SESSION 8C POSTER

APPLIED ASPECTS OF WEED CONTROL

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THE CONTROL OF CYNODON DACTYLON IN VINES WITH FLUAZIFOP-BUTYL

J. Targanyi
Interco-operation R.T., ICI Iroda, Budapest

J. Mikulas
Institute for Wine Research, Kecshemet

Summary. The weed flora in vines has undergone many changes due to cultural practices and one perennial grass, Cynodon dactylon presents a most difficult problem.

During 1981, field trials were conducted with fluazifop-butyl against this weed in severely infested vineyards. Laboratory tests were also completed.

Fluazifop-butyl was herbicidally active against grass weeds at rates of 0.5-8 kg ai/ha. No harmful effects were seen on vines. Increasing doses caused greater control of both foliage and nodes of C. dactylon. Laboratory studies on C. dactylon treated in the field confirmed this trend and also showed greater control of regrowth with increasing dose of fluazifop-butyl. Very good control of C. dactylon growing from undisturbed rhizomes was recorded in field tests during 1981 and 1982 with 2 kg ai/ha fluazifop-butyl.

Further trials are in progress to determine the optimum growth stage for treatment with fluazifop-butyl.

INTRODUCTION

The weed flora of vines has changed considerably due to the regular use of fertilizers, herbicides and mechanical cultivation methods. Decreased mechanical cultivation with the use of herbicides has favoured perennial weeds such as Cirsium arvense, Sonchus arvensis, Convolvulus arvensis, Taraxacum officinale, Agropyron repens and Cynodon dactylon, (Harmann 1981). Control of these perennial weeds is necessary as they are harmful to vines not only by competing for moisture and nutrients but also A. repens and C. dactylon produce toxins which damage root hairs (Mez 1961).

Annual weeds, and at higher rates perennial weeds, have been controlled with triazine type pre-emergence herbicides but these can prove harmful to the vines (Hegedus 1962; Hunyardi 1980). The problematic grass weed in vines is C. dactylon and although herbicides such as dalapon, paraquat and glyphosate are effective, there are problems of safety to vines and variation in performance due to climatic conditions (Johnson 1980).

Evidence from earlier trials results in 1980 against C. dactylon with fluazifop-butyl (unpublished) and also those of Finney-Sutton 1980; Plowman et al 1980; Sarpe, Dinu 1980 encouraged further trials during 1981 and 1982.

METHODS AND MATERIALS

Trials were carried out in the Institute for Wine Research in Kecshemet, Hungary during 1981 and 1982.

The vine variety was of the 'Kadorka' type, a hardy variety resistant to the strong winter and spring frost. The vines were planted in wide rows (240 cm) and were 15 cm high at the time of spraying. Spray from the treatments reached most of the vine foliage which in some cases prevented spray reaching C. dactylon growing underneath. Temperature at the time of application was 26°C and relative humidity was 50%.

Fluazifop-butyl formulated as an emulsifiable concentrate containing 250 gms/litre ai ('Fusilade' EC) was tested at 0.5, 1, 2, 4 and 8 kg a.i./ha. Plot size was 10 m^2 with four replicate plots. Application was made using 'SHS' Japanese sprayer fitted with Teejet 1006 nozzle. Each treatment was applied in the equivalent of 500 litres/ha of water. Treatments were applied on 12 June 1981 when the C. dactylon had achieved complete ground cover. The C. dactylon had not been mechanically cultivated for 20 years so rhizomes and stolons were undisturbed.

Assessments were made one month after treatment and only the upper 10 leaves and nodes were examined. The number of dessicated leaves and nodes were recorded and only fully dessicated leaves were recorded as dead. Brown, rotten nodes were counted as dried stems.

Laboratory studies were carried out on rhizomes of C. dactylon treated with fluazifop-butyl in the field. Rhizomes from each treatment were collected, cut into segments and grown on for 14 days in controlled environment cabinets. The number and length of shoots regrowing from the rhizomes were recorded for each treatment.

RESULTS

Field results from 1981 are expressed graphically in Figure 1 with Y-axis showing the number of dead leaves and nodes and the x-axis showing the dose of fluazifop-butyl.

The number of dead leaves and nodes of C. dactylon increased with increasing dose of fluazifop-butyl. Doses from 0.5 to 2 kg a.i. killed the upper three to four leaves within a month, the youngest leaves being the first to die. 4 kg a.i./ha killed 8 leaves and more than 4 nodes. 8 kg a.i./ha killed the complete plant with an average of 5 nodes dead per plant. Untreated plots showed no differences.

No harmful effects were seen on vines even at the highest doses tested.

The laboratory studies on rhizomes collected from the treated field plots are shown in Figure 2. The results indicated a good correlation between increasing dose of fluazifop-butyl and the control of the number of shoots regrowing from rhizome pieces. There is also a correlation, although less dramatic, between increasing doses of fluazifop-butyl and the reduction of shoot length.

Figure 1

C. dactylon control in vines with fluazifop-butyl
Kecskemet 1981

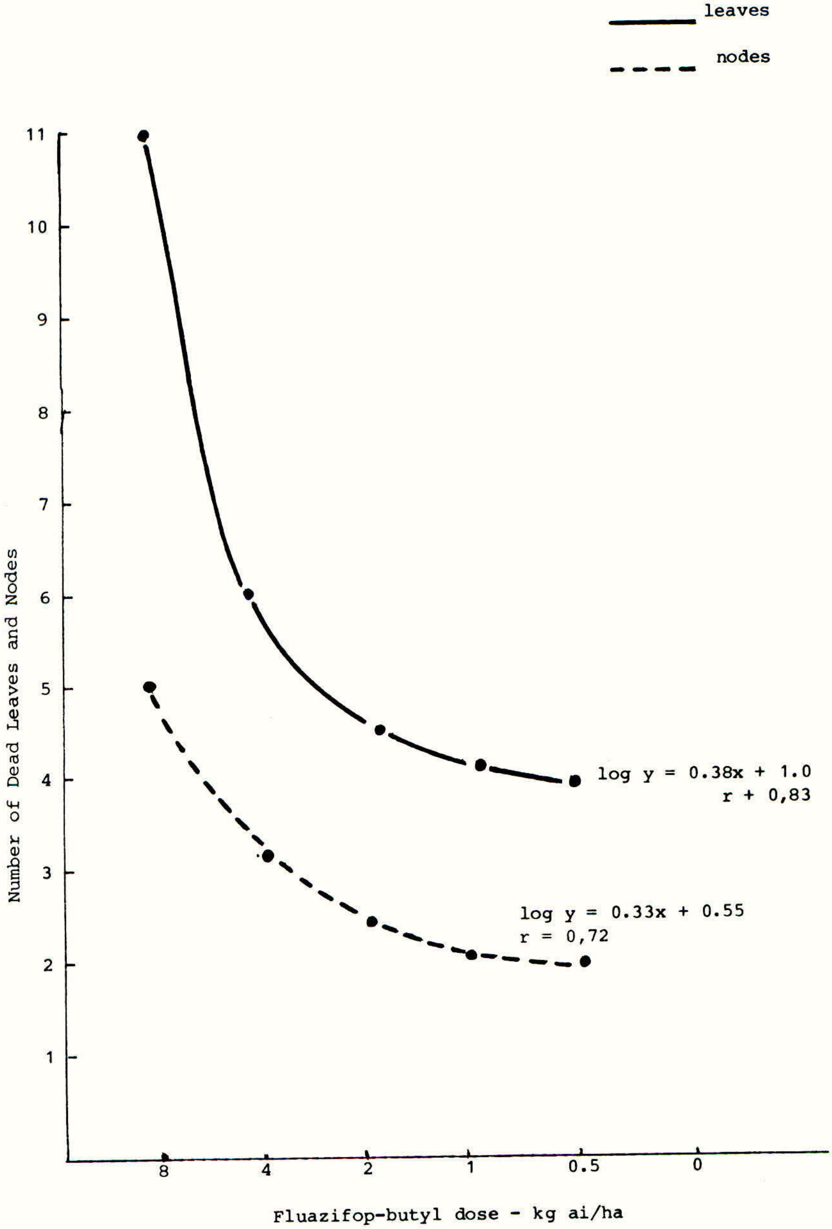

Figure 2

Control of C. dactylon shoots regrowing from rhizome pieces taken from field material treated with fluazifop-butyl

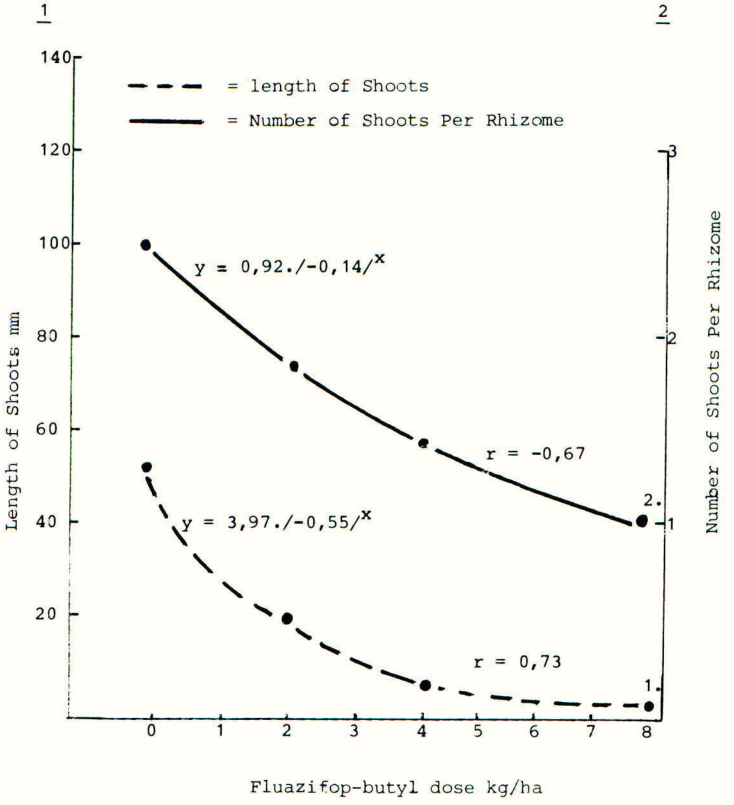

Table 1

Control of C. dactylon in vines with fluazifop-butyl, Kecshemet 1982

Dose kg/ha	EWRC Value of Replicate Plants				Average EWRC
	1	2	3	4	
0	9	9	9	9	9
0.5	7	7	6	6	6,5
1	6	7	5	6	6
2	2	3	2	3	2,5
4	1	2	1	2	1,5
8	1	1	1	1	1

Results from field trials in 1982 carried out in a similar manner to experiments already described in this paper confirm the trends shown in 1981 and are shown in Table 1. Assessments have been made using the EWRC scale where 9 = healthy and 1 = complete kill.

DISCUSSION

C. dactylon in vines can be controlled effectively with fluazifop-butyl at doses up to 8 kg a.i./ha. The results from two years trials have been consistent with a dose of 2 kg a.i./ha giving acceptable control in this situation where the rhizomes have remained undisturbed for over 20 years. Plowman, et al 1980 suggest lower doses of fluazifop-butyl can be used where the rhizomes of perennial grasses have been fragmented by mechanical cultivation. Fluazifop-butyl has shown a high level of safety to vines with even the highest dose, 8 kg a.i./ha showing no harmful effects.

Fluazifop-butyl will cause death of leaves and nodes of C. dactylon. Increasing the dose of fluazifop-butyl, will cause greater death of leaves and nodes within a month. A similar trend is shown for control of shoots regrowing from treated rhizomes. The increased dose of fluazifop-butyl causes reduction in the number and length of shoots regrowing from the treated rhizome pieces.

More work is required to study not only the optimum growth stage for C. dactylon control by fluazifop-butyl but also the optimum doses and application method.

ACKNOWLEDGEMENTS

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FURTHER STUDIES IN THE LONG TERM CONTROL OF SORGHUM HALEPENSE IN SOYABEAN CROPS WITH FLUAZIFOP-BUTYL, ALLOXYDIM SODIUM AND GLYPHOSATE

N Sarpe, F Popa, C Dinu

Research Institute for Cereals and Industrial Plants,
Fundulea, Romania

Summary

The results obtained in 1980;1982 showed that the most effective control of rhizome *Sorghum halepense*, was obtained with treatments containing fluazifop-butyl at the rate of 0.75 kg a.i/ha. Alloxydim-sodium and glyphosate were less effective.

After soyabeans were treated with fluazifop-butyl, alloxydim-sodium and glyphosate, trial plots were planted with sunflower and winter wheat (in subsequent years (1981 and 1982)). It was found in those plots treated originally with fluazifop-butyl in 1980, *Sorghum halepense* did not regenerate from rhizomes. A yield increase resulted in the following year. This effect was not recorded with alloxydim-sodium and glyphosate. Soyabean, Sorghum halepense, fluazifop-butyl, alloxydim-sodium, glyphosate.

INTRODUCTION

Many new selective herbicides are able to control all annual and perennial grass weeds in broad leaf crops. The effectiveness of fluazifop-butyl in the control of annual and perennial grass weeds was demonstrated by the studies carried out in England and USA by Plowman et al. (1980) and Hart (1981). Sarpe and Dinu (1980) also obtained a good control of *Sorghum halepense* (from seeds and rhizomes) with fluazifop-butyl in soyabean crops. Positive results were also obtained in the control of *Avena fatua* and *Agropyron repens* by Slater and Hirst (1980) with alloxydim-sodium.

In Southern Romania (mainly in the Danube Plain) soyabean, maize, sunflower, sugarbeet and bean crops are severely infested by *Sorghum halepense* growing from seeds and rhizomes. Fluazifop-butyl, alloxydim-sodium and glyphosate were tested. (For the control of *Sorghum halepense*, in particular from rhizomes). Observations were continued on the long term effect of the herbicide treatments on *Sorghum halepense* rhizomes in the second and third year.

MATERIALS AND METHODS

Experiments were conducted at Fundulea on soyabean ovar, Flora, on medium-leached cherpnozem soil containing 3.5% humus and 36% clay. Trifluralin and metribuzin were incorporated in the soil (ppi) before sowing to a depth of 8-10 cm with a rotatiller. Alloxydim-sodium and fluazifop-butyl were applied post-emergence as a tank-mix with bentazon when seedling *Sorghum halepense* was 5-10 cm high and shoots, emerging from rhizomes, were 15-20 cm high. Details of the treatments are given in table 1.

At Braila in the Danube Plain, the experiments were carried out with irrigation on alluvial soil highly infested by rhizome Sorghum halepense. The herbicide rates and timing of treatments are given in tables 2 and 3. The herbicide glyphosate ('Round-up') was applied at the stage when most weeds were 60-80 cm high. The treatment was applied above soyabean plants using an applicator designed by Monsanto. During the vegetative period observations were made on herbicide selectivity and efficacy. The total weight of weeds and, separately, of Sorghum halepense were measured prior to soyabean or sunflower harvesting. The regeneration of weeds from rhizomes was assessed in the sunflower crop in the second year, and after harvesting winter wheat in the third year.

RESULTS

In addition to Sorghum halepense (representing more than 70-80% of all weed species present), several dicotyledonous species such as Amaranthus retroflexus, Chenopodium album, Thlaspi arvense and Cirsium arvense were present. The data presented in table 1 show that fluazifop-butyl was the most effective giving 97% control of Sorghum halepense. The alloxydim-sodium treatment gave a good control of Sorghum halepense emerging from seeds but a poor effect against rhizome Sorghum halepense. After 30-40 days new shoots appeared from the rhizomes of treated plants, which eventually headed and formed seeds by early autumn. The regrowth reduced the growth of soyabean plants and resulted in a significant reduction of the yields. The higher yields recorded in the plots treated with fluazifop-butyl are due to the high level intitial control of the weeds and the excellent suppression of regrowth from rhizomes. The level of regeneration of Sorghum halepense from rhizomes after treatment with fluazifop-butyl remained at a low level throughout the second and third year. This effect was not observed with alloxydim-sodium and glyphosate.

In the experiments conducted at Braila, Sorghum halepense was the dominant weed but weeds such as Chenopodium album, Xanthium strumarium, Abutilon theophrasti and Solanum nigrum were also present at very low levels. With such weed populations as shown in table 2, the most successful control of Sorghum halepense was recorded with fluazifop-butyl + bentazon treatment. Two weeks after the treatment the weed turned brown and gradually dessicated. In the autumn no regrowth appeared from the rhizomes. On average over 2 years, the highest soyabean yields were obtained with this treatment.

Alloxydim-sodium was less effective against Sorghum halepense, particularly against the plants growing from rhizomes, 2-3 weeks after treatment, regrowth occurred and prior to soyabean harvesting the infestation level was very high and adversely affected the yields of soyabean.

Very poor results were also obtained in the plot treated by "smearing" with glyphosate. Those weeds left untouched were less high than soyabean plants and grew vigorously up to the autumn. This caused soyabean yields to be decreased by 48%. In soyabean crops highly infested by Sorghum halepense from rhizomes, the "smearing" - method with glyphosate would not be successful and its economic effectiveness is far lower than that of selective herbicides controlling Sorghum halepense from seeds and rhizomes.

Table 1

Effect of different herbicides in the control of *Sorghum halepense* in rainfed soyabean and long term effect on the rhizomes, Fundulea, 1979-1981

Average results 1979-1981

Herbicides	Dose kg a.i/ha	% Weed control *Sorghum halepense*	Yield soyabean kg/ha	%
Control 3 hoeings	-	30	2300	100
Control - not hoed	-	0	650	28
Trifluralin + metribuzin	0.96+0.35	27	1200	52
Alloxydim-sodium + bentazon	1.5 +1.92	40	1630	71
Fluazifop-butyl + bentazon	0.75+1.92	97	2380	100

LSD 5% 200 kg
1% 380 kg

Average results 1980-1981

Herbicides	Dose kg a.i/ha	*S.halepense* regrowth from rhizomes EWRS scale
Control 3 hoeings	-	6.0
Control -not hoed	-	9.0
Trifluralin + metribuzin	0.96+0.35	9.0
Alloxydim-sodium + bentazon	1.5 +1.92	9.0
Fluazifop-butyl + bentazon	0.75+1.92	2.0

x) EWRS scale: 1. No shoots appeared from *Sorghum halepense* rhizomes.

9. Regrowth of 95-100% new shoots from *Sorghum halepense* rhizomes.

Table 2
Effectiveness of different herbicides in irrigated soyabean
Braila, 1980-1981

	Herbicides		Application method	Weed weight Total Weeds t/ha	Sorghum halepense t/ha	% Control S.halepense	Average soyabean yeild kg/ha	%
1.	Control 3 hoeings	-	-	0.0	0.0	100	3705	100
2.	Control -not hoed	-	-	37.6	19.7	0	1125	30
3.	Trifluralin + metribuzin + Bentazon	0.93+0.25 1.92	ppi post	33.4	21.0	0	1795	48
4.	Trifluralin + metribuzin + Glyphosate	0.96+0.28 1.08	ppi post	19.5	8.6	57	1935	52
5.	Trifluralin + metribuzin+ fluazifop-butyl + bentazon	0.96+0.28 0.75+1.92	ppi post	2.8	0.0	100	3815	103
6.	Trifluralin + metribuzin + Alloxydim-sodium + bentazon	0.96+0.28 2.25+1.92	ppi post	14.4	12.8	36	2205	59

Table 3
Results on the effectiveness of the herbicides
on *Sorghum halepense* regeneration from rhizomes in the 2nd and 3rd year
Braila, 1980-1981

	Herbicides	1980 Dose kg a.i/ha	1980 Application method	1980 Yield soyabean kg/ha	1981 Sunflower* Yield kg/ha	1981 Sunflower* S. halepense % regeneration	1982 Winter Wheat** Yield %	1982 Winter Wheat** S. halepense % regeneration
1.	Trifluralin + metribuzin + Bentazon	0.96+0.28 1.92	ppi post	1110	2200	100	100	100
2.	Trifluralin + metribuzin+ fluazifop-butyl + bentazon	0.96+0.28 0.75+1.92	ppi post	3190	2780	1	100	5
3.	Trifluralin + metribuzin + Alloxydim-sodium + bencazon	0.96+0.28 2.25+1.92	ppi post	1650	2170	87	100	75
4.	Trifluralin + metribuzin + Bentazon + Glyphosate	0.96+0.28 1.92 1.08	ppi post post	1280	2230	97	100	80

*) In 1981 all plots were treated with with trifluralin + prometreyne for the control of annual weeds.

**) The regeneration of *Sorghum halepense* from rhizomes was evaluated 30 days after wheat harvesting.

In a further experiment conducted at Braila in 1980, soyabean plants were treated with the herbicides listed in table 3. The most successful control of Sorghum halepense was obtained by the post-emergence treatment of fluazifop-butyl + bentazon which resulted in the highest yield. In the various treatments containing alloxydim-sodium and glyphosate, both weed control and soyabean yields were lower. The results obtained in 1981 in the sunflower crop (grown after soyabeans) are highly important from an agronomic viewpoint. The highest seed yields were obtained from those plots previously treated with fluazifop-butyl. This is probably due to the lack of regeneration from rhizomes and commensurate reduction in competition with the crop. Following the reinfestation with Sorghum halepense from rhizomes, sunflower seed yields decreased by 700 kg/ha in the plots previously treated with alloxydim-sodium and glyphosate. The results obtained in 1982 after winter wheat harvesting (grown after sunflower), revealed that the reinfestation with Sorghum halepense was again low after a further year onlyin fluazifop-butyl treated plots.

DISCUSSION

Of the herbicides tested in these experiments to control Sorghum halepense growing from seeds and in particular from rhizomes, fluazifop-butyl was the most effective, totoal control being achieved with the rate of 0.75 kg/ha. The effectiveness of fluazifop-butyl against Sorghum halepense rhizomes persisted into the third year after treatment in rotational crops following soyabeans.

Alloxydim-sodium at 2.25 kg/ha was effective in the control of seedling Sorghum halepense. In this study, alloxydim-sodium was less effective on rhizomatous Sorghum halepense and hence the benefit was not observed in subsequent rotational crops. In 1981 such crops were severely infested by this weed and the seed yields were diminished.

In this study, glyphosate, applied in soyabean crops by the "smearing" method, was not effective in the control of Sorghum halepense from rhizomes and this technique shows little promise in the control of severe infestations.

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THE CONTROL OF SORGHUM HALEPENSE AND AGROPYRON REPENS IN POTATO CROPS WITH FLUAZIFOP-BUTYL ALLOXYDIM-SODIUM AND SETHOXYDIM

N Sarpe, C Dinu

Research Institute for Cereals and Industrial Plants - Fundulea, Romania

and

P Sebok, P Gus, A Mester

Groza Institute of Agronomy, Cluj-Napoca, Romania

Summary

During 1980-1981 initial experiments were carried out in Romania for controlling perennial weeds especially *Sorghum halepense* and *Agropyron repens* using the new herbicides fluazifop-butyl, alloxydim-sodium and sethoxydim. This study demonstrates that these herbicides are selective to potatoes. Fluazifop-butyl gave better control of *Sorghum halepense* than alloxydim-sodium. Both fluazifop-butyl and sethoxydim gave good control of *Agropyron repens*. Results are presented showing selectivity, efficacy on perennial weeds and effects on potato yield. Potatoes, *Sorghum halepense*, *Agropyron repens*, fluazifop-butyl, alloxydim-sodium, sethoxydim.

INTRODUCTION

In Romania, potato crops are generally infested by annual weeds that can be well controlled with herbicides containing prometryne, terbutryne, linuron, momolinuron, metribuzin, EPTC, alachlor, metalachlor, paraquat, etc. (Sarpe et al. 1981). In different regions of Romania, potato crops are severely infested with perennial grass weeds; *Sorghum halepense* in Southern Romania and *Agropyron repens* in the Plain of Transylvania. Bredt et al. (1978) showed that these perennial weeds can be controlled by dalapon or TCA applied after cereal harvesting. This technique presents some difficulties as compared to the use of new selective herbicides in controlling *Sorghum halepense* and *Agropyron repens*. (Plowman et al. (1980), and Ingram et al. (1980).)

Experiments to control *Sorghum halepense* in potato crops began in 1980 at Fundulea with the herbicides alloxydim-sodium and fluazifop-butyl. Recent results obtained in Romania in the control of *Sorghum halepense* and *Agropyron repens* are presented.

MATERIALS AND METHODS

The experiments for the control of *Sorghum halpense* in potato crops were conducted at the Research Institute for Cereals and Industrial Plants, Fundulea, on a medium leached chernozem soil with 3.5% humus and 36% clay. In this crop, *Sorghum halepense* was prevalent (95%) as compared with the other weed species.

The trials for the control of Agropyron repens were carried out at the research farm of the Dr P Groza Institute of Agronomy, Cluj-Napoca, on leached chernozem soil heavily infested by Agropyron repens.

At both locations, the field experiments were arranged in plots of 25 m^2 replicated 4 times. The herbicide rates and time of application are given in tables 1 & 3.

At Fundulea, the pre-emergence treatments were applied immediately after potato planting, and post-emergence treatments when Sorghum halepense was 10-30 cm high. At Cluj-Napoca, post-emergence treatments with fluazifop-butyl or sethoxydim were applied Agropyron repens was 10-15 cm high.

Observations on herbicide selectivity were made during the vegetative period of the potatoes as well as herbicidal effectiveness for the control of weeds. At harvesting, tuber yield per hectare was evaluated.

To estimate the regeneration ability of Agropyron repens from the post-emergence treatments, the rhizomes were collected after potato harvesting from the soil of each plot and transplanted into fresh soil on benches in a heated glasshouse. The regrowth of Agropyron repens was assessed in the spring both in the glasshouse and field.

In order to investigate the long term (residual) effect of fluazifop-butyl and sethoxydim on Sorghum halepense, the plots were seeded in spring of 1982 with beans and treated for trifluralin and bentazon to control annual weeds.

RESULTS

The experimental results obtained at Fundulea in the control of Sorghum halepense in potato crops are summarized in tables 1-2, 10-15 cm high potato plants tolerated alloxydim-sodium and fluazifop-butyl when treated post-emergence. No phytotoxic effects were recorded in the treatments receiving maximum herbicide rates.

90-95% control of annual and mainly dicotyledonous weeds (Sinapis arvensis, Chenopodium album, Amaranthus retroflexus) was achieved with prometryne at the rate of 2.5 kg/ha.

The results on the effectiveness of herbicides in the control of Sorghum halepense from seeds and rhizomes are presented in table 1.

The Sorghum halepense infestation was very high in this experiment with 400 plants fromseeds and 200 plants from rhizomes in a single plot presenting a considerable challenge to the herbicides.

Both alloxydim-sodium and fluazifop-butyl gave a similar development of symptoms on seedling and rhizome Sorghum halepense. 7-10 days after treatment, plants turned yellow and then red. This effect was more evident on the apical rather than the basal leaves.

On seedling Sorghum halepense both chemicals gave good initial control. A second flush of plants germinating from seed after 60 days was only controlled by fluazifop-butyl probably due to a soil residual effect.

On rhizome Sorghum halepense, after 30-50 days, regrowth of new shoots was seen following alloxydim-sodium treatments. The control of regrowth with alloxydim-sodium was rate dependent, although the highest rate of 4.5 kg a.i/ha achieved only 30% control of Sorghum halepense after 60 days.

Fluazifop-butyl gave good control of rhizome Sorghum halepense, plants becoming completed dessicated by 30-40 days. Some Sorghum halepense regrowth did occur in fluazifop-butyl treatments at harvest time probably from rhizomes located deep in the soil at the time of treatment.

The average tuber yield of 1980 and 1981 correlate closely to the effectiveness of the herbicides against Sorghum halepense (table 2). The data shows that a dose related yield response up to 36% was obtained with treatments alloxydim-sodium. Yield responses of 94% were however obtained with the lowest rate of fluazifop-butyl tested.

Table 1

Effectiveness of alloxydim-sodium and fluazifop-butyl in the control of Sorghum halepense from seeds and rhizomes Fundulea, 1980-1981 (average)

Herbicides	Rate kg a.i/ha	S.halepense from seeds Post-treatment effectiveness % after 20 days	30 days	60 days	S.halepense from rhizomes Post-treatment effectiveness % after 20 days	30 days	60 days
Control 3 hoeings	-	100	100	80	100	100	60
Control - not hoed	-	0	0	0	0	0	0
Prometryne + alloxydim-sodium	2.5+1.5	100	90	80	90	40	20
Prometryne + alloxydim-sodium	2.5+3.0	100	90	85	100	60	30
Prometryne + alloxydim-sodium	2.5+4.5	100	95	85	100	60	30
Prometryne + fluazifop-butyl	2.5+0.5	100	90	90	100	100	89
Prometryne + fluazifop-butyl	2.5+1.0	100	95	95	100	100	98
Prometryne + fluazifop-butyl	2.5+1.5	100	100	100	100	100	100

Table 2
Potato tuber yields
Fundulea, 1980-1981

Herbicides	Rate kg a.i/ha	Application method	Average Yield t/ha	%
Control 3 hoeings	-	-	28.5	100
Control - not hoed	-	-	0.9	3
Prometryne + alloxidim-sodium	2.5+1.5	pre-em + post-em	7.1	25
Prometryne + alloxydim-sodium	2.5+3.0	"	10.5	37
Prometryne + alloxydim-sodium	2.5+4.5	"	10.2	36
Prometryne + fluazifop-butyl	2.5+0.5	"	26.8	94
Prometryne + fluazifop-butyl	2.5+1.0	"	27.7	100
Prometryne + fluazifop-butyl	2.5+1.5	"	29.3	103

LSD	5%	7.2
	1%	9.7
	0.1%	11.4

In the trials conducted at Cluj-Napoca, the tank mixes of metribuzin with both fluazifop-butyl and sethoxydim demonstrated a high level of selectivity to potatoes 10-20 cm high. Transient phytotoxic symptoms at a low level were observed which were typical to metribuzin.

The control of Agropyron repens with both fluazifop-butyl and sethoxydim was similar in the Cluj-Napoca trials (table 3). After treatment, 10-15 cm Agropyron repens plants turned yellow and gradually dessicated. The determinations in untreated plots made prior topotato harvesting showed that the air dried mass of Agropyron repens weighed more than 3.000 kg/ha, whereas in the plots treated with fluazifop-butyl and sethoxydim the Agropyron repens was negligible (20 kg/ha).

Table 3
Weed control in potatoes (prior to harvest)
Cluj-Napoca, 1981

Herbicides	Rate kg a.i/ha	Dry weight of weeds Total kg/ha	Dicotyledons kg/ha	Monocotyledons kg/ha	Agropyron repens control %
Control 3 hoeings	-	500	260	240	93.7
Control - not hoed	-	4160	900	3260	0.0
Metribuzin + fluazifop-butyl	1.0+1.5	400	400	0	100.0
Metribuzin + fluazifop-butyl	1.0+2.5	210	190	20	99.4
Metribuzin + sethoxydim	1.0+2.0	400	380	20	99.4

The tuber yields for this experiment are presented in table 4.

Table 4
Tuber yields in potatoes cv Desiree
Cluj-Napoca, 1981

Herbicides	Rate kg a.i/ha	Application method	Yield t/ha	Yield %
Control 3 hoeings	-	-	27.8	100
Control - not hoed	-	-	7.1	25
Metribuzin + fluazifop-butyl	1.0+1.5	post-em	23.0	83
Metribuzin + fluazifop-butyl	1.0+2.5	post-em	22.6	81
Metribuzin + sethoxydim	1.0+2.0	post-em	19.2	69

LSD 5% 6.2
8.8
10.7

It is interesting to note that the yields from chemical treatments did not reach that from the hand hoed control plot. This may be due to either the early initial phytotoxicity or from competition by broad leaf weeds which were not controlled by metribuzin.

In the glasshouse and field study to determine the effect on rhizomes taken from the Cluj-Napoca trials, both fluazifop-butyl and sethoxydim showed no regrowth of shoots from the incubated rhizomes or those in the field in 1982.

DISCUSSIONS

The studies conducted at Fundulea and Cluj-Napoca show that the herbicides fluazifop-butyl and alloxydim-sodium and sethoxydim have a good physiological selectivity for potato plants. No phytotoxicity symptoms could be observed, even at the highest rates tested, i.e. 4.5 kg/ha for alloxydim-sodium, 2.5 kg/ha for fluazifop-butyl and 2.0 kg/ha for sethoxydim.

This work shows that fluazifop-butyl controls well the perennial grass weed species Sorghum halepense at 0.5-0.75 kg/ha and Agropyron repens, at 1.5 kg/ha. At the time of the treatment, Sorghum halepense, plants grown from rhizomes should be 10-30 cm high, and those of Agropyron repens at least 10-15 cm high. Earlier application of the treatment should be avoided since new shoots can emerge from the rhizomes and stolons located deep in the soil.

In this study, alloxydim-sodium was less effective in the control of Sorghum halepense than flauzifop-butyl. After the application of alloxydim-sodium new shoots regrew from the rhizomes of treated plants. This regeneration is probably due to the low translocation rate of alloxydim-sodium.

Sethoxydim applied at 2.0 kg/ha however successfully controlled Agropyron repens and further experiments with this herbicide are in progress.

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RELATIVE TOLERANCE OF CALABRESE AND SWEDE TO THREE SPECIFIC GRAMINICIDES

H.M. Lawson and J.S. Wiseman
Scottish Crop Research Institute, Invergowrie, Dundee DD2 5DA

Summary. Alloxydim sodium had no adverse effect on growth or yield of calabrese or swede at up to 3 kg a.i./ha in 1980 or 1981. Fluazifop butyl at 1 kg a.i./ha distorted calabrese leaves in both years, while at 2 kg a.i./ha it reduced yield of spears in 1980 and delayed spear development in 1981. This herbicide reduced yield of swedes at both rates in 1980, but not in 1981. Sethoxydim at 1.29 kg a.i./ha had no effect on swedes in 1981, but distorted calabrese leaves, although less so than the double dose of fluazifop butyl. More attention should be paid to the relative safety of these graminicides to brassica crops.
Alloxydim sodium, fluazifop butyl, sethoxydim, crop safety.

INTRODUCTION

The control of perennial grasses in the brassica part of the rotation in Scotland has for many years been achieved by applying TCA just prior to drilling or transplanting. The introduction of a new range of post-emergence grass herbicides, selective in broad-leaved arable crops, offers greater flexibility in timing of application and allows the farmer to assess the extent and density of infestation before making his decision to apply a control treatment. Preliminary reports have indicated that brassica crops show acceptable tolerance to alloxydim sodium (Ingram *et al*, 1978), fluazifop butyl (Plowman, Stonebridge & Hawtree, 1980), at least to doses required for the control of annual grass weeds. Published information on the safety of the higher rates of application needed for perennial grasses is less readily available and field experience frequently relates to experiments carried out in weedy crops, where crop tolerance may be confounded with the effects of reducing competition by weeds. In these experiments weed-free crops of calabrese and swede were used to evaluate relative tolerance to the three herbicides applied at and above rates suggested for the control of *Agropyron repens*.

MATERIALS AND METHODS

The experiments were sited at Invergowrie, on sandy loam soils with organic matter content (as determined by chromic acid oxidation) of 6.5%. Two experiments were carried out in 1980 and two in 1981. In each year, calabrese cv. Corvet and swede cv. Marian were sown on the same date in adjacent experiments, each with treatments laid out in a randomised block design with 4 replicates. Plots were 4 m long and contained 4 rows, sown 38 cm apart, on the flat. Crop seedlings were singled to 22 cm apart in 1980 and 15 cm apart in 1981. Annual weeds were removed by hand at singling. In 1980 no herbicides other than the experimental treatments were applied, but in 1981, to reduce the amount of hand-weeding required, trifluralin at 1.12 kg a.i./ha was incorporated on all plots immediately prior to sowing. Perennial weeds were absent from the trial sites in both years.

Alloxydim sodium, fluazifop butyl, and sethoxydim were applied when the crops were 10-15 cm tall at the rates suggested by manufacturers for perennial grass control and at twice that rate, in medium water volume using an Oxford Precision

Sprayer. Herbicide doses are shown in Tables 1 and 2. In 1981, at the request of ICI Plant Protection, 0.1% Agral by volume was added to spray solutions containing fluazifop butyl. Sethoxydim was not available in 1980; in 1981 only the double rate of this herbicide was applied on calabrese. Harvest samples were taken from the two middle rows of each plot. For calabrese, the central spear from each plant was cut and weighed at a growth stage suitable for freezing. For swedes, all roots were cut, cleaned and weighed, once the leaves had begun to senesce.

Crop diary	1980	1981
Sowing date	11 June	11 May
Treatments applied	29 July	18 June
Harvest - Calabrese	25 August - 5 September	30 July - 10 August
Swede	13 - 17 November	30 October

RESULTS

1980 Expts. Heavy rain occurred within 12-24 h of herbicide treatment and at intervals thereafter for several days. Fluazifop butyl had no immediate effect on calabrese, but by mid August, considerable leaf cupping and malformation were recorded, particularly at the double rate (Table 1). On these latter plots, yield of spears was significantly lower than on untreated plots, due mainly to higher proportions of blind or stunted plants or of rotted spears. In swedes, no visible leaf malformation was recorded in response to application of fluazifop butyl, but yield of roots was significantly lower with both rates in comparison with the untreated control (Table 2). Alloxydim sodium had no visible effect on the foliage of either crop and did not affect recorded yield, even at the double rate of application (Tables 1,2).

1981 Expts. There was a light shower on the day after treatment; no further rain fell in the next four days. In August the swedes came under severe water stress and lost much of their foliage due to premature desiccation. Adequate rainfall from mid September onwards resulted in the production of new leaves and further development of the roots, but growth had effectively ceased by late October. Fluazifop butyl again caused leaf malformation in calabrese. Yields from treated plots were not significantly lower than on untreated plots, but crop maturity was delayed, particularly with the double rate (Table 1). This herbicide had no adverse effect on growth or yield of swedes (Table 2). Sethoxydim also produced leaf malformation in calabrese, but the effect at twice the recommended dose was no worse than that with the lower rate of fluazifop butyl. There was no significant effect on yield of either calabrese or swede. Alloxydim sodium again produced no leaf malformation or yield reduction in either crop.

DISCUSSION

The lower level of tolerance by both crops to fluazifop butyl in 1980 than in 1981 may have been due to the heavy rain after application in the first year promoting uptake of the herbicide via the soil rather than the foliage. Stonebridge (1981) reported that fluazifop butyl had a certain amount of residual activity in the soil. Calabrese was more sensitive than swede in both years. The addition of extra wetter to the spray solution in 1981 might have been expected to increase the likelihood of foliar spray injury in that year, but this was not the case. Since these trials were initiated, the rate of fluazifop butyl recommended for control of perennial grasses has been reduced to 0.75 kg a.i./ha. This is however unlikely to alter substantially the apparent lower margin of safety on these brassicas of fluazifop butyl in comparison with alloxydim sodium, which had no adverse effects on either crop in either year. There was no

Table 1

Effects of grass herbicides on calabrese cv. Corvet

Herbicide	kg a.i./ha	Leaf injury score	Marketable spears[I] No./plot	Wt t/ha	Mean spear wt(g)	50% harvest date[+]
1980						25 August
Untreated		0	24.2	4.88	60.6	2.7
S.E. mean ±			1.56	0.392	4.27	0.42
Alloxydim sodium	1.50	0	22.3	4.87	65.7	2.3
	3.00	0	24.2	4.33	52.2	2.0
Fluazifop butyl	1.00	2	23.7	4.35	55.4	2.9
	2.00	5	16.0**	2.97**	54.9	2.9
S.E. mean ±			2.20	0.355	6.04	0.59
1981						30 July
Untreated		0	32.0	6.64	62.5	4.9
Alloxydim sodium	1.50	0	31.8	6.98	66.5	5.1
	3.00	0	31.5	7.06	68.0	4.1
Fluazifop butyl	1.00	2	30.0	5.87	59.0	5.3
	2.00	4	32.9	5.50	50.3	7.3**
Sethoxydim	1.29	2	31.0	6.13	59.9	4.8
S.E. mean ±			1.47	0.408	5.45	0.47

I - excluding blind, stunted or malformed.
** - significantly different from Untreated at the 1% level.
+ - days after 1st cutting date.

indication that prior application of trifluralin in 1981 affected crop tolerance to the grass herbicides.

Comparative trials in other weed-free crops at SCRI have indicated a lower margin of safety in raspberry and black currant for fluazifop butyl than for alloxydim sodium, but the opposite situation with field and broad bean (Lawson & Wiseman, 1982 and unpublished). Results with sethoxydim on these crops suggest that it may be intermediate in crop safety between the other two herbicides at rates required for perennial grass control. Our experiments were carried out on only one major cultivar each of calabrese and of swede. The results may therefore not apply to these crops universally. There is however, enough evidence to suggest that the relative safety of these grass herbicides (at the rates recommended for control of perennial grasses) should be investigated on a wider range of Brassica crops and cultivars. This aspect should be given as much weight as the more widely publicised work on their relative performance on weeds, especially when the appropriate rate of application for an individual crop is being considered.

Table 2

Effects of grass herbicides on swede cv. Marian

Herbicide	kg a.i./ha	No. roots harvested/plot	Wt roots harvested (t/ha)	Mean wt g/root (overall)
1980				
Untreated		33.7	79.2	706
S.E. mean ±		0.96	3.29	35.2
Alloxydim sodium	1.50	32.7	72.8	668
	3.00	33.7	77.4	691
Fluazifop butyl	1.00	32.3	66.8*	620
	2.00	32.3	66.4*	616
S.E. mean ±		1.36	4.66	49.7
1981				
Untreated		48.0	99.3	628
Alloxydim sodium	1.50	48.6	94.6	589
	3.00	46.4	95.0	618
Fluazifop butyl	1.00	47.9	103.7	649
	2.00	47.3	102.0	652
Sethoxydim	0.64	50.5	93.6	556
	1.29	47.5	100.3	651
S.E. mean ±		1.67	5.98	40.7

* Significantly different from Untreated at the 5% level

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DEVELOPMENTS IN WEED CONTROL IN SWEDES

H. T. H. Cromack and W. I. C. Davies

Agricultural Development and Advisory Service,

Trawsgoed, Aberystwyth, Dyfed SY23 4HT

Summary. Fifteen chemicals were applied either singly or in mixtures or in sequences at various stages in the development of the swede crop. Trials were conducted at nine sites in Wales and South West England. Where the weed population was moderate, all herbicides increased the yield of root dry matter. The effect of herbicide treatment was generally larger than the differences in response between individual herbicides.

Mixtures and sequences generally increased the weed spectrum controlled and improved yield response. Propachlor + chlorthal dimethyl, trifluralin + propachlor, trifluralin + napropamide, propachlor + nitrofen and trifluralin + nitrofen were the best treatments. Butam was the most effective single treatment when judged by yield response. Herbicides, mixtures, sequences, broad-leaved weeds, grass weeds.

INTRODUCTION

Early competition from weeds significantly reduces the yield of swedes; keeping the crop weed free for about 42 days enables the competitiveness of the crop thereafter to prevent significant yield reduction (Fiveland 1974). Traditionally the stale seedbed technique has been used for weed control in swedes (Prytherch and Toulson 1960). In recent years there has been a significant swing to the use of herbicides (Cox 1977) except where Sinapsis arvensis is a problem. Prytherch et al (1978) showed that single applications of the herbicides then currently available, while controlling a reasonable weed spectrum, all had deficiencies. The initial experience of Prytherch et al (1978) with herbicide mixtures and sequences indicated a potential for such techniques.

This paper reviews the last three years work with a range of herbicides used alone and in mixtures and sequences for weed control in swedes in Wales and South-West England.

METHODS AND MATERIALS

Trials were carried out on nine sites in Wales and South West England, site details including weed spectrum are given in Table 1. Treatment details are given in Table 2 which also indicates the sites at which each treatment was applied.

Treatments were applied in 200-450 l water/ha through an Oxford Precision Sprayer. Incorporation where necessary was carried out by an L blade rotovator. The design used at each site was a randomised block with three replicates.

Table 1

Site details

Year		1979			1980			1981	
Site No.	1	2	3	4	5	6	7	8	9
Location	Merthyr Cynog Brecon	Bangor-on-Dee Clwyd	Shobrooke Devon	Amlwch Gwynedd	Brecon Powys	Sandford Devon	Brecon Powys	Llansannan Clwyd	Sandford Devon
Soil type	Silty loam	Fine sandy loam	Loam	Silty loam	Fine sandy loam	Coarse sand	Fine sandy loam	Silty loam	Silty loam
Altitude (m)	305	50	91	76	240	137	260	280	91
Rainfall (cm)	120	70	80	95	140	90	140	110	90
Variety	Marian	Ruta Otofte	Marian	Marian	Marian	Ruta Otofte	Marian	Marian	Ruta Otofte
Drilled	13 June	2 June	29 June	12 June	21 May	24 April	14 June	13 June	26 June
Harvested	18 Dec	14 Jan	14 Jan	NA	10 Dec	19 Nov	26 Jan	21 Jan	20 Jan
Principal broadleaved weeds	S.arvensis P.persicaria S.media	Matricaria spp. 525/m^2 P.persicaria 12/m^2	C.album 3.4/m^2 P.aviculare 1.2/m^2	S.media 18% ground cover P.persicaria 48/m^2	S.arvensis 45/m^2 C.album 37/m^2 P.persicaria 28/m^2 C.bursa-pastoris 24/m^2	V.persica 20/m^2 S.media 12/m^2 P.aviculare 15/m^2	P.persicaria 56/m^2	S.media 5/m^2	Matricaria spp.19/m^2 C.bursa-pastoris 8.5/m^2
Principal grass weeds	P.annua	A.repens 46/m^2 P.annua 22/m^2	Poa spp. 11/m^2	Poa spp. 2% ground cover	Poa spp. 45/m^2	Poa spp. 31/m^2	Poa spp. 67/m^2	Poa spp. 69/m^2	Poa spp. 0.6/m^2 A.repens 0.1/m^2

Table 2

Experimental treatments

Treatment	Timing	Herbicide	Application rate kg ai/ha	Sites
1	a	trifluralin	1.12	All
2	b	propachlor	4.5	All
3	a	trifluralin + napropamide	0.84 + 0.84	All
4	b	butam	4.32	All
5	a	propachlor + chlorthal dimethyl	4.5 + 4.55	All
6	-	control	-	All
7	a	butam	4.32	1,2,4,5,7,8,9
8	a	butam	2.88	7,8,9
9	a/b	trifluralin + propachlor	0.84 + 3.25	1,2,4,5,7,8,9
10	a/c	trifluralin + nitrofen	0.84 + 1.22	1,2,3,5,6
11	a	trifluralin	0.84	1,2,4,5
12	a/c	trifluralin + 3,6 dichloro-picolinic acid	1.12 + 0.1	7,8
13	b	metazachlor	0.75	4,5,7,8,9
14	c	metazachlor	0.75	4,5
15	a/b	trifluralin + metazachlor	1.12 + 0.75	7,8,9
16	b/d	propachlor + sodium monochloracetate	4.5 + 20.2	1,2,4,5
17	b/d	propachlor + desmetryne	4.5 + 0.27	1,2,3,4,5,6
18	b/c	propachlor + nitrofen	4.5 + 1.22	1,2,4,5
19	b/c	propachlor + alloxydim sodium	4.5 + 0.94	1,2,3,6
20	c	propachlor + cyanazine	4.5 + 0.1	7,8,9
21	a	dinitramine	0.38	1,2,3,4,5,6
22	b	alachlor	1.9	1,2,4,5
23	c	nitrofen + alloxydim sodium	0.94	1,2
24	c	alloxydim sodium	1.5	9
25	c	sethoxydim		9
26	b	butam	2.88	1,2,4,5

Timings	a	Presowing incorporated
	b	Post sowing pre-emergence
	c	Post-emergence after first flush of weeds
	d	Crop 3-5 true leaves

RESULTS

The percentage control of the main weed species is given for Sites 2-9 in Table 3. At Site 1 where detailed records were not taken, *S. arvensis* was the main weed, propachlor followed by desmetryne was the most effective treatment.

Table 3

Percentage control of main weed species

Site 2

Treatment	A. repens	Poa spp.	Matricaria spp.	P. persicaria
1	44	96	98	83
2	26	32	98	58
3	48	100	99	92
4	0	77	97	25
5	41	32	99	42
7	63	100	99	100
9	37	96	99	58
10	17	86	92	50
11	17	64	96	33
16	17	55	98	100
17	44	23	97	83
18	0	59	98	92
19	72	23	96	58
21	54	86	98	83
22	35	59	96	33
23	4	14	94	33
26	39	68	90	83

Site 3

Treatment	Poa spp.	C. album	P. aviculare	A. arvensis
1	97	100	100	100
2	52	0	50	0
3	97	100	100	100
4	81	0	0	100
5	57	4	100	100
10	100	100	100	100
17	77	76	100	100
19	75	0	100	0
21	92	100	50	100

Site 4

Treatment	Poa spp.	P. persicaria	Matricaria spp.	L. purpureum	R. repens	S. media
1	0	75	0	34	43	94
2	0	69	64	44	72	78
3	0	79	0	61	86	50
4	50	42	82	44	57	66
5	0	66	100	78	36	94
7	0	62	82	33	93	89
9	0	69	55	83	29	66
11	0	77	36	83	72	17
13	0	79	91	55	50	50
14	0	40	73	0	7	78
16	0	56	91	100	0	100
17	0	98	91	94	79	94
18	0	81	82	44	14	61
21	0	83	0	89	79	83
22	0	0	91	94	36	94
23	50	65	18	66	14	0
26	0	50	36	44	57	33

Site 5

Treatment	Poa spp.	C. bursa-pastoris	P. persicaria	C. album	S. vulgaris	S. arvensis
1	98	0	18	70	0	53
2	18	0	0	49	100	47
3	93	0	0	95	100	80
4	98	0	0	100	0	78
5	93	0	53	100	100	93
6	0	0	0	0	0	0
7	100	0	32	81	0	76
9	20	0	0	78	73	62
10	56	0	57	76	0	0
11	29	0	0	68	10	76
13	100	96	0	0	91	100
14	56	0	39	0	82	0
16	0	0	22	68	64	100
17	80	67	43	76	100	100
18	69	71	93	97	82	82
21	78	0	0	65	27	76
22	89	38	0	0	73	80
26	98	0	54	76	0	71

Site 6

Treatment	Poa spp.	C. bursa-pastoris	P. aviculare	C. album	S. media	V. persica
1	99	9	95	96	98	99
2	95	96	36	83	40	96
3	95	28	95	100	94	99
4	100	0	92	88	94	91
5	92	87	80	100	80	100
6	0	0	0	0	0	0
10	98	28	98	96	98	100
13	94	59	0	65	27	80
17	99	96	50	96	75	96
19	91	82	0	39	0	66
21	99	54	95	100	100	94

Site 7

Treatment	Poa spp.	P. persicaria	F. officinalis	C. bursa-pastoris
1	70	62	0	0
2	22	46	14	43
3	79	77	43	14
4	73	68	0	0
5	55	38	0	57
6	0	0	0	0
7	9	70	14	29
8	87	61	29	14
9	87	72	29	57
12	76	72	43	0
13	85	68	0	43
15	94	75	14	43
20	33	43	86	86

Site 8

Treatment	Poa spp.	S. media
1	81	80
2	60	60
3	97	80
4	83	80
5	72	80
6	0	0
7	97	80
8	93	100
9	87	80
12	83	80
13	86	80
15	83	100
20	0	60

Site 9

Treatment	Poa spp.	A. repens	Matricaria spp.	C. bursa-pastoris
1	100	0	39	14
2	50	0	50	73
3	100	0	100	20
4	83	0	100	27
5	50	0	28	82
6	0	0	0	0
7	100	0	100	6
8	100	0	100	0
9	100	0	39	57
11	100	0	0	0
13	100	0	94	97
15	100	0	100	97
20	0	0	83	76
24	50	100	0	4
25	0	100	44	53

Trifluralin at 1.12 kg ai/ha gave good control of Chenopodium album, Polygonum aviculare, Stellaria media and variable control of Polygonum persicaria, the control of Matricaria spp., Capsella bursa-pastoris, Senecio vulgaris, Fumaria officinalis and S. arvensis was poor. Reducing the application rate of trifluralin to 0.84 kg ai/ha resulted in poorer weed control. Propachlor was generally less effective than trifluralin except on Matricaria spp., C. bursa-pastoris and S. vulgaris. Trifluralin + napropamide gave slightly better weed control than trifluralin especially on S. vulgaris, Spergula arvensis and Thlaspi arvense but C. bursa-pastoris and Matricaria spp. were poorly controlled. Propachlor + chlorthal dimethyl generally gave slightly better results than trifluralin on P. aviculare, C. bursa-pastoris and S. vulgaris but poorer results on Poa spp.

Butam 4.32 kg ai/ha pre-emergence gave slightly inferior results to trifluralin except on Matricaria spp. and S. arvensis, incorporation of this rate improved weed control. There were only small differences between the effectiveness of 4.32 and 2.88 kg ai/ha rates.

The post-sowing application of propachlor following trifluralin pre-sowing improved the control of Matricaria spp. and C. bursa-pastoris. The post-emergence application of nitrofen after trifluralin pre-sowing resulted in a marginal improvement, whereas its addition to propachlor produced significant improvement in the spectrum of weeds controlled.

Metazachlor applied pre-emergence gave better control of Matricaria spp. and C. bursa-pastoris than trifluralin; when applied post-emergence its performance was significantly inferior. The combination of trifluralin and metazachlor produced a high level of weed control. The post-emergence application of sodium monochloracetate in sequence with propachlor produced only a small improvement in weed control but had no adverse effect on crop safety. Post-emergent application of desmetryne in a similar sequence caused variable amounts of crop damage but did improve weed control notably on S. arvensis at Site 1. The sequence of propachlor followed by cyanazine improved the control of C. bursa-pastoris and F. officinalis but caused crop scorch and plant loss at one site.

Dinitramine generally gave similar weed control to trifluralin. Alachlor was superior to trifluralin in the control of Matricaria spp. and C. bursa-pastoris but inferior on P. persicaria and C. album. Alloxydim sodium had a significant effect on Agropyron repens where it occurred at Sites 2 and 9. Sethoxydim at the one site where it was applied appeared marginally superior to alloxydim sodium.

The yields of root dry matter are given in Table 4; Site 4 was not harvested due to erratic plant population. Except at Sites 3 and 8 where weed populations were low, all herbicide treatments increased the yield of root dry matter; this increase was generally larger than the differences between herbicides.

Table 4

Yield of root dry matter (t/ha)

Treatment	1	2	3	5	6	7	8	9
1	4.9	5.7	6.4	4.2	6.8	9.3	5.8	4.1
2	2.8	5.3	6.8	4.2	6.6	8.0	6.2	2.9
3	4.0	6.1	7.0	4.5	6.5	9.2	6.7	4.8
4	3.1	4.0	7.6	5.3	6.0	9.3	6.4	3.6
5	6.9	5.1	6.6	6.3	7.2	9.5	6.5	4.8
6	3.2	1.5	7.5	2.2	5.2	7.9	5.9	3.0
7	4.0	8.0		3.2		9.6	6.3	3.7
8						11.1	6.2	4.0
9	6.5	5.8		5.6		10.3	6.4	5.4
10	6.6	3.4	6.6	5.4	7.3			
11	3.4	4.2		4.7				3.6
12						9.4	6.5	
13				5.6	5.8	7.7	6.2	4.0
14				3.1				
15						9.6	6.3	4.2
16	2.5	3.5		4.8				
17	7.8	0.0	2.7	4.7	4.9			
18	5.1	4.5		6.6				
19	5.5	6.2	6.5		6.9			
20						5.6	5.0	3.0
21	5.1	5.5	6.6	5.2	6.5			
22	6.4	4.4		5.0				
23	4.2	4.8						
24								2.2
25								3.2
26	3.8	3.6		4.8				
SED	±1.46	±1.12	±0.37	±1.06	±0.79	±0.87	±0.47	±0.996

Generally mixtures and sequences gave larger yield responses than their individual components. There were considerable differences in the ranking of herbicides between sites because of the variability in weed spectrum. Considering the results in yield response terms, the most effective single treatment was Butam, particularly 4.32 kg ai/ha incorporated; the most effective mixtures/sequences were propachlor + chlorthal dimethyl, trifluralin + propachlor, trifluralin + napropamide, propachlor + nitrofen, trifluralin + nitrofen. Yield depressions from the use of herbicides were recorded following the use of propachlor + desmetryne at Sites 2 and 3 and propachlor + cyanazine at Sites 7 and 8.

DISCUSSION

The variability in the distribution of weeds within sites and the variability in weed spectrum between sites makes interpretation of the results difficult but is typical of the field situation.

The trials reported confirm earlier work by Prytherch et al (1978) that single herbicides have a restricted weed spectrum which can be significantly improved by the use of mixtures and sequences.

The withdrawal of nitrofen has severely limited the potential for post-emergence weed control in swedes. Despite variable performance and some reports of crop damage (Prytherch, et al 1978), this herbicide produced good results in combination with trifluralin and propachlor.

Desmetryne gave variable levels of damage, from complete crop loss to insignificant plant effects. This variability may have been due to differences in the waxiness of crop leaves at application or to the protection of the crop by severe weed infestation (Site 1). Therefore the advantages of this material cannot safely be utilised in the swede crop. Variability of crop damage was also noted with propachlor + cyanazine. Trifluralin + napropamide caused no damage to the swede crop and no damage could be detected in the following grass crop sown after ploughing, thus confirming the results of Waterson and Potts (1974). No herbicide or combination was capable of controlling S. arvensis, this therefore still remains the most serious deficiency in swede herbicides.

The performance of the best materials and mixtures/sequences gave acceptable weed control at high weed populations and it is suggested that progress has been made in the control of weeds in swedes since 1974 when Waterson and Potts concluded that at high weed populations weed control cannot be achieved by herbicides alone.

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THE EVALUATION OF EIGHT HERBICIDES, IN BOTH POT AND FIELD EXPERIMENTS, FOR THE CONTROL OF VOLUNTEER POTATOES

P.J.W. Lutman, T.M. West and W.G. Richardson
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary. The potential of 8 herbicides for the control of volunteer potatoes was evaluated in six experiments between 1978 and 1981. Triclopyr at doses up to 2.0 kg/ha reduced tuber production and viability. The related herbicide, 3,6-dichloropicolinic acid (0.1-0.3 kg/ha) was less active. Dowco 433 (0.2-0.75 kg/ha) had a dramatic effect on the foliage, but did not completely suppress viable tuber production. These three herbicides have potential for the suppression, if not complete control of potatoes in a range of crops including grassland, cereals and sugar beet (3,6 DCPA only). Glufosinate (0.25-2.25 kg/ha) killed the foliage but not the tubers. Metamitron (6-12 kg/ha), R 40244 (1.5-3.0 kg/ha) and chlorsulfuron (0.037-0.1 kg/ha) had little effect on the potatoes, although the latter at 0.2 kg/ha was somewhat more active. Fosamine (3-6 kg/ha), despite the absence of foliar effects, almost completely suppressed the sprouting of the daughter tubers.

INTRODUCTION

Volunteer potatoes remain serious weeds in certain parts of British agriculture, although the use of glyphosate in cereals both pre- and post-harvest has provided farmers with a potential method of achieving control (Lutman, 1979; O'Keeffe, 1980). There still remains a need to develop herbicides that can be used selectively in other crops such as vegetables and sugar beet. In consequence a limited amount of herbicide evaluation work has continued at WRO. Earlier work was summarised in 1978 (Lutman & Richardson, 1978). This paper reports the results of a further 6 pot and field experiments carried out in 1978-1981 with a range of herbicides and herbicide mixtures, including triclopyr, 3,6-dichloropicolinic acid, Dowco 433, chlorsulfuron, R 40244, glufosinate, fosamine and metamitron.

METHODS AND MATERIALS

Pot experiments

One pot experiment, of randomised block design with three replicates, was done each year between 1979 and 1981. Single potato tubers (cv. Desiree) were planted in 25 cm pots containing a light sandy loam soil with added sand, peat and fertilizer, late in March or early in April. These pots were placed outside on a paved area. The herbicide treatments were applied early in June, when the plants were well established and had already produced some daughter tubers (27, 92 and 278 g/pot in 1979, 80 and 81 respectively). All were sprayed with a laboratory pot sprayer at a volume rate of 200 l/ha and a pressure of 210 kPa using a single 8001 Spraying Systems Tee Jet nozzle. Details of most of the herbicides, formulations and doses tested are given in Tables 1 and 2. As well as the individual herbicides a number of mixtures were also investigated.

Visual symptoms were noted during the summer. In late August or early September of each year the tubers were harvested, counted and weighed. These were kept in paper bags in a cool store during the winter and were replanted in soil in the following spring. The percentage of tubers producing healthy plants was recorded.

Field experiments 1978

Two trials were done, both using Pentland Crown seed tubers planted in ridged rows 30-40 cm apart in early April. Both were laid out in three randomised blocks. The first trial was sown with tubers 3-6 cm in diameter, whilst in the second the plots were split and sown with either small (3-4 cm diameter) or large (5-6 cm diameter) tubers. Each plot comprised 2 rows 5 m long. Annual weeds were controlled in early May with metribuzin. The metamitron and triclopyr treatments were applied on 1 June with a back-pack sprayer and 3 m boom at a volume of 225 l/ha and a pressure of 210 kPa, when the potato plants were 30-40 cm high with stolons but no daughter tubers. Details of the treatments are given in Tables 3 and 4. The same two herbicides were applied again on 26 June, when although the plants appeared to be no larger, daughter tubers up to 7 cm in diameter were present.

The damage caused by the various herbicide treatments was recorded at intervals during the summer. In September the tubers from the central 2 m of both rows in each plot were harvested, counted and weighed. Samples of tubers were kept in trays in a cool store and the numbers producing healthy sprouts were recorded during the winter and spring.

Field experiment 1981

Fifteen tubers (cv. Pentland Hawk, 2-4 cm diameter) were planted 50 cm apart in beds on 15 April. The experiment was of randomised block design with two replicates. The first of the two sets of herbicide treatments was applied on 10 June, when the potatoes were approximately 35 cm tall with stolons and the occasional small daughter tubers. Application details were the same as in 1978 and the 3,6-dichloropicolinic acid and Dowco 433 treatments are listed in Table 5. Later treatments and repeat applications were sprayed one month later (9 July), when the potatoes were in flower and had many daughter tubers, some up to 5 cm in diameter.

The visual effects of the herbicide treatments were noted during the summer and in early November the tubers were harvested, counted and weighed. As in 1978 a sample of tubers was stored and their sprout production recorded in the following spring.

RESULTS

Pot experiments

Triclopyr. This herbicide reduced plant vigour markedly (Table 1), causing twisting and epinasty within hours of spraying, followed by necrosis of the apical leaves. Tuber weights were reduced significantly in two of the three years but the reduction was not outstanding. Tuber numbers were not significantly different from the controls (Table 1), but they appeared to be damaged exhibiting dark patches and surface cracking. This was reflected in their low viability; many rotted during the winter or failed to sprout. There was little dose response, but the level of activity was poorest in 1981 when the plants were most mature when sprayed and highest in 1979 when they were smaller.

3,6-dichloropicolinic acid. The plants treated with this herbicide were slightly less vigorous than the controls and exhibited some epinasty. Tuber numbers were almost unaffected (Table 1) but there was a significant reduction in weights in 1979. Despite this apparent absence of effect many of the tubers failed to sprout or produced deformed shoots with vestigial leaves. In contrast to the triclopyr treatments few tubers rotted. There was little dose response and the level of activity was similar in all three years.

Dowco 433. Within 24 hours of treatment the potatoes sprayed with Dowco 433 became severely twisted and their vigour, particularly after the 0.75 kg/ha dose, was drastically reduced. Despite these effects tuber numbers were hardly affected (Table 1). Tuber weights were lower than the controls but the reduction was less than 50%. Tuber viability was inhibited, particularly following the higher dose.

Table 1

Performance of triclopyr, 3,6-dichloropicolinic acid and Dowco 433 against potatoes grown in pots (figure in brackets = % of control)

Herbicide	Year	Dose (kg/ha a.i.)	Plant vigour	Tuber no. /pot	Tuber wt. /pot(g)	% Tubers with healthy sprouts
Triclopyr (48% e.c.)	1979	0.37	47	29 (78)	341 (32)	2
		0.75	42	25 (67)	350 (33)	7
		Control	100	37	1058	100
	1980	0.37	52	29(236)	489 (82)	16
		0.75	52	23(189)	480 (80)	19
		Control	100	12	599	100
	1981	0.5	47	17 (90)	311 (60)	25
		1.0	39	19 (98)	346 (67)	27
		Control	100	19	518	100
3,6-Dichloro-picolinic acid (10% a.c.)	1979	0.10	83	26 (71)	571 (54)	6
		0.20	76	26 (71)	806 (76)	27
		Control	100	37	1058	100
	1980	0.10	50	19(157)	555 (93)	0
		0.20	57	16(128)	383 (64)	0
		Control	100	12	599	100
	1981	0.12	100	21(109)	476 (92)	35
		0.25	43	17 (88)	463 (89)	0
		Control	100	19	518	100
Dowco 433 (25% e.c.)	1981	0.37	33	16 (84)	299 (58)	65
		0.75	19	19 (98)	288 (56)	39
		Control	100	19	518	100
Standard error of means (n = 3)			1979	4.85	60.6	
			1980	3.55	56.1	
			1981	2.92	46.7	

Chlorsulfuron. The apices of the stems of the plants treated with chlorsulfuron were inhibited, growth being taken over by axillary buds. In 1979 the 0.2 kg/ha dose reduced tuber weights by 90% (Table 2). At the lower doses there was less effect. Tuber numbers and viability were not greatly affected.

Fosamine. This compound had only slight visible effects on the potato plants, and did not reduce tuber production (Table 2). However, both doses, especially 6.0 kg/ha, severely affected the ability of the tubers to produce sprouts. At the higher dose no sprouts were recorded in 1979 and only 4% of tubers sprouted in 1980.

R 40244. Within 10 days of treatment the plants developed pronounced albinism with a pinkish tinge. New shoots were produced later from axillary buds. Both doses significantly reduced tuber numbers and weights (Table 2), 3.0 kg/ha being more effective than 1.5 kg/ha. Neither dose affected tuber viability.

Glufosinate. All three doses caused the plants to become chlorotic and necrotic and most plants died. Tuber numbers were not reduced but there were some reductions in tuber weights (Table 2). The two higher doses appeared to affect the viability of the tubers as some of the shoots from the replanted tubers were stunted and chlorotic. Only 50% produced healthy sprouts following 2.25 kg/ha.

Table 2

The activity of chlorsulfuron, fosamine, glufosinate and R 40244 against potatoes growing in pots (figures in brackets = % of control)

Herbicide	Year	Dose (kg/ha a.i.)	Plant vigour	Tuber no. /pot	Tuber wt. /pot (g)	% Tubers with healthy sprouts
Chlorsulfuron (80% w.p.)	1979	0.1	53	29 (78)	209 (20)	89
		0.2	50	32 (86)	88 (8)	81
		Control	100	37	1058	100
(20% dry flowable)	1980	0.037	40	36(295)	434 (72)	96
		0.075	29	26(214)	236 (39)	91
		Control	100	12	599	100
"	1981	0.04	67	21(109)	366 (71)	92
		0.08	43	19(102)	381 (74)	90
		Control	100	19	518	100
Fosamine (48% a.c.)	1979	3.0	100	28 (75)	828 (78)	27
		6.0	100	29 (78)	907 (86)	0
		Control	100	37	1058	100
	1980	3.6	36	20(163)	592 (99)	0
		6.0	50	28(230)	590 (99)	4
		Control	100	12	599	100
R40244 (24% e.c.)	1979	1.5	64	19 (51)	375 (36)	106
		3.0	50	13 (35)	151 (14)	97
		Control	100	37	1058	100
Glufosinate (20% a.c.)	1981	0.25	14	20(107)	346 (67)	100
		0.75	14	20(104)	289 (56)	73
		2.25	14	17 (91)	257 (50)	49
		Control	100	19	518	100
Standard error of means (n = 3)		1979		4.85	60.6	
		1980		3.55	56.1	
		1981		2.92	46.7	

Mixtures. Results from the range of two and three way mixtures which were also investigated indicated that their performance rarely exceeded that of the individual component herbicides; so the results have not been included.

Field experiments

Metamitron. The upper leaves and apices of the treated plants became chlorotic and died. New shoots produced after treatment were unaffected. Those plants treated on 1 June were not very seriously damaged and showed only slight symptoms 50 days after spraying (Table 3). The 12.0 kg/ha dose had the greatest effect. Tuber weights were reduced significantly by all treatments, 12.0 kg/ha sprayed on 26 June being most effective. Actipron did not appear to influence the level of control.

Tuber numbers were unaffected by the metamitron treatments although a few of them showed surface pitting, over 90% produced normal healthy sprouts.

Triclopyr. In both trials all doses caused epinasty, twisting of the stems and deformation of new leaves. The symptoms were more severe at the higher doses and at 2.0 kg/ha some stems were killed completely. No large differences in response were noted in the first trial between plants sprayed on 1 June and 26 June (Table 3) but plants from the smaller tubers in the second trial appeared slightly more sensitive to 2.0 kg/ha (Table 4). The weights of tubers produced by the plants treated on 1 June (both trials) were reduced by up to 95% (Tables 3, 4). The later application in the first trial was less effective. Although all doses significantly reduced tuber weights only 2.0 kg/ha reduced tuber numbers. Many of the tubers were damaged by triclopyr as their surfaces were often badly pitted and at the higher doses they were partially rotted. These visual effects were reflected in the viability data. The application late in June was most effective, even 0.5 kg/ha reducing the number of viable tubers by 80% (Table 3). The size of the parent tuber did not affect daughter tuber viability.

Table 3

The field performance of triclopyr and metamitron applied to potatoes in early and late June

Herbicide	Dose kg/ha a.i.	Damage Scores* (50 days) Early	Late	Tuber Wgts kg/plot Early	Late	Tuber Nos. /plot Early	Late	% Tubers with healthy sprouts Early	Late
Metamitron	6	5.0		15.2		144(100)[x]		90	
(70% w.p.)	9	5.0	4.0	10.7	9.5	111 (89)	102 (86)	95	96
	9+A[+]	5.0	1.7	10.8	6.1	112 (97)	91(100)	96	100
	12	4.8	3.5	11.7	9.3	91 (99)	99 (68)	96	92
	12+A		3.3		8.0		101 (82)		99
Triclopyr	0.5	3.7	4.2	14.7	14.6	139 (41)	98 (18)	88	20
(48% e.c.)	1.0	2.2	3.0	5.9	11.3	112 (37)	101 (7)	68	7
	2.0	1.2	2.3	0.6	4.1	19 (48)	45 (7)	32	4
	Control	5	5	21.0		121(100)		94	
Standard error of mean (n = 3)				1.07		11.8			

* Damage scores 5 = healthy 0 = dead

x Figures in brackets = % healthy tubers, without surface pitting

\+ A = Actipron 5 l/ha

3,6-dichloropicolinic acid. By 18 June the upper leaves of the treated potato plants were slightly twisted and the new apical leaves were small and deformed. Where phenmedipham had been included the leaves were chlorotic. By early September there were no differences between the treated plants and the controls. Tuber weights were slightly reduced by all the June treatments but those applied in July had little effect (Table 5). There was no dose response but the inclusion of phenmedipham slightly increased phytotoxicity. Tuber numbers were not reduced by any treatment and over 90% of them produced normal healthy sprouts.

Table 4

The effect of parent tuber size on the field performance of triclopyr applied in early June

Parent tuber size	Triclopyr dose (kg/ha a.i.)	Damage Scores* (54 days)	Tuber Wgts /plot (kg)	Tuber No /plot	% tubers with healthy sprouts
3-4 cm	0.5	3.3	14.07	125(50)+	89
	1.0	3.0	4.17	72(32)	79
	2.0	1.0	0.16	9(37)	44
	Control	4.5	15.32	71(97)	100
5+ cm	0.5	3.5	11.16	160(32)	86
	1.0	2.7	5.24	110(47)	73
	2.0	2.2	0.71	32(14)	41
	Control	4.8	18.00	113(96)	100
Standard error of means (n = 3)			1.50	15.1	

* Damage scores 5 = healthy 0 = dead
+ Figures in brackets = % healthy tubers, not exhibiting surface pitting

Table 5

The field performance of 3,6-dichloropicolinic acid and Dowco 433

Herbicide	Date of Application 10.6.81 Dose g/ha	9.7.81 Dose g/ha	Tuber Wgt /plot (kg)	Tuber No. /plot	% tubers with healthy sprouts
3,6-Dichloro-picolinic acid (10% a.c.)	200		10.3	102	90
		200	16.1	122	95
	200	200	10.8	100	92
	100	200	10.9	98	98
	100+	200	8.7	107	93
	300		10.5	129	92
		300	14.0	131	92
Dowco 433 (25% e.c.)	200		6.5	162	67
	600		1.3	103	45
	Control		14.9	110	97
Standard error of mean (n = 2)			1.37	15.9	

+ 100 g/ha 3,6 DCPA + 1.14 kg/ha phenmedipham

Dowco 433. The plants treated with Dowco 433 became severely twisted and there was an epinastic effect on the leaves. By 4 September many plants were dead whilst others were prostrate, twisted and chlorotic. Tuber weights were greatly reduced by both doses (Table 5) but there was little effect on tuber numbers. The viability of these small tubers was not as high as the controls but nearly 50% produced sprouts during the winter.

DISCUSSION

None of the herbicides tested were as active on the potatoes as glyphosate but some treatments gave reasonable levels of control. The performance of triclopyr in both pot and field experiments indicated that it could be used to suppress, if not eliminate, volunteer potatoes. Doses of 1.0-2.0 kg/ha appeared to be needed in the field trials but lower doses were as effective in the pot experiments. Other research has indicated that grass species will tolerate at least 1.7 kg/ha (McCarty, 1979; Gorrell et al., 1981; Plant Protection, 1982), suggesting that triclopyr could be used selectively in grassland. However, (Lutman & Richardson, 1978) showed that barley would not tolerate 0.75 kg/ha.

The related herbicide, 3,6-dichloropicolinic acid, was clearly less active than triclopyr, but suppressed plant growth and tuber weights. This agrees with earlier work (Lutman & Richardson, 1978; Hübl et al., 1979). As it can be used safely in a range of crops including strawberries and sugar beet (Gilchrist & Lake, 1978; Lake & Bennett, 1980) it provides the opportunity of suppressing potatoes in these particular situations. Dose seemed to have little effect on performance but in the field trial the early application (pre tuberisation) was more effective than a later one. Complete control should not be expected.

The dramatic initial effects on the potatoes from Dowco 433 suggested exceptional control but although tuber production was reduced, the viability of the surviving tubers was at least 40%. Even so this herbicide has some potential for use in cereals which tolerate doses of up to 0.9 kg/ha (Richardson, West & Parker, 1981).

Glufosinate, a potential potato haulm desiccant (Schwerdtle et al., 1981), severely damaged pot-grown potato plants but, as it is a non-selective herbicide and it did not have a great effect on the daughter tubers, its potential for volunteer potato control is limited. The application of glufosinate to rapidly growing plants in mid-summer and at doses in excess of those envisaged for haulm desiccation, may have resulted in effects on the daughter tubers not seen from later treatments at lower doses. Metamitron failed to cause appreciable damage to the haulm even at high rates and only slightly reduced tuber production. Consequently its potential for potato control, even in sugar beet, is small. The results of pot experiments with R 40244 and chlorsulfuron, were also disappointing, although the latter provided moderately good control at 0.2 kg/ha. In contrast fosamine had only slight effects on the plants but greatly reduced tuber viability. This chemical appears to have considerable potential for sprout control in potatoes and in this respect resembles maleic hydrazide (Bishop & Schweers, 1961). Although it has been developed primarily for brushwood control the results presented indicate that it could also be used for the control of perennial weeds, such as potatoes, in annual crops. Further work is needed to clarify its potential for these situations.

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SULPHATE OF IRON : NEW TECHNIQUES WITH AN OLD HERBICIDE

T. Kavanagh and T.P. Cormican
Kinsealy Research Centre, Agricultural Institute, Malahide Road, Dublin 5

Summary. In the past, sulphate of iron has chiefly been used in lawn sand with sulphate of ammonia to control moss and weeds. At Kinsealy Research Centre its use has been extended to energy conservation in turfgrass maintenance with additional beneficial effects in weed control. Sulphate of iron alone applied at 56 kg/ha at 4 to 6 week intervals instead of sulphate of ammonia reduced mowing requirements by almost 50% without appreciable deterioration in lawn appearance and quality and can be recommended as an energy saving technique in turfgrass maintenance. Applying the sulphate of iron as a spray at 336 l/ha gave adequate cover of the turfgrass foliage and produced an initial greening effect in two hours which lasted 4 to 6 weeks. Hunter Colour Meter 'L' values suggest that the 'greening' effect is largely a darkening of leaves and of senescent and chlorotic tissue at the base of the sward. Experiments in which sulphate of iron was applied at monthly intervals over a 2 year period at rates of up to 168 kg/ha had no adverse effects on the grass or soil but eliminated difficult weeds including *Veronica filiformis*, *Trifolium repens* and *Bellis perennis*.

INTRODUCTION

Sulphate of iron has been in use for well over half a century as a turfgrass treatment usually in conjunction with sulphate of ammonia. Its properties of controlling weeds and disease, inhibiting earthworm activity and greening grass are well recognised (Dawson, 1959; Madison, 1971). For the most part sulphate of iron has been applied with other fertilisers especially nitrogen and this may be the reason why the effects of sulphate of iron alone on turfgrass are not as widely known and its use not as widespread as would be expected considering the benefits which ensue from its frequent use. A minimum maintenance study on turfgrass was initiated at Kinsealy Research Centre in 1979 as part of an energy conservation programme. Sulphate of iron was used in this study largely to promote colour in lawns which for energy conservation reasons were receiving no fertiliser. The benefits of using sulphate of iron alone were such that this study was intensified and continued over several years. The results of this study are presented in this paper.

METHODS AND MATERIALS

Sulphate of iron which had been finely powdered and dried during manufacture was used in all experiments. It was usually applied as a solution in water but was also applied as a dry powder with sand as a carrier. In solution it was applied to large areas at 336 l/ha with a Dorman wheelbarrow sprayer with a two metre boom with seven fan type nozzles. Application to small plots was made at one litre per $3m^2$ with a watering can fitted with a fine rose or at 800 l/ha with a knapsack sprayer. Plots were treated at monthly intervals from August 1980 to August 1982. Three rates were used: 56, 84 and 168 kg/ha.

The following turfgrass areas were used for these experiments:

(a) old lawn composed largely of Festuca spp., Agrostis spp., and Lolium perenne

(b) old lawn composed largely of Poa pratensis, Poa annua and with a high content of weed

(c) newly sown Agrostis - Festuca turf

(d) newly sown Lolium perenne turf

Hunter 'L', 'a' and 'b' values were recorded on grass clippings using a D25A Hunter Colour Difference Meter. From these, colour difference was calculated from the Hunter Scofield Equation $\sqrt{\Delta L^2 + \Delta a^2 + \Delta b^2}$ and hue angle from the formula $\cot^{-1} a/b$. These were correlated with visual assessments of colour.

RESULTS

Effects on weeds and grasses:

Monthly applications of sulphate of iron at 84 and 168 kg/ha to old turfgrass consisting largely of Festuca spp., Agrostis spp., and Lolium perenne resulted in the elimination of almost all weeds and a reduction in coarse grasses (Table 1). Of particular interest was the killing of weeds which are difficult to control in turf e.g. Veronica filiformis and Trifolium repens. By comparison with untreated turfgrass, sulphate of iron treated plots had a lower percentage of Lolium perenne and higher Festuca spp. but Agrostis spp did not show a definite trend. As the actual number of applications necessary to kill particular weeds was not noted in this first study, an experiment was started in February, 1982 on an especially weedy piece of Poa pratensis - Poa annua turf in which the following weeds were present: Bellis perennis, Cerastium holosteoides, Geum spp., Hypochaeris radicata, Plantago spp., Ranunculus acris, Sagina procumbens, Senecio jacobaea, Taraxacum officinale, Trifolium dubium, Trifolium repens and moss. Six applications of a solution of sulphate of iron at 56 and 84 kg/ha were given at monthly intervals between February and July. Many of the weeds present were severely scorched by the treatments but moss was the only one which was eliminated.

Effects on colour

When sulphate of iron at 56 and 84 kg/ha was sprayed on to separate areas of Agrostis - Festuca and Lolium perenne turfgrass a greening effect was visible one hour later and the two rates could be distinguished visually. Staff presented with grass clippings taken 2 hours after spraying distinguished the untreated in 100% of the samples and ranked the 56 kg/ha and the 84 kg/ha correctly in 93% of the Agrostis -Festuca samples and in 72% of the Lolium. The Hunter Scofield index showed that there was a difference in colour between treated and untreated areas which in the case of Agrostis - Festuca turf declined from 4.7 after 2 hours to 1.3 after 28 days. A similar decline occurred with Lolium perenne. Hunter 'L' values also showed these differences (Table 2). The range of hue angle values was small throughout the experimental period. When areas which had been sprayed with sulphate of iron were examined in situ, they had a much greener appearance than untreated areas, and this effect could be distinguished for 4 - 6 weeks. However, the staff failed to distinguish samples of clippings from sprayed and unsprayed turfgrass which had been treated four weeks previously. On closer examination the in situ 'green' appearance was largely due to a darkening of dead, senescent and chlorotic tissue particularly at the base of the sward at soil level. The effect of sulphate of iron was greater with poor, thatchy turf that was in need of scarification and was more dramatic in autumn, winter and spring than in summer. The darkening effect produced by footprints on turf newly treated with sulphate of iron was not reproduced by rolling the sward immediately after spraying (Table 2)

Table 1

Effect (expressed as percent ground covered) on weeds and coarse grasses of monthly applications of sulphate of iron applied in solution to turfgrass over a 2 year period

Rate of sulphate of iron	Plot no. ($3m^2$)	Agrostis spp.	Festuca spp.	Lolium perenne	Dactylis glomerata	Trifolium repens	Veronica filiformis	Taraxacum officinale	Bellis perennis	Senecio jacobaea
84kg/ha	1	59	34	5	0	0	0	0	0	0
	5	28	42	27	0	1	1	(1)	0	0
	9	33	46	18	0	T	0	(3)	(1)	0
Mean		40.0	40.6	16.6	0	T	0	T	T	0
168kg/ha	3	41	37	21	0	0	0	0	0	0
	4	21	72	5	0	0	0	0	0	0
	8	13	70	16	0	0	0	0	0	0
Mean		25.0	59.6	14.0	0	0	0	0	0	0
Untreated Control	2	38	7	48	4	3	1	(11)	0	(1)
	6	19	6	34	0	28	4	3	(1)	0
	7	15	31	31	0	14	2	4	1	(4)
Mean		24.3	14.6	37.6	1.3	15	2.3	2.3	0.3	T

T = trace. Figures in brackets are actual numbers of plants.

Table 2

Hunter Colour Meter values (L, -a, b) at various intervals after spraying two kinds of turfgrass with sulphate of iron at 84 kg/ha (mean of two readings).

Interval from spraying		Agrostis-Festuca Untreated	Agrostis-Festuca Sprayed	Agrostis-Festuca Sprayed & rolled	Lolium perenne Untreated	Lolium perenne Sprayed	Lolium perenne Sprayed & rolled
2 hour	L	26.5	22.8	23.1	28.6	26.1	26.0
	-a	6.2	4.5	4.8	7.0	6.3	6.0
	b	10.9	8.6	8.0	11.9	10.4	10.2
5 hour	L	27.6	24.4	24.0	28.5	27.4	26.5
	-a	6.1	4.9	4.9	7.1	6.6	5.8
	b	10.5	8.2	7.7	11.4	9.9	9.3
24 hour	L	28.2	22.3	25.0	29.5	24.0	25.7
	-a	6.3	2.7	4.4	6.7	3.5	4.8
	b	11.1	7.1	8.6	11.3	7.9	9.5
3 days	L	28.9	24.0	25.9	29.3	25.6	28.9
	-a	3.9	3.6	4.6	5.5	4.4	5.2
	b	10.2	8.1	9.3	11.0	9.0	9.8
7 days	L	30.4	27.3	27.6	31.2	28.2	28.5
	-a	4.0	4.4	4.4	5.6	5.8	5.8
	b	10.9	9.5	9.8	12.4	10.4	10.8
21 days	L	27.7	29.8	28.1	31.6	30.4	30.4
	-a	4.2	5.8	4.8	6.7	6.4	5.0
	b	9.6	10.6	9.4	12.0	11.2	11.4
28 days	L	28.8	27.8	27.2	30.1	30.0	30.5
	-a	6.1	6.3	6.4	6.6	7.1	6.9
	b	11.4	10.5	10.2	12.2	12.2	12.4

Hunter Meter 'L', 'a', 'b' values measure lightness, redness to greenness and yellowness to blueness respectively. Reducing values for 'L' = greater darkness.

Energy conservation

When sulphate of iron at 56 kg/ha as a dilute spray was substituted for sulphate of ammonia at 168 kg/ha both applied at 6 week intervals the frequency of mowing could be reduced by almost 50% thus resulting in a considerable energy and man-hour saving. The lawns so treated had an acceptable appearance both during the growing season and in the dormant season when the sulphate of iron treatments were also applied. Sulphate of iron applied in powder form with a sand carrier when the grass was dry produced a much weaker effect than when applied in solution. No adverse effects on the turf were noted even where sulphate of iron was applied at 168 kg/ha at monthly intervals for 2 years other than a slight thinning of the sward due to the reduction of coarser species. The pH of the top 2.5 cm of the soil was unchanged at approximately 7.6 even where the 168 kg/ha rate was used for 2 years.

DISCUSSION

The main purpose of this investigation was to see to what extent sulphate of iron could be used as an aid to low cost maintenance of turfgrass. Weed control was therefore of secondary interest. Sulphate of iron has long been known to have weed killing properties but these have been confined to the elimination of moss and reduction of some other weeds (Dawson 1959). The total elimination of several weeds which are difficult to control was unexpected and a previously unreported result of applying sulphate of iron at monthly intervals over a period of up to 2 years. Veronica filiformis is particularly difficult to control with herbicides but was eliminated from plots treated repeatedly with sulphate of iron as was Trifolium repens. Less surprising was the killing of broad leaved weeds such as Bellis perennis and young plants of Taraxacum officinale. Winter applications may be more effective in weed control than spring and summer since weeds were not eliminated by five applications of sulphate of iron between February and July.

The possibility of using sulphate of iron in an energy saving programme for turfgrass maintenance was borne out by the fact that mowing, which is very costly, could be reduced by almost 50%. Unquestionably regular applications of sulphate of ammonia produce an effect superior to that from sulphate of iron at similar frequencies. Nevertheless the latter produced a reasonably acceptable appearance far superior to that of untreated turfgrass.

References in the literature to the greening effect of sulphate of iron are common (Dawson 1959, Deal and Engel 1965, Madison 1971). However the range of hue angle values was small in these experiments suggesting that hue changed very little. The apparent 'greening'seems to be a darkening as indicated by the differences between treated and untreated turfgrass in the Hunter Scofield index and Hunter 'L' values (Table 2). As sulphate of iron in solution is rapidly converted to the insoluble ferric hydroxide one would not expect much foliar absorption unless the solution was made up and applied quickly. Therefore some of the darkening effect would seem to be a staining of the tissues particularly dead or chlorotic tissue at the base of the sward. This then provides a dark background against which the foliage appears greener.

Very high rates of iron up to 168 kg/ha were used at very short intervals (monthly) for a long time (2 years) to hasten the development of adverse effects if such were likely. This compares with very low rates of iron used by some other workers (Deal & Engel 1965, Snyder & Schmidt 1974). These very high rates at frequent intervals over a long period had no adverse effect on soil pH contrary to other findings (Dawson 1959), gave excellent control of weeds and reduced coarse grasses. In practice the 56 kg/ha rate applied at about 6 week intervals would seem to be optimum although lower rates, which were not tested in this study, could probably be used satisfactorily. Obviously turfgrass will deteriorate if simply treated with sulphate of iron at 6 week intervals indefinitely, and some thinning of the turf was noted in these trials. However, with judicious infrequent fertilising with nitrogen and even less frequently with phosphorous and potassium turf could be maintained in an acceptable condition with much reduced inputs compared with intensively managed and frequently fertilised fine turf.

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THE CONTROL OF AGROPYRON REPENS BY THE PRE-HARVEST APPLICATION OF GLYPHOSATE AND ITS EFFECT ON GRAIN YIELD, MOISTURE, GERMINATION AND ON HARVESTING

B. W. Sheppard and J. A. Pascal
Scottish Institute of Agricultural Engineering, Penicuik, Midlothian EH26 0PH

M. C. Richards
East of Scotland College of Agriculture, West Mains Rd., Edinburgh EH9 3JG

H. Grant
Monsanto PLC., Burleys Way, Leicester LE1 3TP

Summary. Where cereal harvests are late and onset of winter early, the control of Agropyron repens may be undertaken by spraying the isopropylamine salt of glyphosate pre-harvest. In comparing two levels of pre-harvest application (1.44 and 0.72 kg a.e./ha), consistent control of A. repens from 95 to 99% was achieved one year after spraying but after two years the lower rate was less effective in some cases. Control from post-harvest sprayed areas was less effective, varying between 0 and 75%.

Crop yields the following season were generally increased from all pre-harvest treated plots. No depression of grain germination occurred after use of the lower rate of glyphosate application, but a depression did occur on one occasion following the higher rate. Combine harvester throughput at a given grain loss level was improved after spraying or conversely, grain losses were reduced at a given throughput. Grain moisture content was reduced by up to 2.5% (wet basis) after spraying and pre-harvest wheeling losses due to spraying varied between one to 5% of crop yield. Yield increases the following year covered the costs incurred by the treatment.

INTRODUCTION

A recent survey of grass weeds in cereals (Elliott et al., 1979) indicated that Agropyron repens infested 92 and 88% of winter and spring cereal fields respectively. Of these, over half were infested with populations > one seed head/10 m^2.

It is known that crop yield reductions occur through infestations of A. repens (Scragg, 1980 and Cussons, 1970); qualitative work has shown that grain yield losses of 10% occur with populations of 100 shoots/m^2 of A. repens.

Monsanto Ltd., introduced the isopropylamine salt of glyphosate as a herbicide in 1974 to control A. repens in stubble. The chemical was not entirely effective in N. Britain where there was inadequate foliage re-growth after harvest to translocate the herbicide effectively (Harvey et al., 1981) due to later harvests and early onset of winter dormancy. It was thus shown that pre-harvest spraying could also give effective control of A. repens (O'Keeffe, 1980). The use of half the standard application rate of 1.44 kg a.e./ha gave 99% control of A. repens (Anon, ESCA, 1979). Germination tests from these trials suggested that the technique of pre-harvest application had no adverse effects on grain germination.

Users of the pre-harvest technique also considered that glyphosate reduced the moisture levels of the crop at harvest, resulting in improved combine harvester performance and lower grain drying costs.

The work reported here was designed to demonstrate the effectiveness of controlling A. repens pre-harvest in Scotland, to give quantitative data on grain yield (including losses due to tractor wheelings during the spray application), the increased yields in subsequent crops, the reduction of grain moisture content, the germination levels of treated grain and on the improved performance obtainable from combine harvesters. Results from some of the early trials have been reported by O'Keeffe et al., 1981.

MATERIALS AND METHODS

Site and crop details   During 1980 and 1981 five crops of spring barley and one of winter barley with varying levels of A. repens infestation were treated. Details of these crops and subsequent work at the sites following glyphosate application are given in Table 1.

Table 1

Site and crop details

Site No. and name	Barley variety	Date of harvest after treatment	Straw treatment	Post-harvest ploughing depth, mm	Second year's crop (var)
1. Biel	Midas	25.9.80	Burnt	200	Barley (Midas)
2. Papple I	G. Promise	28.9.80	Baled	250	Oats (M. Tabard)
3. Danderhall	G. Promise	30.9.80	Baled	300	Swedes (R. Otofte)
4. Earlston	Igri (winter)	21.8.81	Baled	200	Wheat (NR)
5. Papple II	G. Promise	1.9.81	Baled	230	Wheat (Avalon)
6. Stenton	Georgie	2.9.81	Burnt	300	Barley (G. Promise)

NR = Not recorded

Glyphosate application   Plots were laid out in a 3 x 3 randomised block design at all six sites. Treatments consisted of two pre-harvest applications of glyphosate at 1.44 kg a.e./ha and 0.72 kg a.e./ha in 200 l of water and an untreated control. Plot width was equivalent to double the boom span of the individual sprayer used at each site. (Boom widths: Site 1 = 11 m, Sites 2-6 = 12 m.) Plot length varied from 70 to 100 m. Half of each control plot was treated with a post-harvest application of glyphosate at 1.44 kg a.e./ha, date of spraying being a compromise between optimal regrowth of A. repens and winter dormancy.

In 1980 crops were sprayed 1 to 3 weeks prior to the estimated harvest date (at Zadoks 92) but in 1981, grain moisture content was monitored, details in Table 2.

Table 2

Details of spray application

Site	Date of application		Leaf stage and height (mm) of A.repens at post-harvest spray		M.C. of grain at pre-harvest spray % (wet basis)	Sprayer type and tyre size (where applicable)	Tractor rear tyre size*
	Pre-harvest	Post-harvest					
1	8.9.80	10.11.80	2	15-30	NR	Trailed-750x18	13x38
2	1.9.80	4.12.80	2-4	20-60	NR	Trailed-750x18	12x36
3	27.8.80	17.11.80	2-3	20-40	NR	Tractor mounted	13.6x38
4	4.8.81	None **	-	-	30	Tractor mounted	13.6x38
5	22.8.81	14.10.81	2-4	20-40	24	Trailed-750x18	13x38
6	24.8.81	14.10.81	2-3	20-30	26	Tractor mounted	8.3x44

NR = Not recorded;   * Front tyres were all 750x16

** No post-harvest spray possible as winter wheat sown immediately after harvest.

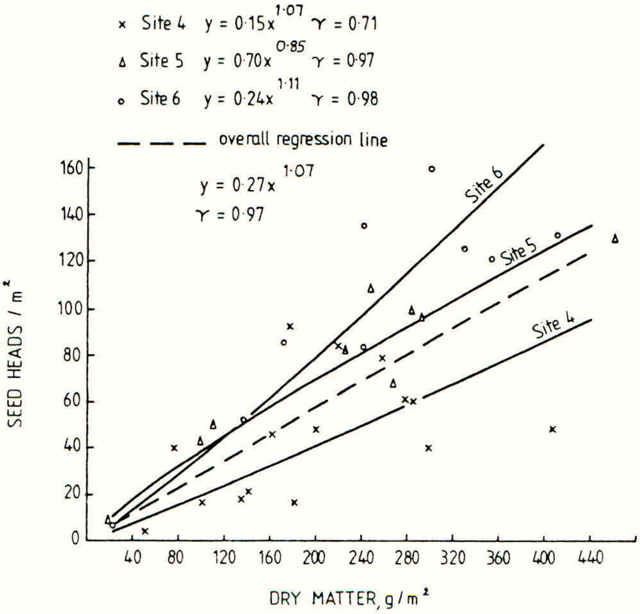

FIG 1 RELATIONSHIPS BETWEEN NO. OF SEED HEADS AND DRY MATTER WT. OF A. REPENS

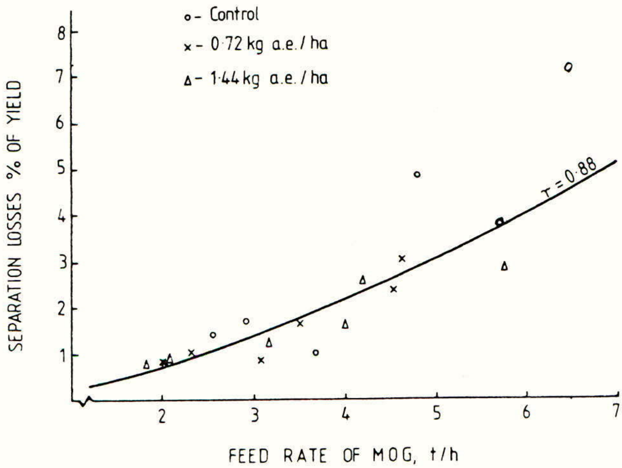

FIG 3 THE EFFECT OF PRE-HARVEST GLYPHOSATE ON COMBINE PERFORMANCE

Population assessment of *A. repens* Populations of *A. repens* were assessed by counting seed heads present in 0.5 m quadrat at 10 random points within each plot. In 1982 an additional assessment was made at the 1981 sites by harvesting all the material present in a 0.5 m quadrat, at 3 random points in each plot. Material was divided into crop, *A. repens* and other weeds, weighed, dried and reweighed to obtain both wet and dry weight proportion of each group.

In 1981 assessments were carried out just prior to spraying the 3 new sites of that year and one year after spraying for the three 1980 sites. All six sites were again assessed just prior to the 1982 harvest.

Assessment of combine harvester performance and crop yield Sites were harvested with a plot combine harvester having a 2.35 m cutting width. Crop yield was determined by harvesting a swath through the centre of each plot and measuring the length of each run (normally 50-80 m). During the run, grain was collected in a separate weighing hopper mounted over the grain tank of the combine. Grain moisture samples were taken.

Additional yield cuts were taken in a similar manner, straddling the wheeltracks from the spraying treatments with the combine cutter-bar, in order to determine the yield losses due to wheelings.

Crop yield determinations were taken in a similar manner from the following seasons crop at each site.

Grain losses from the combine, on sprayed and unsprayed areas were assessed by collecting the efflux from the rear of the combine on special sheets over a 6 m working length (Pascal, 1967). Harvester forward speed, working width, throughput or material other than grain (MOG), grain losses from sieves and straw shaker were all recorded.

Germination of harvested grain Samples were taken at harvest at two sites in 1980 and one in 1981 to examine the germination of harvested grain. The germination test was by standard paper towel method according to international rules for seed testing. Pre-treatment was for 3 days at 7^{o}C and 4 days at 20^{o}C.

RESULTS

Control of *A. repens* and yield effects on succeeding crop The technique of counting seed heads as a measure of *A. repens* infestation correlated with overall dry weight of the above ground material of the weeds using the power curves shown in Fig. 1 where y = dry weight of *A. repens* per unit area and x = no. of seed heads per unit area. Good 'r' values of 0.97 and 0.98 were obtained for Sites 5 and 6 and that from Site 4 was not unsatisfactory. Combining all three regression lines gave an 'r' value of 0.82. As shown in Table 3 there were no significant differences in control of *A. repens* where glyphosate was applied pre-harvest at 0.72 and 1.44 kg a.e./ha on any of the six sites in the year following spray treatment. However, in the second year following spray treatment, the low rate of glyphosate application did not appear to be so effective as the high rate at Sites 1 and 3 although those differences were not significant. Pre-harvest treatment was significantly better than untreated at all sites and better than stubble treatment at Sites 1 and 2.

At the five sites, harvested so far, yield increases following pre-harvest application of glyphosate (mean of both application rates) measured 18% and 52% in succeeding crops of barley, 32% in oats, 24% in wheat and 18% in swedes. Stubble treatment produced significant yield increases in one following oat crop (Site 2), one barley (Site 6), one wheat crop (Site 5), where there were corresponding reductions in *A. repens* infestation.

The relationship between population of *A. repens* and crop yield is given in Fig. 2.

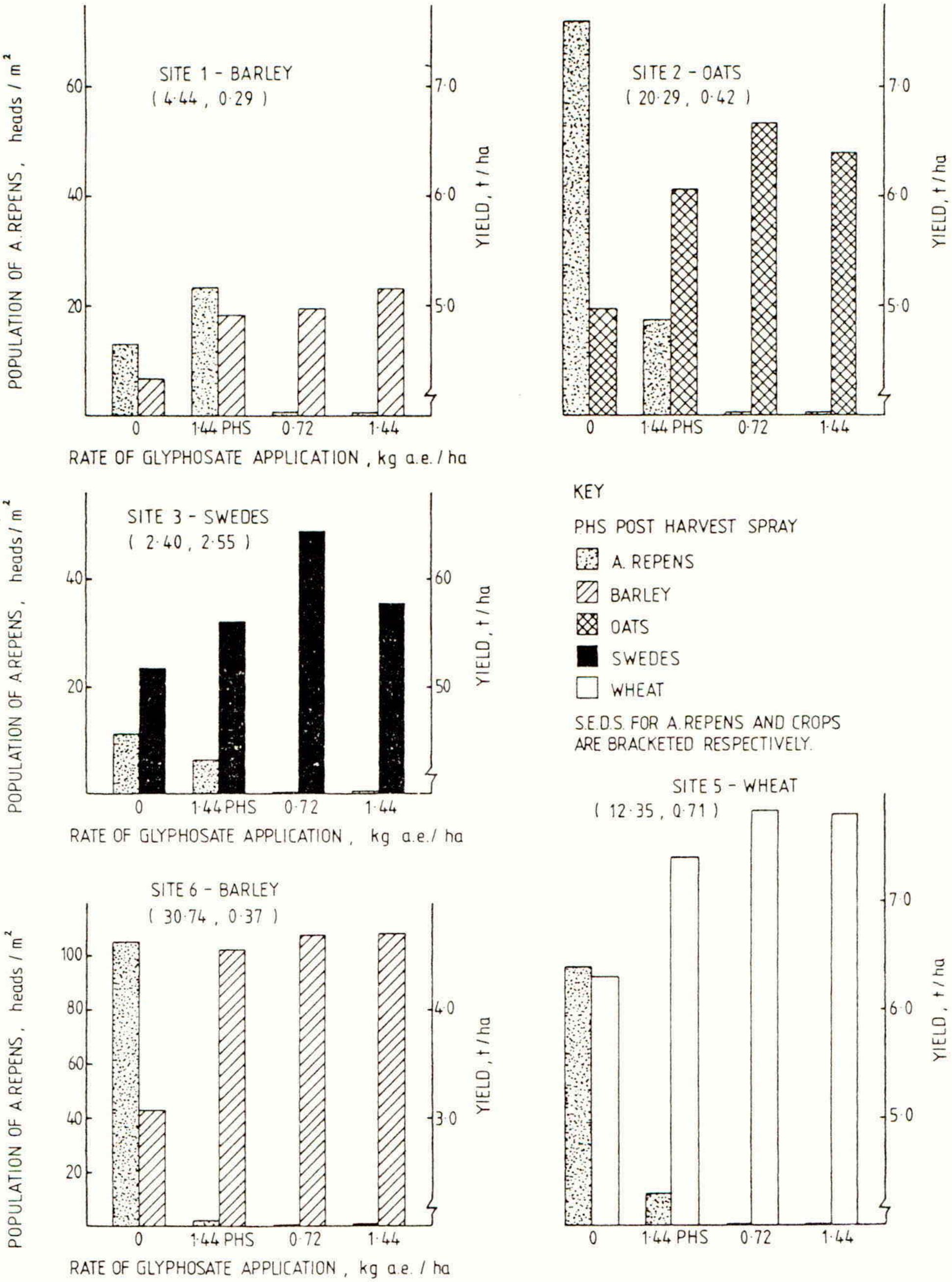

FIG 2 THE EFFECT OF A REDUCED POPULATION OF A. REPENS ON SUBSEQUENT CROP YIELD

Table 3

Percentage control of A. repens after herbicide treatment

Year(s) after spray application	Site	Glyphosate treatment, kg a.e./ha Pre-harvest 0.72	1.44	Post-harvest 1.44
1	1	95	98	0
	2	99	99	76
	3	97	97	44
2	1	87	99	0
	2*	98	97	59
	3	89	98	48
1	4	99	99	NA
	5	99	99	88
	6	99	99	98

NA = Not applicable. * = Shoots counted rather than seed heads.

Note: Significance levels ($P \leq 0.05$) are derived from raw data which have been converted to percentage of control compared with untreated plots, hence no SEDs are quoted.

Yield effects in treated crop Yield reductions occurred occasionally following pre-harvest treatment with glyphosate due to the subsequent embrittlement of the straw. This increased lodging over unsprayed areas when weather conditions were bad (Site 2), especially as there was no living weed carpet to keep the heads off the ground. However, as shown in Table 4, these losses were not significant due to wide variation between replicates. Similarly treated crops are more liable to shedding losses in high winds. This occurred at Site 3 where the yield reduction, as shown in Table 4, was significant.

Throughput of MOG and separation losses during harvesting It has been shown that separation losses from a combine harvester increase exponentially to a corresponding increase in throughput of MOG where there is a reasonably constant grain/straw ratio (Nyborg et al., 1969). An exponential model of the form: $y = 0.373e^{0.296x}$ (where y = separation loss as percentage of yield and x = throughput of MOG in t/h) fits the grain loss data shown in Table 4, with an 'r' value of 0.79. However, a greater 'r' value of 0.88 is obtained using the power curve $y = 0.256x^{1.537}$ shown in Fig. 3.

Results indicated that reductions of 11 to 31% in combine throughput at a given forward speed due to crop desiccation either lead to a corresponding reduction in grain loss of 10-50% or to an increase in forward speed and hence area covered in unit time of 11-31% at a given grain loss level.

Wheeling losses due to spraying Grain losses from wheelings have been calculated for a nominal 12 m boom width sprayer. The losses given in Table 4 vary between 1.3 and 5.3% of grain yield. Row crop wheels were used at Site 6 but this did not reduce yield losses relative to wide tyres. At Sites 1 and 3 wheelings from previous spray applications were used.

Moisture content of grain As shown in Table 4, significant reductions in grain moisture content at harvest occurred at both levels of glyphosate application at Sites 1, 4 and 5. Similarly in the following year, significant reductions occurred in grain moisture at Sites 1 and 2 of 0.6% and 1.7% compared to untreated areas, presumably due to the lack of green weed growth in the crop.

The moisture content of grain grown on post-harvest (stubble) sprayed in the previous year was not significantly lower than the unsprayed.

Table 4

Effect of pre-harvest glyphosate on combine harvester performance

Site	Glyphosate treatment, kg a.e./ha	% reduction in throughput of MOG	% increase in grain yield	% reduction in separation loss	Wheeling loss, % yield	Reduction in % grain M.C.W.B.
1	0.72	14.3	2.5*	41.2	4.5	1.0*
	1.44	25.0	2.5*	47.1	3.5	1.2*
2	0.72	27.1	-14.3	66.7*	3.1	2.1
	1.44	16.7	-33.3	66.7*	1.9	1.9
3	0.72	23.1	- 9.5*	57.9*	5.3	1.6
	1.44	30.8	- 4.8*	57.9*	4.6	1.6
4	0.72	28.1	5.7	58.9	4.7	2.0
	1.44	10.9	11.4	61.6	5.3	2.5*
5	0.72	13.9	14.0	20.0	3.4	1.6
	1.44	11.1	2.0	-20.0	2.0	1.6
6	0.72	21.1*	0	36.8	3.3	0.5
	1.44	26.3*	13.9	34.2	1.3	-0.1

* - significant($P \leqslant 0.05$)
M.C.W.B. - Moisture content on a wet basis.

Germination of pre-harvest treated grain There was no effect on grain germination from crops treated at the 0.72 kg a.e./ha rate. However, at one of the three sites the crop treated with the higher rate, was affected by reduced germination (Table 5).

Table 5

% Germination of barley sprayed pre-harvest with glyphosate

Site	Treatment glyphosate, kg a.e./ha 0	0.72	1.44	SED
2	97.3	97.0	97.0	0.72
3	96.3	96.3	95.0	1.66
6	93.7	91.3	80.7	3.90

DISCUSSION

These trials showed the control of A. repens by pre-harvest application of glyphosate to be a more reliable method than stubble treatment in areas where harvests tend to be late and growth ceases relatively early in the autumn.

There was no difference in the effectiveness of control of A. repens from glyphosate applied pre-harvest at either 0.72 or 1.44 kg a.e./ha one year after application, but after two years there was some indication that the higher rate gave better control. No significant depressions in seed germination occurred at the half rate although the full rate, at one site, reduced germination slightly.

In these trials the yield increases from succeeding crops covered the cost of the chemical, its application and any wheeling losses. The yield reductions that occasionally occurred with treated crops were attributable to particularly bad weather between spraying and harvest. This affected the desiccated crop more than the untreated one.

Separation losses from the combine were lower following pre-harvest treatment or alternatively combine throughput could be increased for the same grain loss level.

Wheeling losses from the pre-harvest treatment averaged 3.5% of yield. No improvement was obtained by using row crop wheels probably because the higher ground pressure squashed the crop so much that none of it recovered sufficiently to be picked up by the combine harvester.

The reduction in crop moisture content that occurred could be used to extend the possible harvesting period or reduce drying costs.

ACKNOWLEDGEMENTS

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BRACKEN REGROWTH IN UPLAND PASTURE FOLLOWING ASULAM TREATMENT

H. C. Lee
Department of Agriculture, Loughgall, Co. Armagh, Northern Ireland*

J. A. Cooke
Department of Biology, Sunderland Polytechnic, Sunderland, Tyne & Wear, SR1 3SD

T. J. Bines
The Nature Conservancy Council, Banbury, Oxon

Summary. Results of field trials between 1975 and 1978 using asulam for the control of bracken, *Pteridium aquilinum* (L) Kuhn, in Teesdale Co. Durham are presented. The control of bracken frond production was high using the recommended application rate of 4.5 kg a.i./ha of asulam. The amount of regrowth after three years varied between sites and the measurement of the frond producing capacity of rhizome suggested that regrowth is related to the number of fronds per unit area prior to spraying, and with the survival of living rhizome. The implication of these results is that a preliminary investigation of the number of fronds per unit area should be undertaken prior to spraying, in order to decide whether one or perhaps two applications should be sufficient for effective control. The total cost of spraying could thus be estimated before treatment commenced. Bracken, asulam, fronds, regrowth, rhizome, buds.

INTRODUCTION

Asulam is an effective herbicide for reducing frond production in *P. aquilinum* when applied after full frond emergence (Holroyd *et al.*, 1970; Soper, 1972; Veerasekaran and Kirkwood, 1972; Pink and Surman, 1974; Scragg *et al.*, 1974). The reduction occurs in the year after spraying and appears to be due to the death of frond buds following translocation of the herbicide to the rhizome (Yukinaga *et al.*, 1973; Martin, 1977; Veerasekaran *et al.*, 1978).

Such reductions in frond density (> 95%) are well documented but studies on any subsequent regrowth are few. At two sites in Scotland four years after spraying, regrowth was approximately 25-35% of the original frond density (Scragg *et al.*, 1974; Veerasekaran *et al.*, 1978). This is often considered unsatisfactory and therefore further work was required to establish the factors which affect regrowth.

METHODS AND MATERIALS

Three sites were chosen on Wooley Hill Farm, Co. Durham (National Grid Reference NZ 044 249) which is situated on the eastern edge of the Pennines at an altitude of 348 m. Preliminary observations indicated that the *P. aquilinum* upland-grassland community in each site was mature and stable, with similar species and soil conditions. An area measuring at least 6 by 8 metres was set up in each site. On 5 August 1975, when fronds were fully expanded, each area was sprayed with asulam (Asulox, May and Baker Ltd.). This was applied at the recommended rate of 4.5 kg a.i./ha (Anon., 1974) using an Oxford Precision Sprayer held 500 mm above the top of the frond canopy. In August of 1975, 1976 and 1978, 10 to 20 metre-square quadrats were laid down within these areas to measure the number of fronds.

* Current address

An investigation into the condition of rhizome was also carried out in 1978, three years after spraying. In each area, six quadrats, measuring 250 by 250 mm were excavated to a depth of 200 mm. Rhizome was classified as either short or long-shoot according to the definition of Watt (1940) and the following characteristics were measured:

i) number of emerged fronds;
ii) number of unemerged fronds (frond crozier development but no emergence);
iii) number of live frond buds;
iv) number of bud scars on live and dead rhizome (a bud scar is a point of previous frond development);
v) total length live rhizome;
vi) total length dead rhizome.

RESULTS

The mean number of fronds per square metre in the years 1975 (year of spraying), 1976 and 1978 is shown for each site in Table 1.

Table 1

Number of fronds per square metre (with standard errors) before (1975), in the year after (1976), and three years after (1978) treatment with asulam

	Site 1 n = 18	Site 2 n = 10	Site 3 n = 20
1975	57.5 (5.8)	24.6 (2.3)	24.3 (3.0)
1976	4.5 (0.8)	0	1.5 (0.6)
1978	52.2 (5.4)	0	10.6 (3.1)
1975-1976	***		***
1975-1978	N.S.		*

Mann Whitney U Test: N.S. $P > 0.05$
* $P < 0.05$
*** $P < 0.001$

n = sample number.

The reduction of frond density was high in 1976 (site 1: 85-100; site 2: 100%; site 3: 77-100%). However, the regrowth varied between sites (site 1: 77-100%; site 2: 0%; site 3: 7-65%). In order to ascertain whether the frond density before spraying may have affected regrowth, these data (Table 1) were re-examined for sites 1 and 3. The frond density in 1975 and 1978, for each quadrat at each site, was plotted on a scatter diagram (Figure 1). A marginally significant positive correlation ($r = 0.48$, $P < 0.05$, $n = 18$) was seen for site 1 covering a wide range of frond densities before spraying (13-106 / m^2). However, no significant correlation was seen for site 3 covering a similary wide but lower range (8-68 / m^2). Although these ranges are large, the majority of quadrats at site 1 showed frond densities, prior to spraying, of >35 / m^2 and, in site 3, <35 / m^2. Thus, it may be possible, by examining the number of fronds per unit area before spraying any site, to determine whether one application of asulam is liable to achieve effective control over at least three years.

The inspection of rhizome revealed that, whilst all rhizome was dead at site 2, some live rhizome remained at site 1 (475 cm/m^2) and site 3 (170 cm/m^2). However, due to the variability of these data for each of the excavated quadrats, results for sites 1 and 3 are shown full in Table 2. These data were not converted to a square metre basis because this would exaggerate the difference between positive and zero values.

Table 2

Rhizome characteristics (per 250 x 250 mm quadrat) three years after treatment with asulam

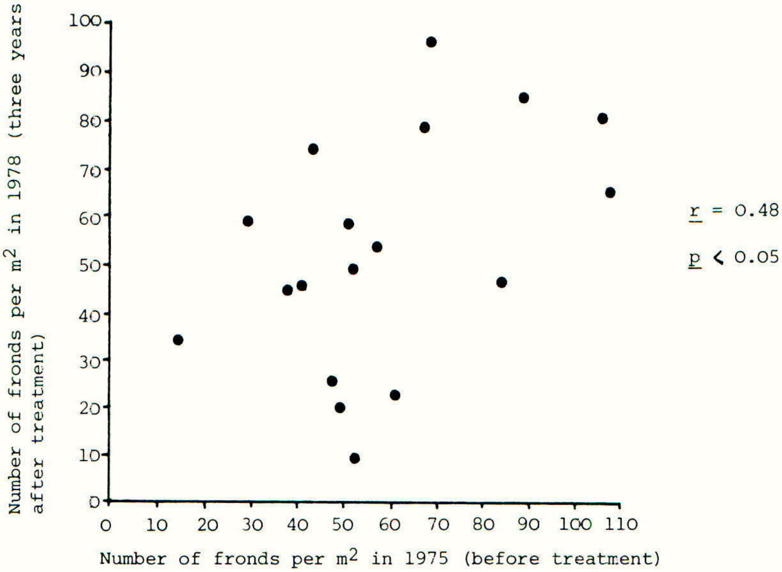
		Site 1		Site 3	
	*	Short Shoot rhizome	Long Shoot rhizome	Short Shoot rhizome	Long Shoot rhizome
Total length live rhizome (cm)	1	0	0	15	0
	2	94	228	80	45
	3	0	0	0	0
	4	124	102	0	0
	5	0	0	33	81
	6	95	69	0	0
Total number live buds	1	0	0	1	0
	2	12	3	11	11
	3	0	0	0	0
	4	38	0	0	0
	5	0	0	1	2
	6	6	2	0	0
Total number unemerged fronds	1	0	0	0	0
	2	8	7	3	0
	3	0	0	0	0
	4	23	0	0	0
	5	0	0	0	0
	6	0	2	0	0
Total number emerged fronds	1	0	0	0	0
	2	3	1	0	0
	3	0	0	0	0
	4	18	0	0	0
	5	0	0	0	0
	6	9	1	0	0
Total length dead rhizome (cm)	1	271	1591	130	52
	2	945	1273	122	228
	3	196	1935	186	211
	4	646	1675	132	131
	5	556	1077	352	169
	6	1052	1395	118	385
Total number bud scars	1	122	76	31	5
	2	427	93	79	0
	3	67	102	110	17
	4	393	68	43	10
	5	291	42	81	7
	6	469	68	63	25

* *Quadrat Reference Number*

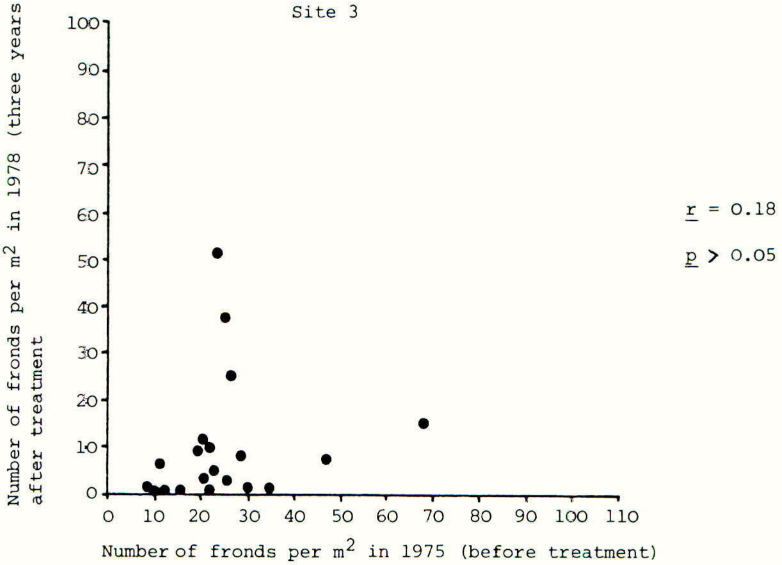
Fig. 1

Number of fronds per square metre at sites 1 and 3 before (1975) and three years after (1978) spraying with asulam

Site 1



Site 3



It should be noted that no emerged fronds were recorded from quadrats in site 3 (Table 2) even though they were present at this site (see Table 1). This was due to the chance position of quadrats which were, nevertheless, known to represent the site. Three years after spraying some live short-shoot and long-shoot rhizome, with some live buds and unemerged fronds, remained in three of the six quadrats measured at each site. Consequently there was potential for frond regrowth at both sites. The total length of surviving rhizome at site 3 was smaller, indicating less regrowth during this period as shown in Table 1. The total length of dead rhizome was much larger than live rhizome in all quadrats. This is most likely due to natural rhizome senescence before spraying and therefore could not be interpreted as rhizome killed by asulam.

A field record of frond density for each excavated quadrat before spraying was not made but estimations were possible using the total number of bud scars, which was assumed to represent the history of accumulated frond production. The majority of bud scars were associated with short-shoot rhizome (Table 2). At site 1 it appeared that the short-shoot rhizome, which is most likely to survive asulam treatment, had a history of greater frond production per unit area before spraying (compare quadrats 2, 4 and 6 with 1, 3 and 5, Table 2). This tends to confirm the results presented in Figure 1.

DISCUSSION

These results indicate that bracken regrowth is substantial if the frond density before spraying was high, ie. greater than $35/m^2$. The frond densities in sites studied by other authors were relatively low (approximately $20-25/m^2$: Scragg et al., 1974; and $25-35/m^2$: Veerasekaran et al., 1978). The amount of regrowth of *P. aquilinum* at these sites three years after spraying was similar to the results obtained from site 3 in this study.

It is possible that the greater regrowth in areas of high frond density is due to a dense mat of live rhizome below ground (up to 70 m/m^2: Lee, 1982). In these dense mats, a greater proportion of rhizome may not produce fronds, or produce them later in the season. They are therefore relatively unaffected by spraying at full canopy development in early August.

For excavated rhizome in site 1, three years after spraying, the proportion of live rhizome and frond buds was quite high. Similar experiments in upland sites in Scotland, covered by dense bracken (Martin et al., 1972) indicated that, two years after spraying with 4.0 kg a.i./ha asulam, nearly all rhizome and approximately 90 per cent of buds were live. This contrasts with another site in Scotland (Veerasekaran et al., 1978) where the number of fronds prior to treatment was low ($25-35/m^2$) and three years after spraying with 4.4 kg a.i./ha asulam only 31 per cent of all buds were live.

The results reported here are partly supported by previous studies and suggest that, before treating any site, careful measurement of the number of fronds per unit area should be carried out. This would indicate whether a single application of asulam would be suitable for effective control or whether a second application after two or three years might be necessary. The likely cost of spraying to achieve effective control of bracken could therefore be estimated, before any treatment commenced. Further work is needed on overall management strategies, which may include the use of asulam, to achieve effective long-term control of bracken in upland pastures.

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GIANT HOGWEED (*HERACLEUM MANTEGAZZIANUM*): ITS SPREAD AND CONTROL WITH GLYPHOSATE IN AMENITY AREAS

J. A. Williamson and J. C. Forbes
The North of Scotland College of Agriculture, 581 King Street, Aberdeen AB9 1UD.

Summary: Giant hogweed (*Heracleum mantegazzianum*) continues to spread, mainly along riverbanks, throughout the British Isles since its introduction last century. It contains furocoumarins which on contact photosensitise the skin causing injuries which can be serious, especially in children. It impedes access to amenity areas and replaces the native vegetation, causing loss of plant and animal species diversity and increasing the risk of riverbank erosion. In field trials in 1981 and 1982 second-year or older *H. mantegazzianum* plants were spot-treated on various dates in April and May with glyphosate applied either as a spray at 7.2 g a.e./litre or as a paste at 7.2, 21.6 or 36.0 g a.e./litre. All treatments gave 100% kill. The use of glyphosate is suggested as part of an overall strategy for giant hogweed control with minimal environmental disturbance. Distribution, paste, spot-treatment.

INTRODUCTION

Giant hogweed (*Heracleum mantegazzianum*) is a native of the Caucasus, introduced as an ornamental to Great Britain in the late nineteenth century and now widely naturalised. It is also widespread in most countries of north-central Europe and Scandinavia (Tutin et al., 1968) and in Canada (Morton, 1978).

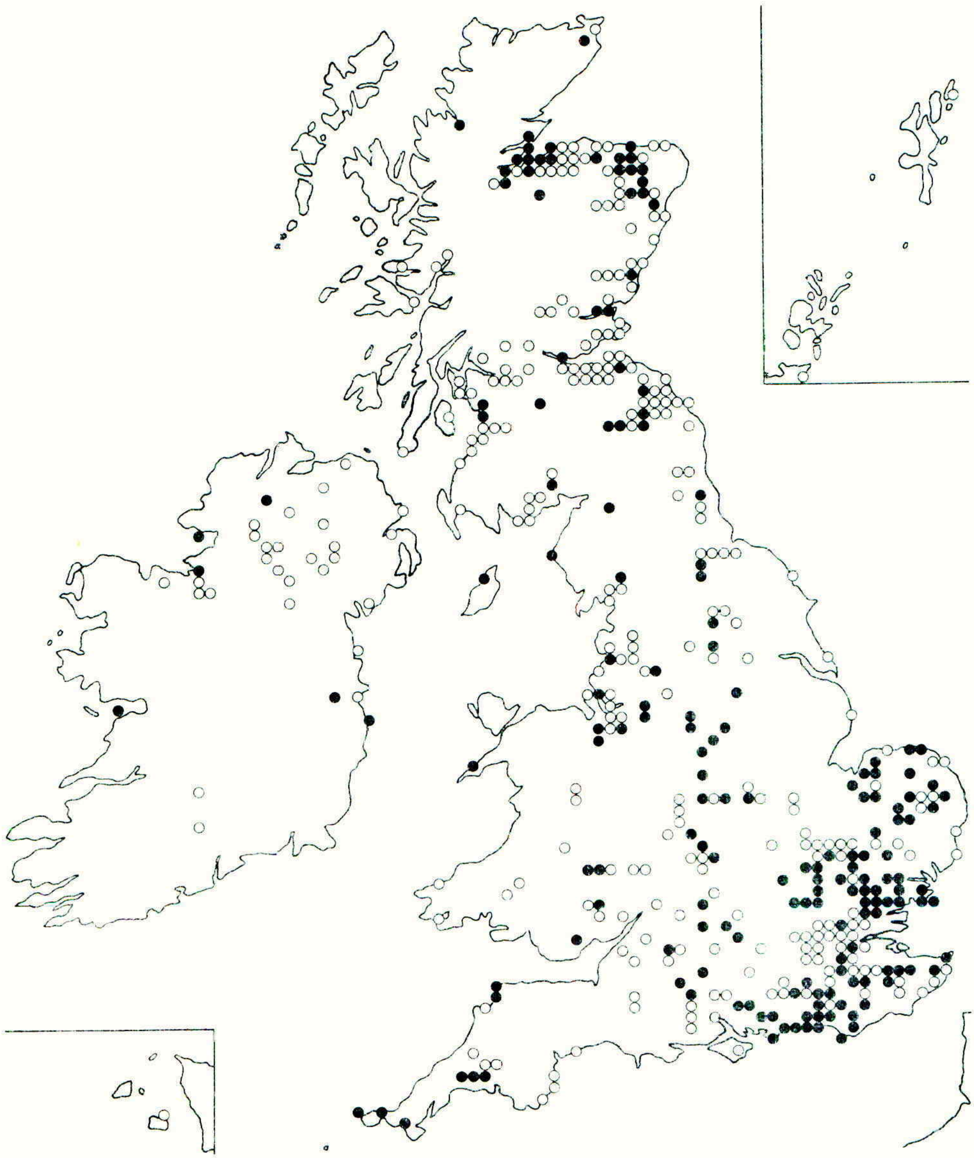
Seedlings of giant hogweed often arise in great profusion in a colonised area. Many die, but the largest become established, each as a rosette of leaves casting a dense shade over smaller vegetation. Even in the first year of growth the leaves may be 1 m or more wide. In winter the foliage dies back, sprouting vigorously again in spring from the fleshy tap root. In the summer of its second, third or fourth year the plant sends up a huge umbel of white flowers on a stem which may reach a height of 4 m or more in favourable conditions. Each plant sheds up to 5000 or more seeds and thereafter normally dies.

The copious sap and exudate from pustulate bristles on the stems and petioles contain furocoumarins which photosensitise the skin on contact. Exposure of affected skin to sunlight, even for short periods, can cause painful watery blisters within 2-3 days (Drever and Hunter, 1970). Unfortunately the plants are very attractive to children due to their spectacular appearance and their long, straight, hollow stems which are frequently used as "telescopes" and blowpipes causing blistering around the eyes and mouth. Occasionally contact with giant hogweed may precipitate a recurrent dermatitis which becomes a serious handicap.

While the injurious nature of the plant attracts most public concern and is the main justification for control measures, giant hogweed causes other problems too. In amenity areas established colonies compete strongly with and rapidly replace most other plants except trees. Where spread is not checked and colonies coalesce, as frequently happens along riverbanks, this can lead to the loss of rare or important species of plants and their associated animal life. The loss of grasses and other vegetation may lead to increased erosion of riverbanks when the giant hogweed dies back in winter leaving bare soil. In addition, dense colonies restrict public access to paths and riverbanks during summer. Finally, giant hogweed is a host for the fungus *Sclerotinia sclerotiorum* which attacks a wide range of arable and horticultural crops (Gray and Noble, 1965).

Fig. 1

Distribution of *H. mantegazzianum* in the British Isles as recorded pre-1974 (○) and 1974-82 (●). Each circle on the map represents occurrence in a 10 km square of the National Grid. Data supplied by the Biological Records Centre.

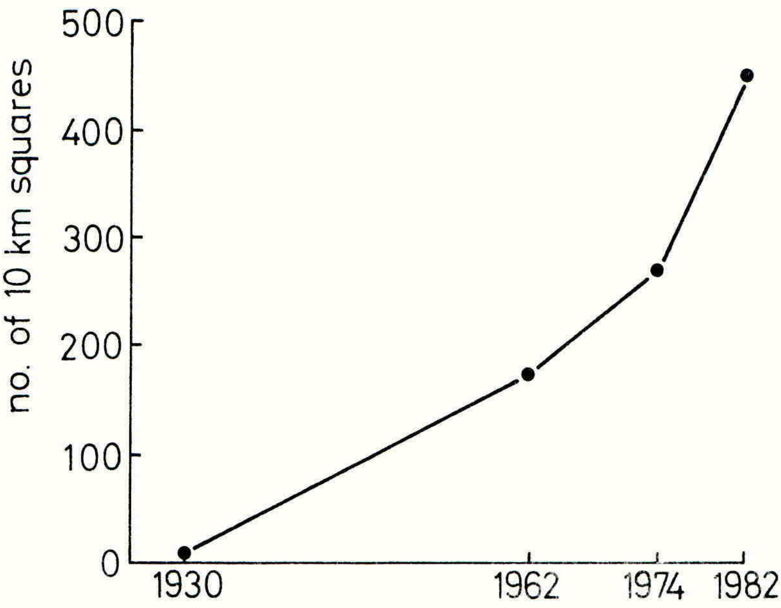


H. mantegazzianum is common near watercourses not because it requires a moist habitat but because its seeds are carried downstream by water and are deposited on the banks, especially during flooding. It also colonises waste or uncultivated ground such as railway embankments and roadside verges and grows even in such apparently inhospitable sites as the stonework of derelict buildings.

The distribution of *H. mantegazzianum* in the British Isles was most recently mapped in 1974 by the Biological Records Centre of the Institute of Terrestrial Ecology (Clegg and Grace, 1974). Records since 1974, including a large number of sites throughout Great Britain reported to J. A. Williamson in response to radio broadcasts, have been incorporated by the Biological Records Centre into an updated map (Fig. 1). Even allowing for increased public awareness resulting in more colonies being reported, the plant has clearly spread greatly since 1974, and there is evidence that the rate of spread may be increasing (Fig. 2).

Fig. 2

Number of 10 km squares in which *H. mantegazzianum* had been recorded by 1930, 1962 (Perring and Walters, ed. 1962), 1974 (Clegg and Grace, 1974) and 1982



Herbicides tested against established giant hogweed have included asulam, bromacil, chlorthiamid, 2,4-D, dichlobenil, dichlorprop, fosamine-ammonium, hexazinone, MCPA, paraquat, picloram, sodium chlorate, 2,4,5-T and 2,3,6-TBA (Drever and Hunter, 1970; Rubow, 1979; North of Scotland College of Agriculture, 1982). With the exception of 2,4,5-T (Rubow, 1979) none of these herbicides has completely killed all plants treated, though some have scorched or killed top growth. Asulam, chlorthiamid, 2,4-D amine and dichlobenil are approved for use near water (Ministry of Agriculture, Fisheries and Food, 1982) but are relatively ineffective against giant hogweed.

In his work in Denmark, Rubow (1979) found that overall spraying with glyphosate at 3.0-4.5 kg a.e./ha in May or June could give good control of giant hogweed, but only at the expense of all other vegetation. Glyphosate is approved for use near water and thus it seemed appropriate to try spot-treatment with this herbicide in April or May, when access to the middle of the stand would still be possible, either as a spot-spray or as a paste applied to the leaves with a brush. Such treatment might achieve effective control and yet cause little damage to the surrounding vegetation, particularly the paste application which is truly selective and could be used by householders or amateur gardeners on small colonies or single plants.

METHODS AND MATERIALS

In 1981 two experimental sites were chosen near Kennethmont, Grampian, one in a shaded beech wood and the other on the unshaded bank of a stream. At each site 65 second-year or older *H. mantegazzianum* plants were selected for uniformity and marked in April. Glyphosate was applied in early or late May as a spot-spray at 7.2 g a.e./litre (the manufacturer's recommendation for spot-treatment) or a paste at 7.2, 21.6 or 36.0 g a.e./litre. Each treatment was applied to five plants allocated at random and all the reamining plants at each site were left untreated. Spot-spraying was done with a knapsack sprayer fitted with a fan nozzle, operating at 100 kPa pressure. The paste was made using a common proprietary wallpaper paste to achieve a consistency similar to that used for hanging wallpaper. It was applied with a 125 mm paste brush along the midribs and petioles of the two upper most fully expanded leaves and across the growing point.

The trial was repeated in 1982 at an unshaded riverbank site near Rothiemay, Grampian, using the same methods and materials but with three dates of application. On each of three assessment dates each plant was scored on a scale from 0 (completely healthy) to 10 (dead with no regeneration from the base).

RESULTS

In 1981 the early May applications of glyphosate had killed all treated plants at both sites by the time of the second application three weeks later. The crowns of these plants showed no sign of regeneration and had begun to rot. All untreated plants remained perfectly healthy. Unfortunately at both sites the effects of late May application of glyphosate were obscured by glyphosate drift from commercial spot-spraying of neighbouring plants. All marked plants, including those intended to be untreated, were killed as a result of this drift, and severe damage was also done to the surrounding vegetation.

In 1982 every glyphosate treatment gave 100% kill of giant hogweed while all untreated plants remained perfectly healthy (Table 1). Most treated plants died within two to three weeks of application. Some damage to surrounding vegetation was seen with both spray and paste application of glyphosate but this was highly localised around the treated plants.

DISCUSSION

In these trials, when each plant was individually and carefully treated, spot-spraying of giant hogweed with glyphosate at 7.2 g a.e./litre clearly gave excellent control at all times of application. By the end of May, however, some plants are very large, which not only makes it difficult and hazardous for the spray operator to penetrate colonies and reach all the plants but creates a dense canopy of leaves protecting smaller plants from the herbicide. It is therefore likely that in practice early applications will be most successful. Most perennials with underground overwintering organs are less susceptible to translocated herbicides such as glyphosate in early spring when phloem translocation is predominantly upward, but our results show that giant hogweed is killed by glyphosate at least as early as mid April. These trials were conducted in north-east Scotland in order to produce recommendations for control in that area (North of Scotland College of Agriculture, 1982), and optimum timing could well be two to three weeks earlier in the south of England.

Table 1

Effect of various glyphosate treatments on giant hogweed (means of five plants)

Method of application	Glyphosate concentration (g a.e./litre)	Date of application (1982)	Mean score (0 = healthy, 10 = dead) Assessment date (1982) 13 May	26 May	6 July
Spray	7.2	24 April	8.4	9.8	10.0
		13 May	0.0	7.4	10.0
		26 May	0.0	0.0	10.0
Paste	7.2	24 April	7.0	10.0	10.0
		13 May	0.0	6.4	10.0
		26 May	0.0	0.0	10.0
Paste	21.6	24 April	7.4	10.0	10.0
		13 May	0.0	7.0	10.0
		26 May	0.0	0.0	10.0
Paste	36.0	24 April	8.0	10.0	10.0
		13 May	0.0	7.4	10.0
		26 May	0.0	0.0	10.0
Untreated			0.0	0.0	0.0

No statistical analysis is presented as all treated plants died and all untreated plants remained perfectly healthy.

In practice even spot-spraying may damage non-target species to a degree which is unacceptable in an amenity area. For example, one of our trial areas in 1981 was devastated by drift from commercial spot-spraying of neighbouring plants. Application of glyphosate as a paste, though too laborious where a large area has to be treated, eliminates the drift problem. Transfer of paste as the treated leaves die or if washed off by rain does purely local damage to non-target species. For selective application (e.g. by rope-wick applicator or roguing glove) much higher concentrations of glyphosate are generally recommended than for spot-spraying; these results show that for control of giant hogweed there is no advantage in using higher concentrations in paste than in spray.

Any strategy for control of giant hogweed over a wide area, as is being contemplated by several local authorities, must take account of the downstream spread of the species in river catchments. Control should start from the furthest upstream occurrence in a catchment. Herbicide application lower down is unlikely to give permanent control if the area is subject to constant reinvasion by seed from uncontrolled colonies further up. Glyphosate is seen not as the complete answer to the giant hogweed problem but as the first step in an overall strategy, killing established plants and preventing seed set. Subsequent steps might involve the re-establishment of vegetation such as grass and the use of selective herbicides to control giant hogweed seedlings as they arise. A wide range of herbicides is currently being screened for this purpose.

In the country as a whole the best strategy is to prevent giant hogweed from establishing itself in new areas, especially in the upper reaches of river catchments. The destruction of small isolated colonies is a relatively simple task, but once an entire river becomes infested, as has already happened, for example, in the case of the Deveron in north-east Scotland, a comprehensive control programme may be prohibitively expensive. Local authorities should undertake regular surveys so that new colonies can be detected before they become foci of invasion of much larger areas. In this way the spread of giant hogweed could be checked. Control of existing infestations will inevitably cause some environmental disturbance but if glyphosate is used in the manner suggested this disturbance will be minimal.

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A COMPUTER MODEL FOR PREDICTING CHANGES IN A POPULATION OF BROMUS STERILIS IN CONTINUOUS WINTER CEREALS

F. Pollard
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary. An arithmetical model of changes in a Bromus sterilis population has been produced from results obtained from field experiments. The model has been converted into a program for a micro-computer because the influence of 16 factors is considered. The user is given a print-out of predicted population changes for the next year or more, from an assessment made of the population in the field, on any one of five growth stages.

INTRODUCTION

When investigating the response of a weed species to various treatments, one first attempts to isolate single treatments and measure their direct effects on the weed. One then examines the way in which different treatments interact in their effect on the weed until a prediction can be made of the weed's behaviour under different conditions and treatments. If this can be expressed in terms of plant number and the conditions to be considered can be varied, then one has a mathematical population dynamics model.

A model may be useful in three ways: First, by allowing predicted changes in a population to be compared with changes in a real population, information on the validity of the experimenter's conclusions can be obtained. Second, a model may point out important areas of ignorance of the weed's behaviour and show where further experiments are needed. Third, a model can be used as an advisory aid to illustrate the response of the weed to different farming practices or the degree of chemical weed control needed to control it in a particular farming system.

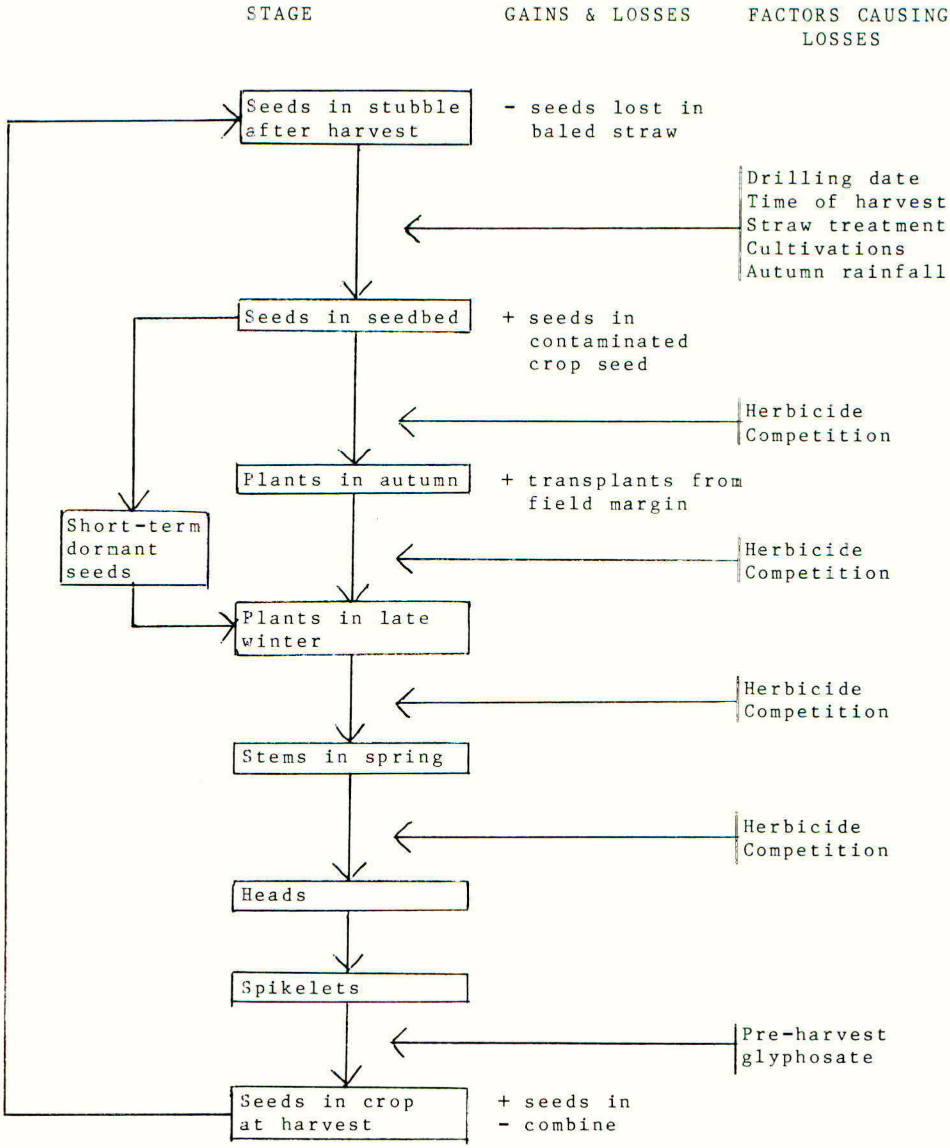
Bromus sterilis has become an increasingly troublesome weed of winter cereals over the last ten years mainly as a result of changes in farming practice. Direct drilling and reduced cultivation systems, increased areas of autumn sown cereals, earlier drilling and greater reliance on herbicides for grass weed control all appear to have encouraged the species. Research on B. sterilis has been undertaken by the Weed Research Organization since 1977 and whilst experiments have shown a variable response to herbicides the effects of cultural treatments have been more consistent. It was decided that a model of the life-cycle of B. sterilis would be useful in illustrating the effectiveness of cultural methods of control and in estimating the percentage chemical control required for B. sterilis control with particular cultural treatments. The weed most commonly occurs in autumn-sown cereal crops and the model considers population changes in winter wheat or barley. One problem with a model is the number of repetitive calculations which must be done but the use of a computer allows the model to be worked without tedium.

Life-cycle of B. sterilis in autumn-sown cereal cropping

The life-cycle of B. sterilis is simple because the weed's seeds exhibit only short-term dormancy (Figure 1). Little evidence of long-term dormancy lasting for a year or more has been found and if it does occur, the numbers involved must be very low and unlikely to significantly affect an existing population. Therefore, only seeds in their first year need to be considered. Many seeds shed on the soil

Figure 1

Life-cycle of Bromus sterilis in a winter cereal crop



surface germinate as soon as sufficient moisture is present and these are normally destroyed by cultivations or herbicides prior to planting the next crop. At this time the seed population is also subject to other losses such as those caused by straw burning and so the period from harvest until sowing the crop is of major importance to the weed's survival. In the seedbed, most seeds germinate and emerge with the crop but a small number may be dormant and not emerge until spring. Tillering usually begins in the autumn when 3-4 leaves are present and is usually completed at the end of winter. There is a reproductive phase which rarely produces more than six viable stems in the crop, each panicle producing up to 16 spikelets, each with up to six viable seeds. Seed shedding begins in June but many seeds remain on the panicle at harvest and may be removed by the combine.

Design of the model

The model is an attempt to represent the life-cycle in the form of a series of equations with numerical values given to each stage of growth and to each condition or treatment affecting the weed. It is important to define the units used to measure the population. With an annual grass this is easier than with some other weeds such as creeping perennials or spreading annual dicots because individual plants can be distinguished and the range of sizes of these plants is limited. Even so, as the plant passes through stages of its life-cycle it undergoes multiplications, also it undergoes changes according to enironmental conditions. Thus equal numbers of plants in spring, grown under different conditions, may differ in their ability to produce new individuals in the summer. It is therefore necessary both to enumerate and describe individuals in a way which gives a consistent measure for a particular life-cycle stage. The model proposed recognises the eight stages shown in Figure 1. Table 1 shows the algebraic code given to each stage, the conditions and treatments which influence population changes and indicates the way in which they act.

In moving from stage to stage, the number of units will usually fall, due to losses of various kinds. These are most commonly fractional losses which are independent of the size of the population but relate to the treatments imposed. In the model, such fractions are expressed as factors of unity or less and are called "discrete factors" because they are fixed for a particular cultural treatment or environmental condition. They are based on experimental results. In addition, the population may be decreased by "variable factors", which in the model are used only for herbicides and relate to per cent kill. They have no fixed values and range from 0 for 100% kill to 1 for no effect.

Some stages (T, B and C) result from a multiplication of the previous stages. Where this takes place the model uses an additional "reproductive factor" reflecting the highest value expected for the multiplication used. The number of individuals at each stage is therefore the number at the previous stage multiplied by discrete, variable and multiplication factors. However, the population may also be increased by direct additions such as seed introduced by 'dirty' combines or in contaminated cereal seed and values must be added to the appropriate stage before calculating the value of the next. In a similar way losses by subtraction may take place. Multiplication, addition and subtraction are the only functions used; division is avoided by using the reciprocal and multiplying.

Table 2 shows the values of the different levels of the discrete variables.

The computer program

It can be seen that by combining all the equations shown in Table 1, calculation of all the changes for a whole year is a laborious process. It was decided to write a program for an Apple II computer and store it on a five and a quarter inch floppy disk. The program is written in the 'Applesoft' version of Basic and is self-loading when the disk is 'booted'. The program asks multiple-choice questions of the user until it has gathered sufficient information

Table 1

Sequence of calculations used in the model

STAGE	CODE	INFLUENCE	ARITHMETIC ACTION	VALUE RANGE
Seeds in stubble	CB=C-R			
	L	Dirty combine	addition	unrestricted
	AA	Time of harvest	discrete	0.9-1
	AB	Straw treatment	discrete	00.25-1
	AC	Seedbed preparation	discrete	0.1-1
	AC	Drilling date	discrete	0.1-1
	AE	Autumn rainfall	discrete	0.5-1
	A=AAxABxACxADxAE			0.001125-1
Seed in seedbed	S=(CB+L)xA			
	M	Dirty seed	addition	unrestricted
	Q	Transplants	addition	unrestricted
	DA	Early herbicide	variable	0-1
	DB	Crop and seed rate	discrete	0.8-1
	D=DAxDB			0-1
Plants in autumn	P=(S+M+Q)xD			
	EA	Crop and plant density	discrete	0.8-1
	EB	Winter herbicide	variable	0-1
	U	Over-wintered seeds	addition	Sx0.005xAC
	E=EAxEB			0-1
Plants in winter	W=(PxE)+U			
	FA	Brome plant density	discrete	0.6-1
	FB	Stems/plant	reproductive	6
	F=FAxEAxFB			2.88-6
Stems in spring	T=WxF			
	GA	Earlier competition	discrete	0.384-0.8
	GB	Tiller competition	discrete	0.6-1
	G=GAxGB			0.2304-0.8
Heads	H=TxG			
	I	Spikelets/head	reproductive	16
Spikelets	B=HxI			
	JA	Pre-harvest glyphosate	discrete	0.9-1
	JB	Seeds/spikelet	reproductive	6
	J=JAxJB			3.6-4
Seeds in crop	C=BxJ			
	R	Taken in combine	subtraction	Cx0.1xAA

Table 2

Values of discrete variables

FACTOR	CODE	LEVEL	VALUE
Time of harvest	AA	before 5 August	0.9
		6 August or later	1
Straw treatment	AB	baled	1.0
		burnt	0.25
Seedbed preparation	AC	direct drilled	0.4
		one cultivation only	0.25
		two cultivations	0.1
		chisel plough	0.05
		mouldboard plough	0.01
Drilling date	AD	before 1 October	1
		1-15 October	0.8
		16-31 October	0.3
		after October	0.1
Autumn weather	AE	dry September	1
		wet September	0.5
Crop & seedrate	DB	wheat <200seeds/m2	0.5
		wheat=>200seeds/m2	0.4
		barley <200 seeds/m2	0.4
		barley=>200 seeds/m2	0.3
Crop & plant density	EA	wheat <200plants/m2	1
		wheat=>200 plants/m2	0.95
		barley <200 plant/m2	0.95
		barley=>200 plants/m2	0.9
(Tillering)	FA	<100plants	1
		=>100 B. sterilis plants	0.95
		=>200 B. sterilis plants	0.95
		=>400 B. sterilis plants	0.9
(Tiller competition)	GB	<100 B. sterilis tillers	1
		=>100 B. sterilis tillers	0.9
		=>500 B. sterilis tillers	0.8
		=>1000 B. sterilis tillers	0.6
Pre-harvest glyphosate	JA	Not used	1
		Used	0.9

Table 3

Examples of predicted and actual B. sterilis population changes

Number/m^2	Straw baled predicted	actual	Straw burnt in 1980 predicted	actual
a. Direct drilled barley with 419 B. sterilis plants/m^2 in autumn 1979				
Plants in crop, spring 1980	398	318	398	318
Stems	2040	-	2040	-
Heads, summer	838	1030	838	1030
Spikelets	13400	-	13400	-
Seeds in crop at harvest	53600	52400	53600	52400
Seeds in seedbed, autumn	8790	-	2200	-
Plants in crop, autumn	2640	1160	658	669
Plants in crop, spring 1981	2390	-	597	-
Stems	103000	-	2580	-
Heads, summer	3570	2210	891	1520
Spikelets	57100	-	14300	-
Seeds in crop at harvest 1981	228000	152000	57100	112000
b. Direct drilled barley with 562 B. sterilis plants/m^2 in autumn 1979				
Plants in crop, spring 1980	505	-	505	-
Stems	2190	-	2190	-
Heads, summer	755	315	755	315
Spikelets	12100	-	12100	-
Seeds in crop at harvest	48300	11200	48300	11200
Seeds in seedbed, autumn	6960	-	3480	-
Plants in crop, autumn	4180	856	1040	279
Plants in crop, spring 1981	3790	-	946	-
Stems	16400	-	4090	-
Heads, summer	5650	1470	1410	1330
Spikelets	90400	23200	22600	24600
Seeds in crop at harvest 1981	362000	96500	90400	99700
c. Barley established after light cultivation only with 239 brome plants/m^2 in autumn 1979.				
Plants in crop, spring 1980	227	264	227	264
Stems	1160	-	1160	-
Heads, summer	478	768	478	768
Spikelets	7650	-	7650	-
Seeds in crop at harvest	30600	48300	30600	48300
Seeds in seedbed, autumn	3130	-	782	-
Plants in crop, autumn 1980	939	710	234	442
Plants in crop, spring 1981	849	-	224	-
Stems	3670	-	1150	-
Heads, summer	1270	1700	471	1100
Spikelets	20300	-	7550	-
Seeds in crop at harvest 1981	81200	134000	30200	62500

at which point it calculates and prints out a prediction of the population movements over the next one year period. The user is then allowed either to continue for another year, with or without changes, or to end and start a new run. The user may start the cycle at any one of the five stages when a field assessment of a population would likely be done.

Validity of the model

The values used in the model are based on field experiment data but many approximations have been made. In a few cases, values have only little experimental backup. Table 3 gives some comparisons of predicted and actual values from some field experiments with and without straw burning. In example a there is good agreement between predicted and assessed values until the post-harvest period of 1980, after which the model tends to under-estimate values following the straw burning treatment. After straw baling, the model gives what is probably an impossible over-estimate. It is probable that the factors used to represent competition are inadequate at such high weed levels, which result in almost total crop loss in any case. It must also be remembered that the assessed values shown are an estimate of true values and as such are also subject to error. Example b suggests that the initial assessment of 562 *B. sterilis* plants/m2 may have been an over-estimate, because the relationship of predicted and assessed values remains more or less constant until summer 1981. At this stage, the model makes an under-estimate on the burning treatment to give close agreement on the number of seeds in the crop at harvest. After baling, the model holds the relationship to give an absurdly high value. In example c the model again under-estimates the assessed values, especially following straw burning. If alterations need to be made to the values of discrete factors, these can be done easily and without interference with the structure of the model but the model now needs further testing on a larger scale.

Availability

A copy of the computer program can be obtained from the author either in the form of a listing or a floppy disk.