 1994 (unpublished data), 2 Nix, (1994).

In these experiments, good weed control was achieved by a combination of pre-planting paraquat and post-planting propachlor, both relatively inexpensive and safe to chinese cabbage. Black polythene and paper were the most appropriate mulches for this crop. Straw, spread as a loose mulch, hindered growth of this short-stemmed plant: a straw 'mat' may be more appropriate. Black non-woven film was not sufficiently opaque to suppress the weeds. In the calabrese experiment, herbicides reduced crop vigour causing a large reduction in gross output. Herbicide scorch often causes a check to young brassica plant development in commercial crops, but the potential loss of yield may not be realised.

The paper mulch tested proved worthwhile economically in this experiment. An advantage of using a paper (or straw) mulch is that the material does not incur recovery and disposal costs, but can be incorporated into the soil after use. In some vegetables, the cost of weed control using polythene mulches is unacceptably high given current average prices to the grower. On some soils such as stony types, mulches may not be appropriate due to difficulties with mechanical laying or tearing.

The extra cost of using a plastic (black polythene) mulch compared with using a herbicide and supplementary hoeing as 'total weed control' is shown for a range of vegetables in Table 5. In some crops the relatively high returns may easily justify the extra cost of polythene mulch. For other, lower unit value vegetables, alternative types of mulch may be considered, for example, paper mulches.

ACKNOWLEDGEMENT

The authors acknowledge the Pesticide Safety Division of the Ministry of Agriculture, Fisheries and Food for funding the work on chinese cabbage as part of a collaborative project with Horticulture Research International.

REFERENCES

Bradley, M (1992) Plastics for crop production. *Growing with plastics* - conference proceedings, pp 1-3. Horticulture Research International, Wellesbourne, Warwicks.

Davies, D H K; Stockdale, E A; Rees, R M; McCreath, M; Drysdale, A; McKinlay, R G; Dent, B (1993) The use of black polyethylene as a pre-planting mulch in vegetables: its effect on weeds, crop and soil. *Brighton Crop Protection Conference 1993 - Weeds,* 467-472.

Marks, M J (1993) Preliminary results of an evaluation of alternatives to the use of herbicides in orchards. *Brighton Crop Protection Conference 1993 - Weeds,* 461-466.

Millington, S; Stopes, C; Woodward, L; Vogtmann, H (1990) Rotational design and the limits of organic systems - the stockless organic farm? In: *Crop Protection in Organic and Low Input Agriculture.* BCPC Monograph No. 45, pp 163-173.

Nix, J (1994) Farm management pocket book, Wye College, University of London, Ashford, Kent, 220 pp.

INTEGRATED CONTROL OF LEAFY SPURGE (*EUPHORBIA ESULA*) AND RUSSIAN KNAPWEED (*CENTAUREA REPENS*) WITH PERENNIAL GRASS SPECIES

M A FERRELL, T D WHITSON, D W KOCH
Department of Plant, Soil, and Insect Sciences, PO Box 3354, Laramie, Wyoming, USA 82071.

R BOTTOMS
University of Missouri, PO Box 407, Oregon, Missouri, USA 64473

A E GADE
Cooperative Extension Service, PO Box 368, Sundance, Wyoming, USA 82729

ABSTRACT

Studies were initiated in Wyoming, USA to determine the potential of grass competition as an alternative to repetitive herbicide treatment for control of leafy spurge (*Euphorbia esula*) and Russian knapweed (*Centaurea repens*). An experiment was established to evaluate the effects grass species on leafy spurge. Russian wildrye cv. Bozoisky (*Psathyrostachys juncea*) and pubescent wheatgrass cv. Luna (*Agropyron intermedium var. trichophorum*) maintained 89 to 99% leafy spurge control four years after establishment. Studies were also started to determine the effects of five grass species on Russian knapweed. Applications of clopyralid plus 2,4-D and picloram, applied to Russian knapweed during the first frost, reduced Russian knapweed from an average of 44% in untreated unseeded plots to 10 to 12% live canopy cover in treated plots. Grass cover increased from an average of 6% in untreated seeded plots to 22 to 23% in plots treated with clopyralid plus 2,4-D and picloram.

INTRODUCTION

Leafy spurge and Russian knapweed are difficult to control perennials found throughout the western United States. They compete with desirable forage and are of no value to cattle producers. Picloram has proved to be the most reliable and effective herbicide for control of leafy spurge with a single application (Vore and Alley, 1982). However, control can be maintained for only three to five years. After this time a retreatment program must be implemented to maintain adequate leafy spurge control. Control is adequate when leafy spurge is suppressed to a level where cattle will be able to effectively utilize desirable forage growing in competition with leafy spurge. Hein (1988) found leafy spurge canopy cover exerted the greatest influence on grazing behavior and forage utilization by cattle. Leafy spurge canopy cover of 10% or less and shoot control of 90% or more were necessary to achieve 50% forage utilization by cattle in Montana (Hein, 1988). In North Dakota, leafy spurge infestations were avoided until early fall when the milky latex in the spurge subsided (Lym and Kirby, 1987). Cattle only used 2 percent of the available forage in leafy spurge densities of less than 20% cover.

Although herbicides play an important part in the control of leafy spurge and Russian knapweed alternative methods are available and may be used where persistent herbicides cannot be tolerated. One such method is plant competition. Grass competition has long been recognized as a method of weed control. Crested wheatgrass has been used successfully in Saskatchewan, Canada to decrease the rate of vegetative spread, limit density, reduce seed production and suppress top growth of leafy spurge (Selleck, 1959). Leafy spurge growth may also be suppressed by planting an early emerging crop such as crested wheatgrass, that will compete with it for early soil moisture (Morrow, 1979).

Russian knapweed is highly competitive on disturbed sites and severely reduces land values. Russian knapweed is also allelopathic. Therefore, areas must be tilled before newly established grass seedlings can survive. Without tillage grass seedlings can survive only after Russian knapweed residues have been exposed to moisture for two growing seasons.

Grasses selected for these studies were pubescent wheatgrass cv. Luna, Russian wildrye cv. Bozoisky, thickspike wheatgrass cv. Critana (*Agropyron dasystachyum*), streambank wheatgrass cv. Sodar (*Agropyron dasystachyum riparium*), crested wheatgrass cv. Hycrest (*Agropyron cristatum*), and western wheatgrass cv. Rosana (*Agropyron smithii*).

The purpose of this research was to determine the potential of perennial grass competition as an alternative to repetitive herbicide treatment for control of leafy spurge or Russian knapweed.

MATERIALS AND METHODS

Studies were established near Devil's Tower in Crook County, Wyoming. Grasses included in the study were pubescent wheatgrass cv. Luna and Russian wildrye cv. Bozoisky. Grasses were selected from a previous study on the basis of productivity, ability to establish in low precipitation areas and ability to compete with leafy spurge. The study area received only natural precipitation.

Glyphosate was applied before seeding grasses in 1989 to control existing vegetation. Plots (10 by 53 m) were arranged in a randomized complete block design with two factors and four replications. Factors were grass varieties and till versus notill. Plots were rototilled and rolled on 7 August, 1989. Grasses were seeded at 64 mm with a double-disc opener Tye drill on 8 August, 1989. Luna was seeded at a rate of 12 kg and Bozoisky at a rate of 8 kg of pure live seed per ha. Row spacing was 20 cm for both varieties. Postemergent applications of 2,4-D and metsulfuron plus 2,4-D were made in 1989 and 1990 to control annual broadleaf weeds. Percent leafy spurge control, number of grass plants per 6 m of row, and kg of air dry grass per ha were taken 12 and 13 September, 1991, 8 July, 1992 and 28 September, 1993.

Two studies were also located on Lander Complex sandy loam soils near Riverton and Ft. Washakie, Wyoming and were treated with herbicides on 10 and 11 October, 1991. Plots were tilled with a rototiller October 20, 1991. Metsulfuron (8.5 g ai/ha), clopyralid (0.32 kg ai/ha) plus 2,4-D (1.65 kg ai/ha), and picloram (0.28 kg ai/ha) were applied in August, 1992. All herbicides, except picloram, were reapplied in August, 1994. Russian knapweed had started into winter dormancy during the 1991 application and in late bloom in 1992 and early bloom in 1994. Plots were seeded with streambank wheatgrass cv. Sodar, thickspike wheatgrass cv. Critana, crested wheatgrass cv. Hycrest, western wheatgrass cv. Rosana and Russian wildrye cv. Bozoisky at 11.2 kg pure live seed/ha, except Russian wildrye which was seeded at 6.6 kg/ha on 11 and 12 April, 1992.

RESULTS AND DISCUSSION

Leafy spurge control was excellent at 89% or better in both rototilled and no-till plots for all years for both grasses (Table 1). The tilled plots had significantly more plants per 6 m of row than the no-till plots for both grasses in 1991 (Table 1). In 1992 there was a considerable increase in plants in the Bozoisky plots (Table 1).

Table 1. Pubescent wheatgrass (Luna) and Russian wildrye (Bozoisky), September 1991 (91), July 1992 (92) data and September 1993 (93) data.

	Leafy spurge control (%)						Grass plants/6 m of row					
	Till			No-till			Till			No-till		
Variety[1]	91	92	93	91	92	93	91	92	93	91	92	93
Luna	99	99	99	99	99	96	34	34	37	25	27	28
Bozoisky	99	99	96	95	97	89	37	56	54	21	28	28
LSD-5%[2]	3	5	ns	3	5	ns	5	11	7	5	11	7

[1]Grasses seeded August 8, 1989.
[2]Comparison of variety means is valid between till and no-till, within years.

Grass production for 1991 was very good for both the till and no-till plots due to good early season moisture. In the tilled plots Luna provided 3440 kg of air dry forage per ha and 2445 kg in the no-till plots (Table 2). Bozoisky production was 1640 kg in the tilled plots and 1173 kg in the no-till plots. In 1992 and 1993 forage production was also very good (Table 2). There were no differences between production in the tilled versus the no-till plots in 1992. There was a significant increase in forage production for Luna plots in the tilled plots compared to the no-till plots in 1993.

Table 2. Pubescent wheatgrass (Luna) and Russian wildrye (Bozoisky), September 1991 (91), July 1992 (92) data and September 1993 (93) data.

	Grass production (kg/ha)					
	Till			No-till		
Variety[1]	91	92	93	91	92	93
Luna	3440	2378	3638	2445	2394	2993
Bozoisky	1640	1550	1349	1173	1369	1249
LSD-5%[2]	803	493	337	803	493	337

[1]Grasses seeded August 8, 1989.
[2]Comparison of variety means is valid between till and no-till, within years.

Luna was developed in New Mexico by the USDA/SCS (Onsager, 1987). It had excellent establishment, leafy spurge control, and forage production in both the till and no-till plots. Bozoisky has been significantly more productive and easier to establish on semiarid range sites than other Russian wildryes (Onsager, 1987). It had excellent leafy spurge control and good forage production in the till and no-till plots. Luna and Bozoisky appear to be good grasses for competition with leafy spurge and other weedy species.

Russian knapweed live canopy cover was reduced from an average of 44% in the untreated unseeded checks to 10% in the areas treated with clopyralid plus 2,4-D (Table 3). There was no difference between grass varieties when compaired to % Russian knapweed cover. Reductions to 2% live canopy cover of Russian knapweed were obtained with a single application of picloram.

Table 3. Russian knapweed (Knap) % live canopy cover, Ward (Wd) and Brown ranch (Br).

	Treatment										
	Metsulfuron		Clopyralid+2,4D		Picloram		Untreated unseeded		Untreated seeded		
Grass	Wd	Br	Wd	Br	Wd	Br	Wd	Br	Wd	Br	Mean
Streambank wheatgrass	33	41	14	3	13	6	28	54	20	43	25
Thickspike wheatgrass	40	49	13	5	20	2	33	59	30	53	30
Crested wheatgrass	47	24	14	4	22	2	32	55	23	48	27
Western wheatgrass	34	50	16	6	25	6	30	56	30	52	30
Russian wildrye	37	36	13	10	20	6	33	61	23	53	29
LSD (0.1)	15	15	15	15	15	15	15	15	15	15	
LSD (0.05)											4
Mean LSD (0.05) = 4	39		10		12		44		37		

Stands of the five perennial grasses averaged 22% live canopy cover in the clopyralid plus 2,4-D and 23% live canopy cover in the picloram treatment compared to 6% for the untreated seeded plots (Table 4). The two grasses having the greatest overall establishment were thickspike wheatgrass cv. Critana with an average over all treatments of 17% live canopy cover and streambank wheatgrass cv. Sodar with 16% live canopy cover. The lowest amount of Russian knapweed (2%) and the highest % live canopy of grass (47%) were found in plots treated with picloram and seeded to thickspike wheatgrass (Tables 3 and 4).

Table 4. Percnt grass live canopy cover, Ward ranch (Wd) and Brown ranch (Br).

	Treatment										
	Metsulfuron		Clopyralid+2,4D		Picloram		Untreated unseeded		Untreated seeded		
Grass	Wd	Br	Wd	Br	Wd	Br	Wd	Br	Wd	Br	Mean
Streambank wheatgrass	21	6	24	35	16	47	0	0	7	8	16
Thickspike wheatgrass	12	17	23	40	14	47	0	0	7	7	17
Crested wheatgrass	5	18	3	23	3	26	0	0	1	9	9
Western wheatgrass	5	9	9	29	5	30	0	0	6	6	10
Russian wildrye	8	13	16	19	10	30	0	0	2	5	10
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns	ns	ns	4
Mean LSD (0.05) = 4	11		22		23		0		6		

Critana thickspike wheatgrass and Sodar streambank wheatgrass are very similar grasses. They are native perennial grasses which can be used to vegetate and reduce erosion on disturbed sites such as mined lands, roadsides, recreation areas, and construction sites. Both are excellent for reseeding range sites that are severely eroded or that have low fertility. Both are also strongly rhizomatous and grow to 25 to 30 cm in height on good sites. They produce abundant, fine, light green leaves and form a tight sod under dryland conditions. Both have excellent seedling vigor and are adapted to medium- to coarse-textured soils. They are also adapted to soils derived from granulated shales and clays that behave like coarse-textured soils. They grow in the 25- to 51-cm precipitation zone in the northern Rocky Mountains and adjacent Great Plains regions. Both adapt to elevations ranging from 610 to 2287 m (USDA, 1984). These grasses had the greatest live canopy cover in the study.

Hycrest crested wheatgrass is a winter hardy, drought resistant bunchgrass. Although the new cultivar is well adapted to sagebrush and juniper vegetation sites (30 cm of annual precipitation), good to excellent stands have been established on shadscale, greasewood, and Indian ricegrass sites where annual precipitation is less than 20 cm. In southern areas, it is best adapted to elevations of 1500 m or more. The upper elevation limits are from 2590 to 2740 m. It performs well on a wide variety of soil types; however, it is particularly well adapted to sandy or sandy loam soils. In general, crested wheatgrass will not tolerate prolonged flooding and is only moderately tolerant of saline soils when compared to tall wheatgrass, quackgrass, or western wheatgrass (Asay and Horton, 1985).

Rosana western wheatgrass, a native perennial grass, was developed for reseeding depleted rangelands and abandoned cropland in Montana and Wyoming. Seedling vigor also makes Rosana a valuable grass for mine reclamation. The plants are blue-green, leafy, moderately fine stemmed, and easy to establish. Rosana is adapted to the moderately rolling topography of the northern Rocky Mountain region and the adjacent Great Plains. It does best on medium to fine textured soils and tolerates soils that are neutral to strongly alkaline. Rosana is adapted to areas with 30 or more cm of precipitation. Production is enhanced by extra moisture from irrigation or on overflow sites. Rosana forms a tight sod under dryland conditions. Rosana will produce excellent seed crops under irrigation (USDA, 1979).

Because of their performance in these studies Luna pubescent wheatgrass and Bozoisky Russian wildrye appear to provide effective competition with leafy spurge. Critana thickspike wheatgrass and Sodar streambank wheatgrass also appear to provide effective competition with Russian knapweed. There is a need for long-term research to confirm that these grasses or others will effectively compete with these weeds and reduce the amount of herbicides needed for control of perennial weeds.

REFERENCES

Asay, K H and Horton W H (1985) Hycrest crested wheatgrass. Utah State University, Logan, Utah. Bulletin.

Hein, D G (1988) Single and repetitive picloram treatments on leafy spurge (*Euphorbia esula* L.) and resulting changes in shoot density, canopy cover, forage productions and utilization by cattle. PhD Thesis. Univ. of Wyo. 94pp.

Lym, R G and Kirby D R (1987). Cattle foraging behavior in leafy spurge (*Euphorbia esula*) -infested rangeland. *Weed Technology*. **1**:314-318.

Morrow, L A (1979) Studies on the reproductive biology of leafy spurge (*Euphorbia esula*). *Weed Science*. **27**:106-109.

Onsager, J A, editor (1987) Integrated Pest Management: State-of-the Art in the Sagebrush Ecosystem. U.S. Department of Agriculture, Agriculture Research Service, ARS-50, 85 pp, illus.

Selleck, G W (1959) 1) Leafy spurge control with 2,4-D 2) Granular herbicides on leafy spurge and toadflax. Proceedings. North Central Weed Control Conference: Winnipeg, Manitoba. 70 pp.

USDA (1979) Rosana western wheatgrass. A conservation plant for Montanta and Wyoming. USDA Soil Conservation Service, Plant Materials Center, Bridger, Montana. Bulletin.

USDA (1984) Critana thickspike wheatgrass. A conservation plant for Montanta and Wyoming. USDA Soil Conservation Service, Plant Materials Center, Bridger, Montana. Bulletin.

Vore, R E and Alley H P (1982) Leafy spurge (*Euphorbia esula* L.), Wyoming chemical control research. Univ. Wyo. Agric. Exp. Sta. Bull. MP-46R. 43 pp.

THE CONTROL OF BLACKGRASS AND VOLUNTEER WHEAT IN PERENNIAL RYEGRASS GROWN FOR SEED

E G BUDD
National Institute of Agricultural Botany, Huntingdon Road, Cambridge, Cambs.

ABSTRACT

Fenoxaprop-ethyl (Cheetah R) 0.12 kg ai/ha, tank mixed with 4.75 kg ai/ha of 'TCA' applied to a well tillered crop of perennial ryegrass (*Lolium perenne*), gave a seed yield of 1.18 tonnes/ha. This compared with a seed yield of 1.12 tonnes/ha following an application of 1.0 kg ai/ha of ethofumesate (Nortron) tank mixed with 4.75 kg ai/ha of TCA. The untreated crop gave a yield of 1.0 tonnes/ha. All treatments gave a 98% control of blackgrass (*Alopecurus myosuroides*) and good control of volunteer wheat (*Triticum aestivum*).

Fenoxaprop-ethyl tank mixed with TCA offers a potentially cheaper choice of herbicide for controlling *A. myosuroides* and volunteer cereals in autumn sown perennial ryegrass seed crops. Because of the limited availability of TCA, it is suggested that combinations of fenoxaprop-ethyl and ethofumesate could give good control of *A. myosuroides* and volunteer cereal species and also hopefully avoid the increase of grass weed tolerance.

It is further suggested, that if fenoxaprop-ethyl without the cereal safener became available in the United Kingdom, a satisfactory control of volunteer cereal species in ryegrass seed crops could also be achieved when the product is combined with ethofumesate.

INTRODUCTION

Over the last twenty years, ethofumesate has been the most successful selective herbicide for controlling *A. myosuroides* in grass seed crops. Used in conjunction with TCA, ethofumesate has also been used successfully, at reduced rates, to also control volunteer cereals in ryegrass seed crops. This treatment, however, is expensive, costing £76-£150/ha depending on the rate applied. The average perennial ryegrass seed crop will produce 1.1 tonnes/ha of clean seed and this expenditure on herbicide currently requires an estimated 8-15% of the seed crop to pay for the treatment.

The trial reported here set out to determine whether fenoxaprop-ethyl with TCA offered more efficient and cheaper control of *A. myosuroides* and volunteer cereals than ethofumesate with TCA.

Previous successful trial work on the use of ethofumesate and TCA combinations has been reported on by Johnson *et al* (1982).

MATERIALS AND METHODS

This trial consisted of five treatments replicated four times as randomised blocks on an area of 0.25 of a hectare. Each treated plot measured 100 m^2, but was split down to 50 M^2 units for harvesting and analysis of yield and weed content.

The treatments were made on a crop of *L. perenne* perennial ryegrass, cv. Profit, sown in early September, following a farm crop of wheat.

Treatments (Kg ai/ha)	Chemical Cost/ha
1. Untreated	-
2. Fenoxaprop-ethyl 0.12 kg + TCA 4.75 kg, 24 October	£49.69
3. Ethofumesate 1.0 kg + TCA 4.75 kg, 24 October	£84.25
4. Fenoxaprop-ethyl 0.12 kg + TCA 4.75 kg, 24 October, followed by fenoxaprop 0.12 kg, 12 March	£90.97
5. TCA 4.75 kg, 24 October, followed by fenoxaprop 0.12 kg, 14 December	£49.61

+ = Tank mixes

Due to the dry autumn, germination and establishment was interrupted and full tillering was not reached until 24 October. Treatment commenced on this date when most of the ryegrass crop was very well tillered and the remaining 25% was just tillering. Because of this variation in tillering, only 3.8 kg ai/ha of TCA and 0.8 kg ai/ha of ethofumesate was applied on 24 October, but the remaining 0.95 kg of TCA and 0.2 kg of ethofumesate was applied on 14 December. Had the establishment been rapid and complete, the full quantity of herbicide, in most cases tank mixed, would have been applied on 24 October.

Apart from some large early germinating plants, most of the *A. myosuroides* was later establishing and was at the 2-3 leaf stage when treated. The volunteer wheat consited mainly of tillered plants.

Each treatment was applied using an Oxford Precision Sprayer Van der Vey combination, calibrated to deliver 250 L/ha at 2.0 bar pressure. The five sprayer jets used on a 2.5 m boom, were Lurmark 02-F80 brass fan nozzles.

The results of the treatments were measured in respect of:

1. The clean seed yield of ryegrass (T/ha) at 98% purity and 12% moisture.
2. The reduction in *A. myosuroides* contamination in the cleaned seed.
3. The reduction in volunteer wheat contamination.
4. The improvement in harvest purity.
5. The comparative cash return (£/ha).

RESULTS

Fig 1. Yield of ryegrass seed (t/ha) at 98% purity of cleaned seed.

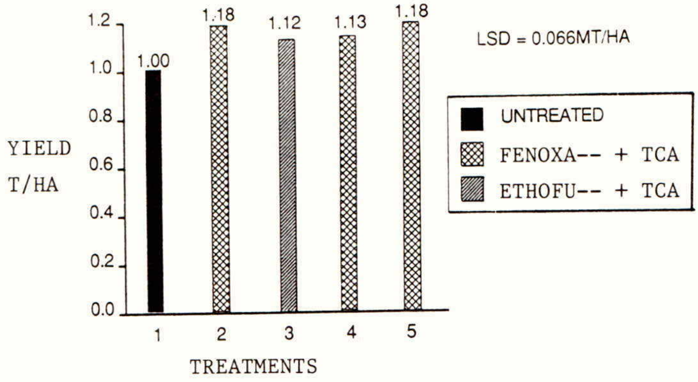


Fig 2. Number of A. myosuroides seeds per 3gm of cleaned ryegrass seed

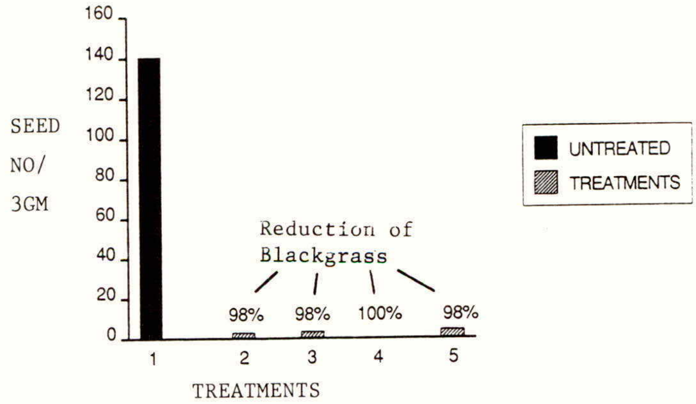


Fig 3. Percentage purity of ryegrass seed, as harvested.

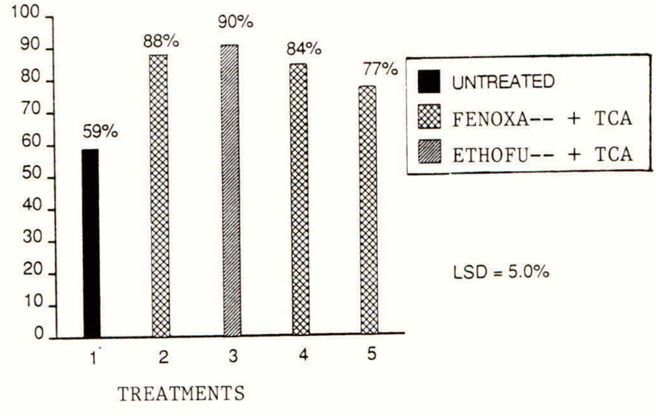


Fig 4. Volunteer wheat contamination of ryegrass seed as harvested.

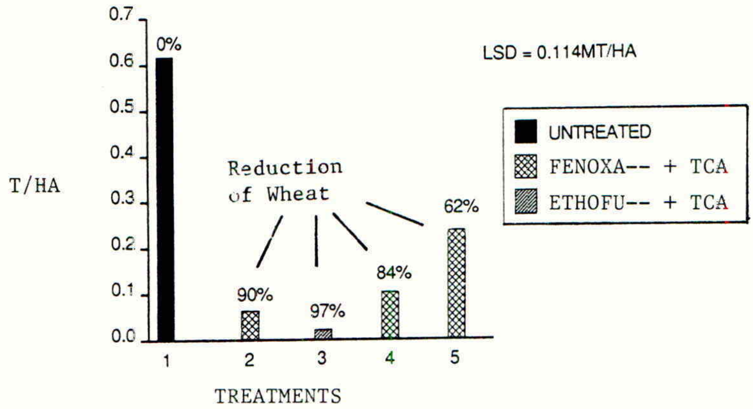
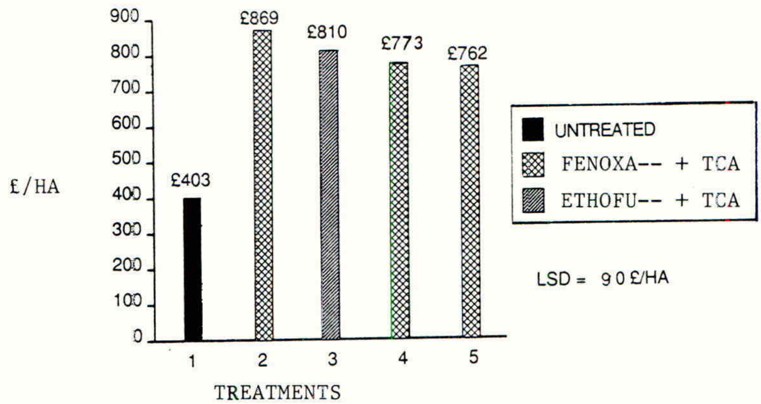


Fig 5. Cash return (£/ha) after cleaning & chemical costs only.



The cash return was calculated after deducting cleaning and chemical costs only. Other variable and all fixed costs were excluded. The calculation was also based on a price of £35.00/50 kg of cleaned seed, together with a subsidy of £10.31/50 kg. Cleaning costs are based on a mean of agreed UKASTA cleaning charges and somewhat lower charges quoted by a seed merchant.

DISCUSSION

This trial was undertaken when TCA was commercially available. Since 1993/94, however, this graminicide can no longer be obtained, but some significant stocks have been collected and reserved for use by a number of diligent seed growers.

The clean seed yields following the treatments were all satisfactory. All treatments yielded significantly better than the untreated. (Fig. 1).

All treatments gave 98% reduction of *A. myosuroides* seed numbers in the clean seed. Treatment 4, which consisted of an additional 0.12 kg/ha fenoxaprop-ethyl application in the spring gave the best reduction but was more expensive. (Fig. 2). The excessive *A. myosuroides* contamination in the cleaned seed, (Fig. 2), produced from the untreated (140 seeds/3g) rendered the seed unsaleable.

The harvested seed purities were all satisfactory, (Fig. 3), with the exception of the untreated control. However, the purity of treatment 5, where the 0.12 kg/ha of fenoxaprop-ethyl followed the TCA seven weeks later, was inferior to treatments 2, 3 and 4. For good reduction of volunteer wheat, the fenoxaprop-ethyl and TCA should be applied at the same time.

The ethofumesate + TCA combination, treatment 3, (Fig. 4), gave the best control of volunteer wheat at 97%, followed by fenoxaprop-ethyl + TCA treatment 2, at 90%.

After deducting cleaning and chemical costs, (Fig. 5), fenoxaprop-ethyl treatment 2, appeared to be the most profitable. The relatively poorer reduction of wheat in treatment 5, only 62%, (Fig. 4), resulted in higher cleaning costs and the cash return was commensurably lower.

Since fenoxaprop-ethyl + 4.75 kg TCA gave incomplete reduction of volunter winter wheat, 90% (Fig.4), it is suggersted that, if fenoxaprop-ethyl without the added cereal safener, became available in the United Kingdom, a satisfactory control of volunteer cereal species could also be achieved. This could go some way towards finding a replaclement for the future unavailability of TCA. Unpublished work in this country by the author, has indicated that this could work on ryegrass seed crops. This 'unsafened' Fenoxaprop is believed to be used in the USA for this purpose, in ryegrass seed crops.

The build up of *A. myosuroides* tolerance to fenoxaprop-ethyl and other graminicides has most recently been reported by Clark, *et al* (1994). It is suggested that this increase in weed tolerance could at least be delayed in grass seed crops, by using tank mix combinations of fenoxaprop-ethyl and ethofumesate. At present, there does not appear to be a build up of herbicide resistance in *A. myosuroides* to ethofumesate. Indeed, some herbage seed growers are reporting successful treatments on a field scale with or without a second application of fenoxaprop-ethyl or ethofumesate in the spring.

Over the last fifteen years, more and more ryegrass seed crops have been established in the autumn following winter cereals, and this exacerbates the problems of volunteer cereals and *A. myosuroides* contamination. It should be emphasised that every opportunity should be taken of establishing ryegrass seed crops where possible in spring nurse crops of spring barley and wheat. In these crops, fewer problems are experienced with volunteer cereals, since the fallen ears and shed grain germinate on the surface and much is killed by frosts, eaten by birds and suffer from disease.

Spring under-sowings also offer good opportunities of controlling *A. myosuroides* with fenoxaprop-ethyl and ethofumesate applications in the autumn, since the seedlings can be better controlled at a young stage when the already established ryegrass crop is offering added competition.

Further trials have indicated that fenoxaprop-ethyl offers good control of rough meadow-grass *Poa* trivialis, a species which is not controlled by ethofumesate. Fenoxaprop-ethyl is also reported to give excellent control of *A. fatua* and *Avena sativa* oats in *Lolium* seed crops.

ACKNOWLEDGEMENTS

This trial was funded by the National Farmers Union Herbage Seed Technical Levy Fund. The assistance of Hugh & Richard Scantlebury is much appreciated for providing a site for this trial. Thanks also to Peter Garland of Mommersteeg International for advice on prices and seed cleaning charges.

REFERENCES

Clarke, J H; Blair A M; Moss S R (1994) The testing and classification of herbicide resistant *Alopecurus myosuroides. Aspects of Applied Biology*. **37**, pp. 181-188.

Johnson, J; Scott J L; Dibb C; Greenwood M A (1982) The effect of controlling volunteer cereals, *Poa trivialis* and ryegrass seedlings on the seed yield of perennial ryegrass. *Proceedings 1982 British Crop Protection Conference - Weeds.*, pp. 407-414.

THIAZOPYR WEED CONTROL IN PERENNIAL CROPS

H L WARNER
Rohm and Haas Company Research Laboratory, 727 Norristown Road, Spring House, PA, 19447 U.S.A.

J A HOLMDAL
Rohm and Haas Company, 100 Independence Mall West, Philadelphia, PA, 19106-2399 U.S.A.

ABSTRACT

Trials conducted in California and the Pacific Northwest on apples, walnuts and vine crops indicate that a single pre-emergence application of thiazopyr at 0.44 kg ai/ha provides annual grass and selected broadleaf weed control equivalent to 2.2 kg ai/ha norflurazon, 4.4 kg ai/ha oryzalin or 4.4 kg ai/ha pendimethalin. Thiazopyr is most effective for the control of annual grass species and provides excellent long term control with pre-emergence rates at or above 0.11 kg ai/ha. Annual grasses controlled include *Echinochloa crus-galli*, *Poa annua*, *Setaria viridis Bromus catharticus* and *Cynodon dactylon*. Broadleaf weeds controlled at 0.45 kg ai/ha include *Stellaria media*, *Calandrinia caulescens*, *Malva parviflora*, *Lamium amplexicaule*, *Urtica dioica*, *Sisymbrium irio*, *Capsella bursa-pastoris*, *Solanum nigrum*, *Hippuris vulgaris*, *Sonchus oleraceus*, *Senecio vulgaris*, *Anthemis cotula*, *Amaranthus retroflexus*, *Chenopodium album*, *Epilobium paniculatum*, *Lactuca serriola*, *Erodium moschatum* and *Ranunculus muricatus*. When tank mixed with oxyfluorfen, additional control of the following weeds was obtained: *Cyperus esculentus*, *Echinochloa crus-galli*, *Calandrinia caulescens*, *Raphanus raphanistrum*, *Sisymbrium irio* and *Kochia scoparia*.

INTRODUCTION

Thiazopyr, Visor®, is a preemergence grass herbicide currently under development worldwide by Rohm and Haas Co. for use in citrus, tree fruit, tree nut and vine crops. Thiazopyr is a pyridine herbicide with ideal environmental characteristics for providing long term residual weed control in perennial crops. Thiazopyr has an average soil half life (DT_{50}) of 64 days (Oppenhuizen et al., 1991), very low water solubility (Duke et al. 1990) and limited movement in the soil profile (Oppenhuizen et al., 1991). The mode of action of thiazopyr is via mitotic inhibition, similar to dinitroaniline herbicides.

Field trials were conducted in California and the Pacific Northwest to determine optimum use rate for long term control of the most predominate winter weeds in perennial crops. A second set of field trials was established to determine if low rates of thiazopyr would complement the spectrum of oxyfluorfen, a residual broadleaf herbicide.

MATERIALS AND METHODS

Field studies were conducted during the fall and winter of 1993 and 1994. All trials were located in row middles of orchards or vineyards to obtain an indigenous population of prevalent weeds. A randomized complete block design was used with four replications. Individual plots were 1.5 by 7.5 m in size. Applications were applied with a four nozzle CO_2 backpack sprayer delivering 187 L/ha . All treatments were either applied to bare soil prior to weed emergence or tank-mixed with 0.84 kg ai/ha glyphosate if weeds were present. Weed control ratings were taken at 90 to 180 days after treatment and are a visual observation of % weed biomass reduction ranging from 0 to 100, where 100 is complete weed control.

RESULTS

Preemergence weed control

Thiazopyr effectively controlled a broad spectrum of winter grasses and broadleaf weeds common to California and Pacific Northwest perennial crops at rates of 0.11 -0.22 kg ai/ha. Thiazopyr provided season long control on five of six grasses and was equivalent to the standard treatments of 4.48 kg ai/ha of pendimethalin or oryzalin and 2.24 kg ai/ha of norflurazon (Table 1).

Table 1. Comparison of thiazopyr, pendimethalin, oryzalin and norflurazon on control of winter grasses in perennial crops.

Weed species[a]	No. of trials	% Control at 90-180 days after treatment					
		thiazopyr			pendimethalin	oryzalin	norflurazon
		0.11	0.22	0.45	4.48	4.48	2.24 kg ai/ha
Ave fa	1	54	74	59	48	71	-
Bro ca	1	95	100	100	74	98	85
Cyn da	1	100	83	90	88	100	90
Ech cg	2	84	96	98	90	95	83
Poa an	4	97	100	100	96	96	100
Set vi	1	89	99	94	100	91	-

[a] Weed species code as given by Bayer (1986)

Thiazopyr at 0.45 kg ai/ha provided commercial control (≥80%) on 18 of 23 broadleaf weed species tested and suppression in the remaining five species (Table 2).

Table 2. Comparison of thiazopyr, pendimethalin, oryzalin and norflurazon on control of winter broadleaf weeds in perennial crops.

Weed species	No. of trials	% Control at 90-180 days after treatment thiazopyr 0.11	0.22	0.45	pendimethalin 4.48	oryzalin 4.48	norflurazon 2.24 kg ai/ha
Ama re	2	68	82	85	88	96	90
Ant co	1	47	68	86	100	98	100
Cal ci	2	98	100	100	98	100	100
Cap bp	5	73	85	97	89	77	97
Che al	2	29	66	82	98	83	-
Epi pc	1	79	76	81	83	83	69
Ero ci	1	0	13	73	21	25	23
Ero mo	1	88	92	100	75	100	72
Hpp vu	1	67	75	95	95	100	33
Kch sc	1	51	68	65	74	62	-
Lac se	1	86	98	100	74	95	56
Lam am	2	88	98	100	100	100	84
Mal ne	1	40	59	68	70	78	-
Mal pa	1	90	99	100	98	98	93
Med po	1	26	59	77	65	74	30
Ran mo	1	85	98	100	98	100	92
Sas kr	2	35	58	65	53	65	-
Sen vu	2	68	59	90	46	96	88
Sol ni	1	85	95	97	100	100	-
Son ol	5	82	94	94	85	95	81
Ssy ir	1	100	99	100	96	61	99
Ste me	2	81	88	98	100	98	99
Urt di	1	67	87	100	100	100	100

Combinations with oxyfluorfen

Thiazopyr at 0.22 kg ai/ha combined with 1.34 kg ai/ha of oxyfluorfen provided commercial control of *Echinochloa crus-galli*, *Stellaria media*, *Calandrinia caulescens*, and *Raphanus raphanistrum*, while oxyfluorfen applied alone did not (Table 3). The higher 0.44 kg ai/ha rate of thiazopyr was required for *Cyperus esculentus*, *Salsola iberica* and *Kochia scoparia* control.

Table 3. Combinations of thiazopyr and oxyfluorfen for broadspectrum weed control.

Weed species	No. of trials	% Control at 90-180 days after treatment oxyfluorfen + thiazopyr 1.34 + 0.22	oxyfluorfen + thiazopyr 1.34 + 0.44	oxyfluorfen + oryzalin 1.34 + 2.24	oxyfluorfen 1.34 kg ai/ha
Bro mo	2	98	99	96	96
Cap bp	4	100	100	100	98
Che al	1	59	95	68	91
Cob te	1	100	100	100	100
Cyp es	3	73	87	56	49
Des so	1	100	100	100	100
Ech cg	1	98	100	100	67
Kch sc	1	65	80	32	65
Lam am	2	100	100	100	96
Med po	1	100	100	100	100
Poa an	3	100	100	100	99
Rap ra	1	91	95	99	82
Run mo	1	96	100	96	91
Sas kr	1	62	91	41	54
Sol ni	1	91	99	98	100
Son ol	3	96	96	98	96
Ste me	1	98	100	100	67

DISCUSSION AND CONCLUSIONS

Thiazopyr applied at 0.11 to 0.44 kg ai/ha provides excellent season long control of winter grasses and many of the broadleaf weeds troublesome in California and Pacific Northwest perennial crops. Most grasses were controlled at the low 0.11 - 0.22 kg ai/ha applications rates. Higher 0.22 - 0.44 kg ai/ha application rates were required for broad spectrum broadleaf weed control. Thiazopyr's low use rate coupled with low water solubility and limited movement in the soil profile characterize it as an environmentally friendly herbicide ideal for use in perennial crops.

Because of its excellent residual pre-emergence properties, thiazopyr at low rates was effective in mixtures with oxyfluorfen to expand both the grass and broadleaf weed control spectrum. Other potential mixing partners for broad-spectrum control are diuron and simazine.

REFERENCES

Duke, J P; Wratten, S (1990) Water solubility of MON 13200. MSL-10822 Monsanto, St. Louis, MO.

Oppenhuizen, M E; Allin, J C (1991) Terrestrial field soil dissipation study of MON 13200 and its major soil metabolites. MSL-11223, Monsanto, St. Louis, MO.

DEVELOPMENT OF VARIOUS STRATEGIES TO CONTROL BOTH ANNUAL AND PERENNIAL WEED SPECIES IN APPLE ORCHARDS ON SANDY SOILS

N SARPE, M IANCU
Academy of Agricultural and Forestry Sciences, 61 Mărăşti Avenue, Bucharest, Romania

C ROIBU
Oltchim S.A. Uzinei 1 Avenue, Râmnicu-Vâlcea, Romania

ABSTRACT

In Romania, apple orchards cultivated on different types of soil, are infested in proportion to 50-75 % with different species of perennial weeds the most frequent being *Elymus repens, Cynodon dactylon, Convolvulus arvensis, Cirsium arvense, Sonchus arvensis, Rumex crispus* and *Taraxacum officinale.* In order to control annual weeds, pre-emergent herbicides were applied: alachlor + simazine, pendimethalin, dimethenamid and imazethapyr. Also, in order to control perennial weeds, post-emergent herbicides were applied such as: glyphosate, dicamba, glufosinate, rimsulfuron and nicosulfuron. Good control of annual weeds was obtained with the following herbicides: alachlor + simazine, pendimethalin + imazethapyr and dimethenamid + simazine. Against perennial monocotyledonous weeds (*Elymus repens* and *Cynodon dactylon*) lower case nicosulfuron was better than rimsulfuron and glyphosate was better than glufosinate.
Based on the results from these experiments, the following strategies are recommended to give effective control:
Strategy No 1 treated pre-emergence with alachlor + simazine and post-emergence with glyphosate
Strategy No 2 treated pre-emergence with dimethenamid + simazine and post-emergence with glyphosate + dicamba + 2,4 -D.
Strategy No 3 treated pre-emergence with pendimethalin + imazethapyr post-emergence with glyphosate.

INTRODUCTION

Chemical control of weeds in apple orchards has been used in most European countries with Caragarde combi (based on terbuthylazine + terbumeton) being the most utilized herbicide. More recently in apple, pear and peach orchards several other herbicides were used including napropamide, oryzalin, linuron (Gainor *et al.* 1982). The herbicides flourochloridone, oxyfluorfen diphenamid, oxadiazon and propyzamide were studied by Tomac *et al.* (1986). Paraquat, glyphosate and glufosinate were also studied by several european and american scientists. Most of these herbicides were tested in Romania by Săndulescu, Şarpe (1980) and Şarpe (1987).

These herbicides applied alone only partially resolve the weeds problems. Some of the herbicides have a magnificent effect on the annual monocotyledous weeds (diphenamid) and others on dicotyledous annual weeds (linuron etc.). Glyphosate applied alone controls all the species of weeds (especially perennials) such as *Elymus, Cynodon, Cirsium, Sonchus spp* etc., but 30-45 days after treatment, orchards are infested again with different species of annual weeds. The same phenomenon appears when we use glufosinate. Because of this, during the years 1991-1994, different strategies have been studied in order to establish the best ones for the total control of all the species of weeds from the four groups, mono - and dicotyledonous annual and perennial weeds. The results are published in this paper.

MATERIALS AND METHODS

Experiments were done in a 16 year old apple orchard cv. James Grieve. The plantation was on ancient sand hills on the bank of river Jiu, close to the Danube. After the level of the dunes, the sand layer was 4-8 m depth. In the upper layer of 30-50 cm deep, the content of organic matter was of 0,3 - 0,5 %, clay 3 - 8 %; and sand 90-93 %. In order to obtain economic yields of fruit, large quantities of fertilizers (NPK) were used as well as irrigation 7-10 times in order to maintain the soil moisture at 50 % of the active humidity interval (a h i) at 50 cm depth.

The experiment was laid out using randomized blocks with individual plots of 50 m^2, trees being planted at 4 m between the rows and 2 m along each row. The herbicides used in every strategy, rates and time of application, are shown in Tables 1-2. The herbicides were applied only to the tree row to a width of 1,5 m.

After the treatments with herbicides, assements were made using the EWRS scales for selectivity for the crop and efficacy in controlling weeds. In October, annual and perennial weeds were assessed separately.

RESULTS AND DISCUSSION

Herbicide selectivity

Results of selectivity assessments on the trees are not presented as there was no damage seen; all treatments gave a score of 1.0 on the EWRS selectivity scale. Due to the irrigation from May till September with rates of 300-500 m^3 of water/ha we presume that some imazethapyr penetrated through the sand layer to the root system. In Bulgaria, Milanova (1995) by applying 300 g/ha of

imazaquin (a similar imidazolinone herbicide) caused phytotoxic effects on 2-3 year old peach trees.
Phytotoxic symptoms were not caused by nicosulfuron, rimsulfuron, glyphosate or glufosinate. These herbicides were applied post-emergent during days with no wind in order to avoid drift.

In contrast to 1991-1992, during 1993-1994, the strategies also used dimethenamid, dicamba, 2,4-D and clethodim. None of theese herbicides caused phytotoxicity to the apple trees, a mean score of 1.0 on the EWRS scale was recorded for all treatments.

Efficacy in controlling weeds

The apple-tree plantation where the experiments with herbicides were done was strongly infested with weeds, especially perennials including:

1. *Cynodon dactylon 70-80 %*
2. *Elymus repens, ocasionally*
3. *Convolvulus arvensis*
4. *Cirsium arvense*
5. *Sonchus oleraceus*
6. *Portulaca oleracea*
7. *Amaranthus retroflexus*
8. *Chenopodium album*
9. *Digitaria sanguinalis*
10. *Erigeron canadensis*

The control of weeds was extremely poor when strategies involving pre-emergence herbicides were used (Table 1). Alachlor + simazine at 2,0 + 2,0 kg/ha controlled 98 % of the annual species such as *Sonchus*, *Portulaca*, *Amaranthus*,*Chenopodium* and *Digitaria*. The most resistant of all was *Erigeron canadensis*. Pendimethalin controlled *Digitaria sanguinalis* well and *Chenopodium album* less effectively. When pendimethalin was applied with imazethapyr the control was more efficient against annual dicotyledonous weeds.

The most important results were those obtained by applying post-emergent herbicides in order to control the perennial species. Glyphosate applied at a rate of 1.8 kg/ha gave 98 % control of the perennial species *Cynodon dactylon*, *Convulvulus arvensis* and *Cirsium arvense*. When it was applied at a lower rate (0,98 kg/ha), the efficacy was low especially for *Cynodon dactylon* which reappeared 30 days after the treatment. Nicosulfuron at a rate of 80 g/ha, gave superior control of *Cynodon dactylon* to rimsulfuron. Glufosinate only controlled all the perennial species well when two treatments were applied. When only one treatment with glufosinate was applied all the species of perennial weeds reappeared after 30-45 days. The yields of apples produced in 1991-1992 (Table 1) are very well correlated with the degree of control of perennial weeds. When the soil was infested strongly with *Cynodon dactylon*, the apple yield decrease by over 5 t/ha or by over 50% comparing with the yield of weed-free soil.

The results from 1993-1994, (Table 2) are similar to those of 1991-1992. In this experiment, the herbicides applied preemergence (dimethenamid + simazine were very effective (96-98 %) in controlling annual species but had no effect on

Table 1. Efficacy of different strategies for annual and perennial weed control in apple orchards (cv. James Grieve, 1991 - 1992)

Weed control strategy	Rate kg. a.i. /ha	Time[a] of applic.	Weed control % (October)		Fruit yield	
			Annual weeds	Perennial weeds *	t/ha[b]	% control 1
1. Control I - 5 hoeings	-	-	100	100	9.8	100
2. Control II - not hoed	-	-	0	0	4,0	40
3. Alachlor + simazine	2,0 + 2,0	pre	98	0	6,5	66
4. Alachlor + simazine + imazethapyr	1,0 + 1,0 + 0,1	pre	92	0	6,9	70
5. Alachlor + simazine + imazethapyr	1,0 + 1,0 + 0,2	pre	96	0	7,3	74
6. Pendimethalin	1.900	pre	62	0	5,0	51
7. Pendimethalin + imazethapyr	1,3 + 0,2	pre	87	0	7,3	74
8. Alachlor + simazine +	2,0 + 2,0	pre				
Glyphosate	0,980	post	97	70	8,0	81
9. Alachlor + simazine +	2,0 + 2,0	pre	98			
Glyphosate	1.800	post		98	9,0	92
10. Pendimethalin + imazethapyr +	1,3 + 0,2	pre	85			
Glyphosate	0,980	post		72	8,4	85
11. Pendimethalin + imazethapyr +	1,3 + 0,2	pre	84			
Glyphosate	1,800	post		99	8,9	91
12. Alachlor + simazine +	2,0 + 2,0	pre				
Nicosulfuron	0,080	post	99	80	8,5	87
13. Alachlor + simazine +	2,0 + 2,0	pre				
Rimsulfuron	0,012	post	99	68	8,0	81
14. Alachlor + simazine +	2,0 + 2,0	pre				
Glufosinate	0,750	post	96	67	8,3	84
15. Alachlor + simazine +	2,0 + 2,0	pre				
Glufosinate +	0,750	post I	99	92	8,8	89
Glufosinate	0,750	postII				

[a] Pre = preemergence; post = post emergence; [b] LSD fruit yield t/ha, 5% = 0.83; 1 % = 1,10; 0,1 % = 1.43

Table 2. Efficacy of different strategies for annual and perennial weed control in apple orchards (cv. James Grieve, 1993 - 1994)

Weed control strategy	Rate kg. a.i. /ha	Time of applic.	Weed control % (October)		Yield	
			Annual weeds	Perennial weeds	t/ha[a]	%
1. Control I - 5 hoeings	-	-	100	98	9.0	100
2. Control II - not hoed	-	-	0	0	4,2	46
3. Dimethenamid + simazine	0,9 + 1,5	pre	86	0	6,6	73
4. Dimethenamid + simazine	1,2 + 2,0	pre	93	0	6,7	74
5. Dimethenamid + simazine	0,9 + 1,5	pre				
Glyphosate + dicamba + 2,4-D	1,0 + 0,2 + 0,8	post	98	90	8,6	95
6. Dimethenamid + simazine +	1,2 + 2,0	pre				
Glyphosate + dicamba + 2,4-D	1,0 + 0,2 + 0,8	post	99	93	8,8	98
7. Dimethenamid + simazine	1,2 + 2,0	pre				
Rimsulfuron	0,012	post	98	62	7,0	77
8. Dimethenamid + simazine	1,2 + 2,0	pre				
Rimsulfuron	0,018	post	98	69	7,3	81
9. Dimethenamid + simazine	1,2 + 2,0	pre				
Glyphosate	0,980	post	97	70	8,0	89
10. Dimethenamid + simazine	1,2 + 2,0	pre				
Glyphosate	1,960	post	97	98	8,8	98
11. Alachlor + dimethenamid +	1,2 + 2,0	pre				
Imazethapyr +	0,100	post	98	40	6,9	76
Clethodim	0,120	post II				
12. Alachlor + dimethenamid +	1,2 + 2,0	pre				
Imazethapyr +	0,100	post I	96	50	7,0	77
Clethodim	0,180	post II				
13. Alachlor + dimethenamid +	1,2 + 2,0	pre				
Imazethapyr +	0,100	post I	99	82	7,6	84
Clethodim	0,240	post II				
14. Alachlor + dimethenamid +	1,2 + 2,0	pre				
Imazethapyr +	0,100	post I	96	90	8,4	93
Clethodim	0,480	post II				
15. Simazine	3,000	pre				
Imazethapyr +	0,100	post I	98	90	8,6	95
Glyphosate + dicamba + 2,4-D	1,0 + 0,2 + 0,8	post II				

[a] LSD fruit yield, t/ha, 5 % = 0.97; 1 % = 1.20; 0,1 % = 1.56

controlling the perennials. Similar results in controlling annual weeds were obtained when alachlor + dimethenamid + imazethapyr were used. For controlling perennial weeds, especially *Cynodon dactylon*, the best results were obtained using strategies in which glyphosate was applied at rates of 1.96 kg/ha. At a rate of 0.98 kg/ha *Cynodon dactylon* was not entirely destroyed. Similar results were obtained when glyphosate + dicamba+2,4-D were applied.
Rimsulfuron applied at rates of 12 or 18 g/ha had little effect on *Cynodon dactylon*. Clethodim only controlled *Cynodon dactylon* well enough when rates of 0.24 - 0.48 kg/ha were applied. At lower rates, *Cynodon dactylon* reappeared.

CONCLUSIONS

In order to control more effectively the annual and perennial weeds, including *Cynodon dactylon*, we recommend the following three strategies:

STRATEGY No1 based on preemergent treatments with alachlor + simazine at rates of 2 + 2 kg/ha and a post-emergent treatment with glyphosate at rates of 1.8 - 1.9 kg/ha.

STRATEGY No 2 based on pre-emergent treatments with dimethenamid + simazine (1.2 + 2 kg/ha) and a post-emergent treatment with glyphosate + dicamba + 2,4-D (1.0 +0.2 +0.8 kg/ha)

STRATEGY No 3 based on pre-emergent treatments with pendimethalin + imazethapyr (1.3 + 0.2 kg/ha) and on a post-emergent treatment with glyphosate at rates of 1.8 - 1.9 kg/ha.

REFERENCES

Gainor J D, Marriage P B, Layne R E, Hamill A.S. (1982) Weedmanagement systems and herbicide residues in nursery trees and newlyplanted peach orchards. *Proceedings British Crop Protection Conference Weeds* 1. 255-261

Milanova D (1995) Weed control in young peach with some soil-applied herbi cides. 9 th EWRS Symposium Challenges for Weed Science in Changing Europe. Budapest, vol. 2. 347-350

Mitchell R B (1987) Evalution of herbicides in establishing stone fruit, *Pro ceedings New Zeeland Weed Control Conference*, 144-148

Săndulescu G H , Şarpe N (1980) . Al II-lea Simpozion Naţional de Herbologie, Piteşti, 197-204

Şarpe N (1988) Combaterea integrată a buruienilor din culturile agricole, Editura „Ceres" Bucureşti, 443-453

Tomac M , Druzetic E , Turcinov V (1986) Rezultati ispitivanja herbicida v mladium nasadima bresada na podzucju istre i Dalmacije, *Fragmenta Herbologica*, Yugoslavija, 15, 87-93

FLAX (*Linum usitatissimum*) TOLERANCE TO IMAZETHAPYR

D A WALL
Agriculture and Agri-Food Canada, Research Centre, Unit 100 - 101 Route 100, Morden, Manitoba, Canada, R6M 1Y5

N HOOKHAM
The Nottingham Trent University, Department of Life Sciences, Clifton Lane, Nottingham NG11 8NS, United Kingdom

J C P DRIBNENKI
United Grain Growers, Unit 100 - 101 Route 100, Morden, Manitoba, Canada, R6M 1Y5

ABSTRACT

Greenhouse and field studies were conducted in 1994 and 1995 to evaluate the tolerance of flax cultivars to postemergence applications of imazethapyr. In the greenhouse FP 967, a transgenic flax line resistant to sulfonylurea herbicides, was more tolerant to imazethapyr than untransformed cultivars. The imazethapyr dosage required to reduce plant fresh weight by 50% was >800 g ai/ha for FP 967 compared with 230 to 256 g/ha for untransformed flax cultivars. In the field, crop injury following imazethapyr application increased concomitant with dosage. Imazethapyr stunted flax plants and delayed flowering by 1 to 6 days. Flax yields did not differ from the untreated control plot in 1994. In 1995, 50 to 100 g/ha of imazethpyr reduced the seed yield of Linola 947 flax, but not Eyre or McGregor flax.

INTRODUCTION

Several troublesome weeds often escape control with herbicides currently recommended for broadleaf weed control in flax, eg. *Galium aparine*, *Amaranthus retroflexus* and *Galeopsis tetrahit*. There are many anecdotal reports of farmers applying low doses of chlorsulfuron or thifensulfuron in tank mixtures with recommended broadleaf herbicides to improve control of these and other weeds. However, low doses of sulfonylurea herbicides may injure flax and reduce seed yields (Derksen and Wall, unpublished data). Research conducted in Australia has suggested that edible oil flax lines (solin and linola) are tolerant to postemergence applications of imazethapyr (C. Kidd, Personal Communication). In western Canada, imazethapyr is registered for use on field pea and alfalfa at 50 g ai/ha and product labels caution against subsequent cropping with sensitive broadleaf crops, including flax. The objective of this study was to investigate the tolerance of flax cultivars to postemergence applications of imazethapyr under western Canadian growing conditions.

MATERIALS AND METHODS

Greenhouse Study.

A dose response study was conducted to evaluate the tolerance of flax cultivars to imazethapyr.

Flax seed was planted in 13 cm diam. pots filled with a mixture of soil:peat:sand:vermiculite (3:2:1:1). Pots were thinned to six plants 1 week after emergence. Cultivars included industrial oil types (NorLin and McGregor), edible oil types (Eyre, Linola 947, and Linola 989) and a transgenic sulfonylurea resistant line (FP 967). Imazethapyr was applied at 0, 12.5, 25, 50, 75, 100, 200, 400, and 800 g ai/ha plus a nonionic surfactant at 0.25% v/v when the plants were 10 to 15 cm tall. Herbicide treatments were applied in a spray chamber equipped with a TeeJet 8001EVS flat-fan nozzle delivering 200 l/ha of total solution at 207 kPa. The experimental design was a split-plot with six replicates. Main and subplot effects were cultivars and herbicide dosage, respectively. Plants were harvested 4 weeks after treatment (WAT) and total plant fresh per pot measured. Data were analyzed by ANOVA and nonlinear regression. The following nonlinear model was used to describe the relationship between herbicide dosage and flax fresh weight: $Y = a + e^{(b + cX)}$, where a, b, and c are estimated nonlinear regression parameters and X is imazethapyr dosage. The herbicide dosage required to reduce flax fresh by 50 percent (GR_{50}) was calculated for each cultivar.

Field Study.

The tolerance of three flax cultivars to imazethapyr was evaluated at Morden in 1994 and 1995 and Rosebank, Manitoba in 1995. The experimental design was a split-plot with four replicates. Main and subplot effects were cultivars (Eyre, Linola 947, and McGregor) and imazethapyr dosage, respectively. Flax seed was planted 5 cm deep in 18 cm wide rows at 47 kg/ha. Imazethapyr was applied at 0, 12.5, 25, 50, and 100 g/ha plus a nonionic surfactant at 0.25% v/v when the flax was 10 to 15 cm tall. Standard herbicide treatments were included in 1995 only. Herbicides were applied with a small plot sprayer equipped with TeeJet SS8002 flat-fan nozzles delivering 139 l/ha of water at 276 kPa. Crop injury was estimated visually 2 and 4 WAT on a 0 to 100% scale, where 0, 15, and 100% corresponded to no visible effect, maximum injury permitted for commercial acceptance, and complete crop mortality. Plant height was determined 4 WAT. Days to flower were estimated visually; flax was considered in flower when 50% of the blossoms had opened. Flax yields (g/m^2) were recorded and seed oil content (%) determined by nuclear magnetic resonance (Robertson and Morrison, 1979). Data was analyzed by ANOVA and means separated by Fisher's LSD at P=0.05.

RESULTS AND DISCUSSION

Greenhouse study.

The cultivar by herbicide interaction was significant for flax fresh weight in both trials. For all cultivars, flax fresh weight decreased with increasing imazethapyr dosage (Figure 1). Eyre, Linola 947, Linola 989, McGregor, and NorLin were more sensitive to imazethapyr than FP 967. Tolerance among sulfonylurea sensitive flax lines were similar and GR_{50} values ranged from 230 to 256 g/ha of imazethapyr compared to GR_{50} values of >800 g/ha for FP 967 (Table 1). However, at recommended field dosages of 50 g/ha of imazethapyr there was little difference among cultivars and fresh weight was reduced by 15 to 17% for untransformed cultivars compared with 10% for FP 967.

Field study.

Crop tolerance did not differ markedly among cultivars in 1994 (Table 2). In 1994, crop injury at 100 g/ha of imazethapyr was unacceptable 2 WAT, but flax had recovered by 4 WAT and injury

Table 1. Estimated nonlinear regression coefficients for flax fresh weight response to imazethapyr dosage and calculated GR_{50} values.

Cultivar	Regression coefficients[a] *a*	*b*	*c*	R^2	GR_{50}
Eyre	6.026	2.409	-0.0061	0.88	239
FP 967	9.507	2.274	-0.0042	0.90	>800
Linola 947	5.702	2.373	-0.0058	0.86	250
Linola 989	5.061	2.480	-0.0048	0.94	256
McGregor	5.863	2.375	-0.0057	0.93	258
NorLin	6.148	2.511	-0.0060	0.90	230

[a]Model: $Y = a + e^{(b + cX)}$ where a, b and c are estimated regression coefficients and X is imazethapyr dosage (g ai/ha).

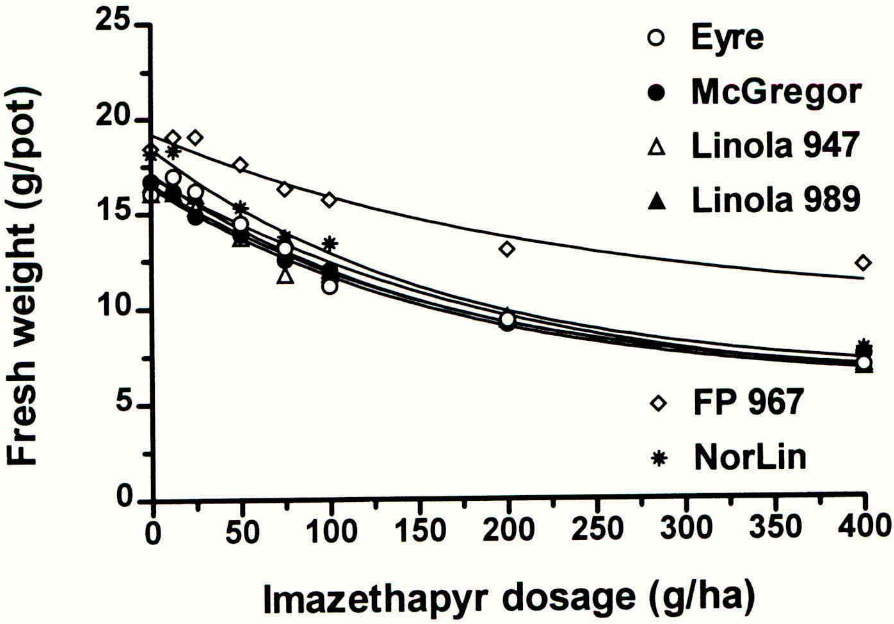


Figure 1. Dose response of six flax cultivars to imazethapyr.

Table 2. Effect of postemergence applications of imazethapyr on flax crop injury and plant height.

			Crop injury (%) 2 and 4 WAT						Plant height 4 WAT (cm)		
			1994		1995						
		Dosage	MOR[a]		MOR		RB[a]		1994	1995	
Cultivar	Treatment	(g ai/ha)	2	4	2	4	2	4	MOR	MOR	RB
Eyre	Untreated		0	0	0	0	0	0	44	46	60
Eyre	Bromoxynil + MCPA	280 + 280	-	-	4	1	2	1	-	45	59
Eyre	Bromoxynil + MCPA + thifensulfuron	280 + 280 + 2	-	-	5	2	4	3	-	45	59
Eyre	Imazethapyr	12.5	1	0	3	4	12	1	46	46	56
Eyre	Imazethapyr	25	5	0	4	4	18	3	46	46	55
Eyre	Imazethapyr	50	10	0	7	9	23	5	45	45	51
Eyre	Imazethapyr	100	18	8	11	12	30	7	43	41	50
Linola 947	Untreated		0	0	0	0	0	0	67	60	83
Linola 947	Bromoxynil + MCPA	280 + 280	-	-	5	3	2	3	-	51	78
Linola 947	Bromoxynil + MCPA + thifensulfuron	280 + 280 + 2	-	-	9	4	4	5	-	45	68
Linola 947	Imazethapyr	12.5	5	1	3	1	8	2	66	58	74
Linola 947	Imazethapyr	25	9	2	4	1	12	7	65	56	67
Linola 947	Imazethapyr	50	16	9	6	3	18	12	65	52	57
Linola 947	Imazethapyr	100	26	14	11	7	22	15	63	44	57
McGregor	Untreated		0	0	0	0	0	0	65	54	81
McGregor	Bromoxynil + MCPA	280 + 280	-	-	6	2	2	3	-	45	75
McGregor	Bromoxynil + MCPA + thifensulfuron	280 + 280 + 2	-	-	7	3	4	4	-	48	75
McGregor	Imazethapyr	12.5	4	3	4	1	8	6	64	55	75
McGregor	Imazethapyr	25	7	8	3	1	13	9	66	55	71
McGregor	Imazethapyr	50	18	14	7	3	21	9	63	53	57
McGregor	Imazethapyr	100	30	20	13	7	29	15	57	42	53
LSD (P = 0.05)											
Cultivar			3	4	ns	2	ns	2	4	ns	6
Herbicide Treatment			2	2	2	2	4	3	2	3	4
Cultivar x Herbicide Treatment			4	3	ns	3	ns	ns	3	4	7

[a] MOR = Morden; RB = Rosebank.

[ns] Not significantly different according to ANOVA.

Table 3. Effect of imazethapyr on flax days to flower at Morden and Rosebank and flax seed yield at Morden.

			Days to flower			Seed yield (g/m^2)	
		Dosage	1994	1995			
Cultivar	Treatment	(g ai/ha)	MOR[a]	MOR	RB[a]	1994	1995
Eyre	Untreated		42	38	42	215	145
Eyre	Bromoxynil + MCPA	280 + 280	-	40	43	-	151
Eyre	Bromoxynil + MCPA + thifensulfuron	280 + 280 + 2	-	43	45	-	156
Eyre	Imazethapyr	12.5	43	42	43	231	151
Eyre	Imazethapyr	25	43	42	43	233	130
Eyre	Imazethapyr	50	45	44	44	230	176
Eyre	Imazethapyr	100	47	45	45	233	123
Linola 947	Untreated		56	49	57	309	274
Linola 947	Bromoxynil + MCPA	280 + 280	-	49	58	-	235
Linola 947	Bromoxynil + MCPA + thifensulfuron	280 + 280 + 2	-	50	60	-	210
Linola 947	Imazethapyr	12.5	56	49	56	332	256
Linola 947	Imazethapyr	25	57	50	57	322	241
Linola 947	Imazethapyr	50	60	50	59	337	193
Linola 947	Imazethapyr	100	61	51	60	304	177
McGregor	Untreated		54	47	55	311	239
McGregor	Bromoxynil + MCPA	280 + 280	-	49	56	-	229
McGregor	Bromoxynil + MCPA + thifensulfuron	280 + 280 + 2	-	50	58	-	196
McGregor	Imazethapyr	12.5	56	47	56	323	211
McGregor	Imazethapyr	25	57	49	57	337	214
McGregor	Imazethapyr	50	60	50	58	329	185
McGregor	Imazethapyr	100	62	51	60	291	199
LSD (P = 0.05)							
Cultivar			1	2	1	20	52
Herbicide Treatment			1	1	1	12	24
Cultivar x Herbicide Treatment			1	1	1	ns	41

[a]MOR = Morden; RB = Rosebank.

[ns]Not significantly different according to ANOVA.

was within the limits of commercial acceptability, ie. <15 percent. In 1995, visual estimates of crop injury were acceptable at 2 and 4 WAT at Morden for all imazethapyr dosages tested. At Rosebank, however, flax treated with 25 to 100 g/ha of imazethapyr exhibited severe injury at 2 WAT, but by 4 WAT the crop had recovered and injury was $\leq$15% (Table 2). Injury symptoms consisted of chlorosis and stunting. Stunting was the most persistent symptom of imazethapyr injury. Eyre is a short stemmed flax cultivar and reductions in plant height were less noticeable than for NorLin or Linola 947. In 1994, flax height 4 WAT was reduced by 1 cm for Eyre and 4 - 8 cm for NorLin and Linola 947 at 100 g/ha of imazethapyr compared with untreated plots. However, at 50 g/ha of imazethapyr, plant height did not differ significantly from the untreated check for any cultivar. Height reductions were greater in 1995 than in 1994 and, at 4 WAT, 50 to 100 g/ha of imazethapyr reduced the height of Eyre by 1 to 10 cm, NorLin by 1 to 28 cm and Linola 947 by 8 to 27 cm compared with the untreated check plot. Similar reductions in plant height have been observed following application of sulfonlyurea herbicides in flax (Courtney, 1986; Derksen and Wall, unpublished data).

Imazethapyr delayed flowering in all three flax cultivars (Table 3). Averaged over the three location years, 50 g/ha of imazethapyr delayed flowering of Eyre, Linola 947 and McGregor by 3, 2 and 4 days, respectively. Flowering in plots treated with the standard herbicide treatment of bromoxynil plus MCPA was delayed by 1 to 2 days compared to the untreated control, which was similar to delays observed with 25 g/ha of imazethapyr. In 1994, the 50 g/ha dosage of imazethapyr delayed Eyre, Linola 947 and McGregor maturity by 3, 4, and 5 d, respectively (data not presented). The same dosage delayed maturity by 3 days in 1995, regardless of cultivar (data not presented).

The cultivar by herbicide treatment interaction was not significant for flax yield in 1994 (Table 3). Flax yields did not differ significantly between the untreated control plot and any dosage of imazethapyr tested. In 1995, seed yields of Eyre or McGregor were unaffected by 100 g/ha of imazethpyr compared with the untreated or bromoxynil + MCPA control plots. However, both the 50 and 100 g/ha dosage of imazethapyr reduced the yield of Linola 947 compared with the untreated or bromoxynil + MCPA control plots. The herbicide and cultivar x herbicide interaction for seed oil content was not significant in 1994 (data not presented).

Based on these results, imazethapyr at 25 to 50 g ai/ha may have potential as a new herbicide treatment for managing annual broadleaf weeds in flax. Further testing is required, however, to investigate the effects of location and environment on flax tolerance to imazethapyr.

REFERENCES

Courtney, A. D. (1986) A comparison of herbicide regimes for weed control in fibre flax. *Tests of Agrochemicals and Cultivars (Annals of Applied Biology 108)* **7**, 88-89.

Robertson, J. A. and W. H. Morrison (1979) Analysis of oil content of sunflower seed by wide-line NRM. *Journal of the American Oil Chemists Society* **56**, 961-964.