DEVELOPMENT OF DIFENZOQUAT, A SELECTIVE HERBICIDE AGAINST WILD OATS IN SPAIN

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Summary Difenzoquat, 1,2-dimethyl-3,5-diphenyl-1-H-pyrazolium methyl sulphate (AC 84.777), a new selective herbicide for the control of wild oats (Avena spp.) in wheat and barley, has been tested in Spain during the last three years. Experiments were conducted to determine the optimum time and rate of application and spray volume.

Best results were obtained when the herbicide was applied at the rate of 1 kg a.i./ha with either 1.25‰ of Agral+ 26.5, or 0.5% of Tensiofix++ HS in the spray solution. The optimum time of application was when the wild oats were in the 3 to 5 leaf stages. Efficacy of the herbicide was not effected by spray volume. Difenzoquat was compatible with ester formulations of 2,4-D and MCPA, chloromequat, malathion, dimethoate and foliar fertilizers. No difference in response to the herbicide was noted between the various varieties of wheat and barley used in these studies. Cold temperatures at the time of application resulted in an apparent temporary sensitivity to frost.

INTRODUCTION

Since the system of cultivation of cereals in Spain as well as the correlated problem with wild oats might be different from the standards of Central Europe, a brief discussion will be dedicated to this subject.

A total of 6 million ha of barley and wheat is grown in Spain mostly under dry land farming conditions. Wheat, which represents 3.2 million ha is sown generally in autumn (October-November) before the arrival of cold temperatures. On the other hand sowing of barley (2.8 million ha) is divided equally between the autumn and early spring or end of winter. Approximately 30% of the acreage of these two cereals is infested with Avena spp. The highest infestations are found in the most productive soils.

Wild oats are found in all areas of Spain where cereals are grown, but the greatest intensity is in the provinces of Sevilla, Badajoz, Granada, Valladolid, Navarra, Burgos and Lerida.

The problem of wild oats has been aggravated in the last year because of the following factors: decrease in the use of fallow fields, increased use of herbicides, broad-leaved weed control and the mechanisation of harvesting.

A survey conducted to investigate the species of wild oats existing in Spain has shown that Avena macrocarpa and A. ludoviciana are the principal species with a small percentage of A. fatua. A. macrocarpa is more important in the southwestern part of the peninsula, A. ludoviciana is dominant in the northeastern part (Cataluna).

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The difenzoquat trials in 1972, 1973 and 1974 were conducted to establish:-

(a) Optimum dosage
(b) Suitable time of application
(c) Selectivity to the main varieties of barley and wheat
(d) Proper spray volume for both aerial and ground treatment
(e) Compatibility with various broadleaved cereal herbicides, insecticides, growth regulators and foliar fertilizers.

In all trials, the possible influence of climatic factors, such as temperature, humidity and rainfall were studied.

METHODS AND MATERIALS

Experiments on application rate

Three experiments were conducted in 1973 at three different locations (site No. 1: Leiva province of Logroño; site No. 2: Mérida province of Badajoz; site No. 3: Villafranca de los Barros province of Badajoz).

Site No. 1 was planted with winter barley var. Pallas, on December 1st, 1972 at the rate of 160 kg/ha.
Site No. 2 was planted with winter wheat var. Impeto on November 20th, 1972, at the rate of 300 kg/ha.
Site No. 3 was planted with winter barley var. Hatif de Grignon on November 28th 1972, at the rate of 120 kg/ha.

Difenzoquat was applied at the following stages of the wild oats:

Site 1: 2-3 leaves, on March 29th, 1973
Site 2: 4-5 leaves, on February 27th, 1973
Site 3: 4-5 leaves, on March 7th, 1973

Experiments on time of application

Three trials were carried out in 1973 to determine the optimum time of application, with regard to the growth stage of wild oats as well as the cereal. Details are as follows:-

Site 4: Location: Valverda de Mérida province of Badajoz. Crop: wheat, var. Impeto. Seeding rate: 120 kg/ha.
Site 5: Location: Mérida province of Badajoz. Crop: barley, var. Trait d' Union. Seeding rate: 150 kg/ha.
Site 6: Location: Torrejón de Ardoz province of Madrid. Crop: barley, var. Aurora. Seeding rate: 200 kg/ha.

Table 1 show details of the applications of difenzoquat.

Table 1

Growth stages and dates of application

Stage of application

	Weed	Crop	Site 4	Site 5	Site 6
1.	2-2½ leaves	3 leaves	Feb. 2nd	Feb. 6th	Mar. 24th
2.	2½-3 leaves	3-5 leaves	Feb. 19th	Feb. 19th	Apr. 4th
3.	3-4 leaves	Shooting	Mar. 5th	Mar. 5th	Apr. 30th
4.	4-5 leaves	Last leaf	Mar. 29th	Mar. 29th	-
5.	Last leaf	Ears emerging	Apr. 21st	Apr. 21st	May 12th
6.	Panicles emerging	Flowering	May 7th	May 7th	-

Experiment on admixture with other agricultural chemicals

Details of this experiment carried out in 1973 are given as follows:-

Location: Leiva province of Logroño. Crop: winter wheat var. Estrella. Seeding date and rate: November 10th, 1973 at the rate of 350 kg/ha. Difenzoquat was applied on March 29th, 1973.

Tolerance of cereal varieties to difenzoquat

Several trials were conducted in 1973 and 1974 in the provinces of Sevilla, Barcelona, Madrid and Badajoz to determine the tolerance of cereal varieties to difenzoquat.

These trials were unreplicated in all four locations. In each site a collection of approximately 20 varieties were sown, each variety occupied 400 m^2, of which half of it was sprayed with difenzoquat.

The formulation of difenzoquat used in this study contained 400 g/l of the active ingredient, expressed as the cation.

The replicated experiments were of a randomized block design with three replicates. The applications in these experiments were made at 400-500 l/ha and with a pressure of 1.5 atm. Pressurised knapsack sprayers were used with flat fan nozzles of 0.5 mm diameter.

The assess the efficacy of herbicides against wild oats, counts were made of the number of panicles per m^2.

RESULTS

Table 2 shows results obtained at three different locations. The wetting agent was Lissapol+ 26.5% at 1% v/v of solution. Application was made when the wild oats were in the 3-5 leaf stage to the fully tillered stage.

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Table 2

Effect of application rate of difenzoquat on wild oat control and on cereal yield

Difenzoquat kg a.i./ha	Site 1 Winter Barley var. Pallas Wild oat control (%)	Site 1 Yield % of control	Site 2 Winter Wheat var. Impeto Wild oat control (%)	Site 2 Yield % of control	Site 3 Winter Barley var. Hatif de Grignon Wild oat control (%)	Site 3 Yield % of control
0.0	0.0	100	0.0	100	0.0	100
0.6	97.1	141.6	86.2	87.1	38.4	119.7
0.7	-	-	-	-	70.8	126.7
0.8	98.8	134.3	87.4	82.8	-	-
0.9	-	-	89.6	78.3	93.0	127.9
1.0	96.5	124.4	97.7	93.5	92.0	126.9
1.1	-	-	96.5	98.1	86.9	116.3
1.2	99.2	124.4	94.2	109.9	98.0	125.6
1.6	99.4	116.1	-	-	-	-

It can be concluded, considering altogether the three experiments, that 1 kg a.i./ha of difenzoquat is the optimum dosage to be used generally. With this dosage a control superior to 90% was obtained meanwhile with lower rates (0.9, 0.8 and 0.7 kg a.i./ha) there is the possibility of obtaining insufficient control. Note that yields of the cereal were unaffected by higher rates (1.1, 1.2 and 1.6 kg a.i./ha).

Table 3 shows the results of three trials carried out to determine the most suitable period for difenzoquat application to control wild oats as well as to increase cereal yield by eliminating undesirable competition. In these trials, difenzoquat was used at 1.0 kg a.i./ha with a suitable wetter at 0.5% v/v of the spray solution.

Table 3

Effect of time of application of difenzoquat at 1 kg a.i./ha on wild oat control and on cereal yield

Stage of application	Site 4		Site 5		Site 6	
	Wheat var. Impeto		Barley var. T. d'Union		Barley var. Aurora	
Weed	Wild oat control (%)	Yield (% of control)	Wild oat control (%)	Yield (% of control)	Wild oat control (%)	Yield (% of control)
2-2½ leaf	90.6	130.3	59.0	87.1	78.0	108.2
2½-3 leaf	93.7	140.6	84.6	86.9	96.9	145.9
3-4 leaf	85.6	142.4	84.6	94.3	97.5	127.1
4-5 leaf	92.5	127.3	93.6	97.8	-	-
Last leaf	0	107.9	76.9	101.7	55.7	109.4
Panicles emerging	0	106.1	20.5	94.3	-	-
Control	0	100	0	100	0	100

Too early application gave insufficient control of wild oats because of subsequent new germination.

Very late applications, when the panicles of the wild oats were emerging, did not kill the weed; though, a retention in growth was obtained.

Several trials have been conducted to establish the selectivity of difenzoquat on the varieties of cereals normally grown in Spain. The list of varieties treated with difenzoquat (1 kg a.i./ha) follows:-

Varieties of barley treated with difenzoquat

Caballar	Beka	Delta	Proctor
Wisa	Rika	Esperanza	Sonia
Trait Union	Ingrid	Impala	Nimphe
Piroline	Hatif de Grignon	Laura	Ager
Pallas	Foma	Minerva	Albacete
Mamie	Berta	Noelle	Guadiana
Hellas	Aurora	Pobo	
Carmen	Ceres	Prelude	

Varieties of wheat treated with difenzoquat

Impeto	Charmorro	Montjoice	Argelato
Aragon 03	Senatore Capelli	Dragon	Mexipak rojo 7 Cerros
Florence Aurora	Mara	Marzotto	Mexipak blanco 3 Enanitos
Rex	Major	Mahisa	Diamante
Capitole	Monteada	Cesar	Rainieri
Pane 247	Ariana	Hardi	Hibrido D
Pane 17	Tovarit	Atys	Mexipak blanco T-87
Estrella	T-85	Dimas	Fartó
			Montanari

Difenzoquat did not cause any significant phytotoxicity in the varieties of wheat or barley tested.

Difenzoquat treated plants were slightly sensitive to cold when frost occurred during or immediately after spraying. It appeared that barley was more sensitive to the interaction of difenzoquat and frost than wheat. However, the yellowing damage was transient and disappeared in two to three weeks.

The symptoms observed were typical of those caused by frost: yellowing of the leaves with a pronounced darkening of the tips.

Normal rates of application (i.e., 1 kg a.i./ha) produced no observable phytotoxicity to the crop except where application was made after the second node of the cereal had appeared.

Evaluation of the various spray volumes in the application of difenzoquat demonstrated that the volume of spray did not alter the herbicidal effectiveness; but, it was very important to obtain uniform coverage. Volumes of 150-500 l/ha provided very good results for ground treatments. For aerial treatment 40-80 l/ha was the preferred range of spray volume.

Table 4 shows the results obtained in a trial where difenzoquat was mixed with various chemicals.

Table 4

Effect of the mixtures of various compounds with difenzoquat+ on wild oat control and on yield of wheat var. Estrella

Treatment	Dosage (kg a.i./ha)	Control of wild oats (%)	Yield (% of control)
Difenzoquat	1.0	95.9	131.7
Difenzoquat + MCPA++	1.0 + 0.5	96.5	125.9
Difenzoquat + 2,4-D+++	1.0 + 0.4	91.7	116.6
MCPA	0.5	16.2	114.3
2,4-D	0.4	7.9	114.3
Chlortoluron	2.4	12.7	96.9
Difenzoquat + chloromequat	1.0 + 1.6	96.2	141.9
Untreated	-	0.0	100

\+ Agral 26.5% was used at the rate of 1%
++ A formulation containing 25% MCPA and 8% flurenol as organic ester
+++ A formulation containing 76% 2,4-D as the isobutyric ester

Difenzoquat was compatible with the following compounds: Malathion, dimethoate, menazon, Fertifoliage+ and maneb. Transient phytotoxicity was observed only in the maneb/difenzoquat mixture.

DISCUSSION

A series of field trials undertaken over three consecutive years have demonstrated the effectiveness of difenzoquat against all species of wild oats existing in Spain.

The optimum dosage for difenzoquat is 1.0 kg a.i./ha With this rate, over 90% control of wild oats is usually obtained. Although barley or wheat will tolerate higher dosages of difenzoquat, there is no practical improvement in control of wild oats. The addition of a nonionic wetter to the spray at 0.5% v/v is essential for good performance. Agral 26.5 and Tensiofix HS have been found to be good surfactants for use with difenzoquat in Spain.

Application of difenzoquat at 3 and 5 leaf stage of wild oats gives maximum control of wild oats as well as the greatest increase in yield, due to elimination of competition by wild oats. The 3 to 5 leaf stage of the wild oats generally coincides with the beginning of tillering to the beginning of the shooting stages of wheat and barley. Earlier applications are less effective because many wild oat seeds may germinate after the treatment. On the other hand, later applications eliminate the advantage of yield increases because of weed competition and therefore damage to the cereal has already occurred.

In these tests, spray volume is of little importance as long as the distribution of the droplets is uniform and the wetting agent is used at 0.5% v/v. All wild oat plants should receive thorough, uniform coverage.

Compatibility has been established between difenzoquat and 2,4-D ester as well as with MCPA ester. If difenzoquat is to be used at the 3 leaf stage of wild oats, the use of MCPA is preferred; but, in later applications, 2,4-D performs better than MCPA.

Other acceptable combinations with difenzoquat are chlormequat and foliar fertilizers. As a convenience difenzoquat can be mixed with insecticides, such as, malathion, menazon and dimethoate in the case of aphid infestation.

The influence of climate on difenzoquat performance has been investigated. A cold temperature (under 3°C) at the time of spraying or immediately after may result in a transient sensitization of the plant to frost damage.

Rain occurring within five hours after the application of difenzoquat will reduce the efficacy of the herbicides. Therefore, in such a case another application should be made. On the other hand, morning dew does not influence the treatment unfavourably.

Difenzoquat has been used on beans and peas infested with wild oats without causing any crop damage and the control of wild oats was as good as in cereals. But, when difenzoquat was employed on vetches, severe phytotoxicity resulted.

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Proceedings 12th British Weed Control Conference (1974)

THE CONTROL OF SOME IMPORTANT GRASS WEEDS OF WHEAT WITH WL 29761

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Summary WL 29761, Methyl N-benzoyl-N-(3-chloro-4-fluorophenyl)-2-aminopropionate (Mataven+) has been shown to give good control of *Avena* spp. in wheat at rates of 0.45 - 0.60 kg/ha in extensive field trials in Europe during 1973 and 1974, with an adequate margin of safety. Limited data from glasshouse and field tests indicate that the compound also has useful activity against blackgrass (*Alopecurus myosuroides*) and couchgrass (*Agropyron repens*).

Résumé Pendant 1973 et 1974 l'activité du WL 29761, méthyl N-benzoyl-N-(3-chloro-4-fluorophényl)-2-aminopropionate, (Mataven) contre *Avena* spp. dans le blé fut etudiée en Europe. Dans les essais de plein champ des bons résultats furent obtenus avec les doses de 0.45 - 0.60 kg/ha ma, ces doses donnant une sélectivité suffisante par rapport au blé. Quelques données obtenues en serre et dans des petits essais de plein champ donnèrent des indications d'une activité intéressante contre le vulpin (*Alopecurus myosuroides*) et le chiendent (*Agropyron repens*).

INTRODUCTION

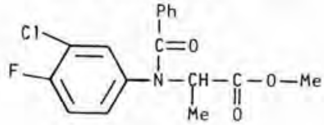
Benzoylprop-ethyl was introduced by Chapman *et al* in 1969 and it has since proved successful for the control of *Avena* spp. in wheat (Bowden *et al* 1970, Stovell and Bowler 1972). However, it is not suitable for use in barley. When looking for better selectivity in barley during 1971/2, a closely related series of compounds was investigated. This led to the introduction in 1974 of flamprop-isopropyl (Haddock *et al* 1974). At the same time another ester in this series, the methyl ester, WL 29761, was shown to have greater activity against *Avena* spp. than either benzoylprop-ethyl or flamprop-isopropyl, and to retain a satisfactory measure of selectivity in wheat.

Chemical and Physical properties of WL 29761

Proposed Common Name : Flamprop-methyl

Chemical Name : Methyl N-benzoyl-N-(3-chloro-4-fluorophenyl)-2-aminopropionate

Structure



Physical form : Off-white crystalline powder

Melting point : 81 - 82

Solubility :

Water	35 ppm at 20^{o}
Acetone	>500 g/kg at 20^{o}
O-xylene	250 g/kg at 20^{o}
Cyclohexanone	414 g/kg at 20^{o}

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<u>Stability</u> :	1) Hydrolytic	Stable at pH 4-5
	2) Photochemical	Stable
	3) Thermal	Stable up to 280°

<u>Toxicology</u> : WL 29761 has been shown to be relatively non-toxic when administered as a single oral dose in rats, mice and fowls.

Species	Vehicle	LD_{50} (mg/kg)
Rat	25% in aqueous CMC	>5000
Mouse	20% in aqueous CMC	>5000
Fowl	20% in DMSO	>1000

Glasshouse tests with cultivated oats

In the initial glasshouse tests, 7cm pots containing oat, wheat or barley were sprayed when the plants had reached the 1-2 leaf stage. Each compound was applied at five doses to each species and growth assessments made before the untreated plants had become pot-bound. The dose in kg/ha, of each compound required to give 50% depression in growth was then calculated (GID_{50}). Results from one of these tests are given in Table 1.

Table 1 - Results of a glasshouse test to compare benzoylprop-ethyl, flamprop-isopropyl and WL 29761

Compound	Avena fatua		Oat cv. Mostyn		Barley cv. Imber		Wheat cv. Dove	
	GID_{50}	95% limits	GID_{50}	95% limits	GID_{50}	95% limits	GID_{50}	95% limits
Benzoylprop-ethyl	0.58	0.48-0.69	0.33	0.24-0.43	1.8	1.4-2.2	11.0	8.0-16.0
flamprop-isopropyl	0.44	0.37-0.53	0.36	0.27.0.46	3.4	2.7-4.2	25.0	15.0-0.54
WL 29761	0.20	0.16-0.25	0.08	0.05-0.12	2.3	1.8-2.8	7.4	5.4-10.6

GID_{50} values are in kg/ha

The compound works in a similar manner to the other two wild oat herbicides mentioned, basically by arresting growth, through preventing cell elongation (Jeffcoat and Harries, 1973/74). It is however more active than the other two and the mode of action and translocation form the subject of separate studies.

Work on the effect of WL 29761 on the subsequent growth of oats in the glasshouse, illustrated the way in which seed production is affected.

50 replicates (each of three oat plants in a pot) were sprayed with either 0.25 or 0.5 kg/ha of WL 29761 as technical material in acetone/water and were grown to maturity together with a similar number of control plants. Most treated plants died, but approximately 20 plants out of the 150 treated at each dose survived and managed to produce seed. Table 2 shows the average number of seeds produced on the surviving plants.

Table 2 - Seed production following treatment of oats with WL 29761

Treatment WL 29761	Mean no. of surviving plants	Mean no. of seeds per surviving plant	Total seed production relative to control (100)
nil	150	47.2	100
0.25 kg/ha	21	4.9	1.5
0.5 kg/ha	15	4.5	1.0

Preliminary field experiments on wild-oats

Field applications of WL 29761 have given similar control of wild-oat plants, resulting in a reduced number of panicles being produced, these producing fewer seeds per panicle than with untreated plants. The results in Table 3 are a comparison of total panicles and an assessment of panicles by size class as suggested by Holroyd (1972). This latter method has been included because it gives a better estimate of seed production.

Three of the replicated trials which were conducted in 1973 were assessed in this way and are given as examples in Table 3. Crops of winter wheat were sprayed between growth stages G - I (Keller - Baggiolini) when all the wild-oats had germinated.

Table 3 - Control of A. fatua

Crops details and dose WL 29761 in kg/ha	Total panicles per m^2	Total spikelets per m^2	Average No. of florets/ surviving panicle	% reduction in panicles	% reduction in spikelets
Lincs - West Desprez sprayed at G/H					
0.2	49.1	1875	38	61	65
0.4	10.9	226	21	91	96
0.6	8.0	132	17	94	98
0.8	10.0	126	13	92	98
Control value	126.3	5425	43		
GVSL	66.8	2444			
LSR	2.42	3.02			
LVSG				47	55
Essex - Bouquet sprayed at H/I					
0.2	71.1	4602	65	68	81
0.4	32.0	972	30	86	96
0.6	28.6	1052	37	87	96
0.8	8.4	194	23	86	99
Control value	221.2	24443	111		
GVSL	113.4	8067			
LSR	2.52	4.66			
LVSG				49	67
Suffolk - Cappelle sprayed at I					
0.2	43.0	3116	72	81	91
0.4	8.8	277	31	96	99
0.6	6.3	165	26	97	99
0.8	4.5	67	15	98	100
Control value	221.0	33664	152		
GVSL	139.9	17264			
LSR	1.89	2.53			
LVSG				37	49

Counts were transformed by $y = \log_{10}(x + 1)$ for panicles and $y = \log_{10}(x + 6)$ for spikelets

GVSL = Greatest value significantly less than control
LVSG = Least value significantly greater than control
LSR = Least significant ratio between treatment means

Extensive field trials on wild oats

Dose

Only panicle counts were supplied from most countries, so the wild oat data in the subsequent tables are based on panicles only. The sample size per trial varies but in the UK is based on a minimum of one square metre per plot, taken as four quadrats each 0.5m x 0.5m.

Wild-oat control in 23 replicated trials carried out in six European countries during 1973 is summarised in Table 4.

Table 4 - Mean % reduction in panicles of *Avena* spp achieved with WL 29761 in Europe

A) 1973

Dose WL 29761 kg/ha	Benelux	France	Germany	Greece	Spain	UK
0.2	86	80	59	77	70	74
0.4	94	94	74	85	77	84
0.6	97	96	84	87	87	91
0.8	98	98	98	87	90	94
No. of trials	3	5	5	2	2	6

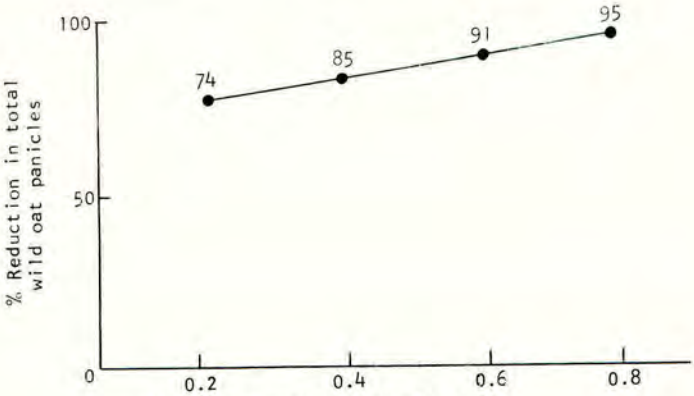
B) 1974

Dose WL 29761 kg/ha	Morocco*	Portugal	Spain	Greece	France	UK	Austria	Germany
0.45	98	-	86	-	85	83	72	90
0.5(25)+	98	94	92	86	86	84	73	95
0.60	-	-	95	87	94	89	83	94
1.05	99	96	99	-	98	94	91	
No. of trials	5	5	9	4	13	4	3	2

*Based on visual assessments
+The rates of 0.5 kg/ha and 3.5 litre/ha EC (0.525 kg/ha) have been bulked as one dose

These data are taken from all of the trials in each country, sprayed between crop stages G and J. The mean values are presented in Fig. 1, showing the overall dose response.

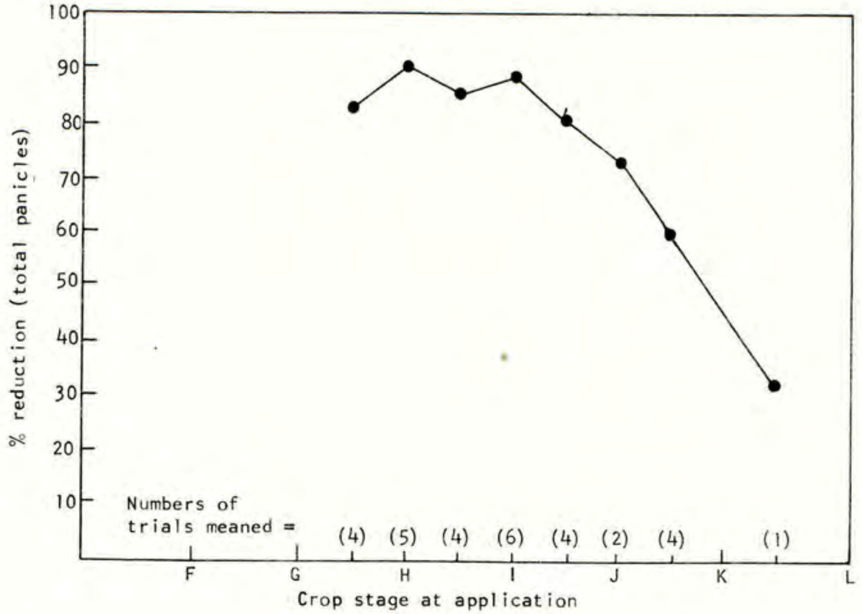
Fig. 1 - Graph showing the relationship between dose of WL 29761 and wild oat control in 23 wheat trials in 1973



Timing of application

In the 1973 trials, the actual range of crop stages varied from the end of tillering (Keller, Baggiolini Scale G/H) until just before the ligule formation (K/L). The wild-oat control obtained was good up to early shooting, but after formation of the second node (stage J) control deteriorated rapidly. This is illustrated in Fig. 2.

Fig. 2 - The results of 30 field applications of WL 29761 at 0.6 kg/ha plotted against time of application



Crop yield

Yield response to the wild-oat control has been excellent. Some examples from 1973 UK trials are given in Table 5. Similar yield responses were obtained in other countries when high wild oat infestations occurred.

Table 5 - Yield response as a percentage of 'untreated' yield for all trials occurring in Table 4 that were harvested

A) 1973

Dose WL 29761 kg/ha	France	Germany	UK	Spain
0.2	125	120	128	113
0.4	134	125	139	115
0.6	132	122	147	118
0.8	124	122	142	116
No. of trials	4	4	6	2
Mean control yield t/ha	1.86	3.28	3.70	2.55

Table 5 - continued

B) 1974

Dose WL 29761 kg/ha	France	UK	Spain
0.45	110	116	134
0.5(25)	111	118	133
0.60	113	119	148
1.05	118	117	137
No. of trials	11	3	2
Mean control yield t/ha	4.11	4.75	4.45

Selectivity

Most of the crops were completely unaffected by the 0.8 kg/ha dose rate. In a few trials slight stem shortening and/or a small amount of leaf tip necrosis occurred with this dose.

Crop yields on weed-free sites

Some trials were laid out in oatfree crops and in these high rates of WL 29761 were used (Table 6). The visual effects of 2.0 kg/ha were as above, but more marked, and at 4.0 kg/ha were severe. These trials demonstrate that the selectivity of the compound is good and is characterised by only a slow decline in yield with increasing dose.

Table 6 - Yield data from selectivity trials

Dose of WL 29761 kg/ha	1973 Yield as % of untreated control N. Suffolk	S. Suffolk	Ablis France	1974 Mean of 7 trials in France
1.0 5	97	100	-	99 (95)
1.35	-	-	-	96 (92)
1.5 75	-	-	91	96 (91)
2.0	84	99	-	-
3.0	-	-	73	-
4.0	73	81	-	-
6.0	-	-	60	-
Control yield t/ha	4.62	5.40	4.24	6.04
Wheat cv.	Capelle	Nimrod	Capitole	

( ) = minimum value occurring.

Based on the field data presented WL 29761 can be seen to give very good control of wild oats at doses of about 0.5 kg/ha and this allows for dramatic yield increases in heavily infested crops. The selectivity of the compound has also been shown to be good, with rates in excess of four times that required for weed control giving only a 20% reduction in yield in a weed-free situation.

Activity against blackgrass (Alopecurus myosuroides)

Glasshouse work has indicated that the compound has an interesting activity against blackgrass (Alopecurus myosuroides). Comparisons were made between WL 29761 and its analogues against a range of grass species.

In this particular test no established blackgrass herbicide was included. The results however, show WL 29761 to be about three times more active than benzoylprop-ethyl (Table 7).

Table 7 - Dose in kg/ha necessary to produce a 50% inhibition in growth of blackgrass in a glasshouse test

Days after spraying	WL 29761	Benzoylprop-ethyl
8	0.4	1.7
14	0.7	1.6
22	0.6	1.7

Some 1973 field trials showed interesting activity, with earlier applications giving better control of the blackgrass than later applications. For example, control achieved with 1.0 kg/ha was 68% in a crop of winter wheat cv. Nimrod sprayed at stage F/G, 67% in cv. Cappelle sprayed at I/J and 26% in cv. Ranger sprayed at stage J. More data are being collected in 1974. Counts from some of the trials are given below.

Table 8 - Percentage reduction in flower heads of blackgrass with WL 29761 in France during 1974

Trial Near	Bordeaux	Bordeaux	Evreux
Wheat stage at application:	I-J	I	J
Dose WL 29761 (kg/ha)			
0.45	85	-*	64
0.525	99	52	54
0.60	93	83	-
0.80	-	-	-
0.90	91	-	81
1.05	97	-	82
Flower heads/m^2 in control plots	69	10	72

*not applied

Activity against couch grass (*Agropyron repens*)

In one glasshouse test, a range of doses of the wild-oat compounds were sprayed onto 1½ - 2 leaf plantlets of couch grass, generated from two node sections of rhizome. Assessments of growth were made 21 days after application. The scores for growth depression were used to calculate the dose required for 50% plant depression (PD_{50}). Although the precision of the test was not high, differences between the compounds were well illustrated.

Table 9 - PD_{50} values (kg/ha) for the activity of three wild oat herbicides on Agropyron repens

Compound	PD_{50} (kg/ha)	95% fiducial limits
flamprop-isopropyl	5.26	3.15 - 9.11
benzoylprop-ethyl	0.65	0.32 - 1.12
WL 29761	0.42	0.18 - 0.76

Following the glasshouse work, one field test was carried out in winter wheat using high rates of all three compounds. Doses of 1, 2 and 4 kg/ha were applied to winter wheat cv. Ranger at the two node (J) crop stage. Results, given in Table 10, show that a very considerable suppression of couch was obtained and that this was reflected in the increased yield. The visual score was more sensitive than the flower head counts. Control assessments were based on four untreated plots per replicate, the least significant difference of 15%, therefore, is a good indication of the patchy nature of the weed in the trial.

Table 10 - A field trial on selectivity between A. repens and winter wheat. Sittingbourne 1973

Compound	Dose (kg/ha)	% reduction of flower heads of A. repens	A. repens score+ (0 = no weed (9 = complete cover)	Wheat Yield as % of control
flamprop-isopropyl	1	17	6.0	102
	2	5	6.8	99
	4	28	5.8	89
benzoylprop-ethyl	1	35	4.3	129
	2	49	4.0	123
	4	51	3.2	128
WL 29761	1	41	4.7	145
	2	50	4.3	124
	4	75	3.6	134
Control	-	mean $51/m^2$	6.8	2.00 t/ha
Values significantly different from control P=0.05		47 or more	5.8 or less	15

+Based on mean values for two observers

Activity on couch grass was also reported from France (De Gournay 1973). Work is continuing in 1974 to try and define more clearly the effect of WL 29761 on couch grass, but more information is still necessary before a clear indication of its value against this weed is apparent.

Acknowledgements

The authors wish to thank their colleagues both at Sittingbourne Research Centre and also those overseas for their considerable help with this work.

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CHEMICAL CONTROL OF AVENA FATUA IN SPRING BARLEY

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Summary Eighteen replicated trials in the three years 1972 to 1974 included a total of 8 herbicides, with treatments including different formulations or times of application for some of these herbicides.

The use of those herbicides normally recommended for use in spring barley - barban, flamprop-isopropyl, chlorfenprop-methyl, difenzoquat and tri-allate - controlled over 70% of the *Avena fatua* in most trials and led to a considerable yield response from the crop.

Benzoylprop-ethyl, isoproturon and chlortoluron were not effective as selective herbicides in barley.

Comparisons of different times of application for chlorfenprop-methyl and difenzoquat suggested that application at the normal recommended date was early enough to prevent serious competition from *Avena fatua* to the crop.

INTRODUCTION

Tri-allate, barban and chlorfenprop-methyl have been available for the control of *Avena fatua* in spring barley for some years and data is available on the degree of control of this weed that may be expected both on an annual basis, and over a number of years. (Holyroyd and Bailey 1970, Roebuck and Hughes 1972). More recently flamprop-isopropyl and difenzoquat have been introduced for post-emergence use.

There is information available on the importance of the time of application of individual herbicides for obtaining maximum control of the wild oat, and also a good indication of their likely pattern of survival in relation to time of emergence. (Martin Morris and Rieley 1972, Pfeiffer Baker and Holmes 1960, Chancellor and Peters 1972).

There is rather less information available to clarify when the competition actually takes place between wild oats and spring barley, and therefore when a chemical treatment must be applied to reduce the chance of ultimate crop yield being affected. This trial series therefore included not only comparisons between the degree of wild oat control that might be expected, from the various herbicides now available, but also attempted to find what the effects were on crop yield from different spray timings. There are advisory problems which make more information necessary. If eradication of this weed is the immediate objective of a farmer, then obviously maximum percentage control must be the aim and current recommendations of commercial firms as regards timing must be strictly followed. On many farms, however, infestations are so dense that the first objective is to aim for maximum yield response from the crop; and it could be postulated that early removal of wild oat competition was more important than obtaining maximum percentage control of wild oats per se.

METHOD AND MATERIALS

All the experiments were done on commercial crops where naturally occurring infestations of Avena fatua were expected. Relevant site details, treatment application dates, stages of crop and weed growth, and the herbicides used are listed in table (1) for each year.

In these tables the stages of growth are abbreviated. Number of leaves, as 'L'; or Feekes-Large Growth Stage as 'G.S.' Growth stages for the crop without brackets, for the wild oats within brackets.

The general sequence of the different times of application is indicated in the tables by numbering, (i)-(v) against treatments: though individual sites were often sprayed rather earlier or later than this numbering suggests.

A randomised block design was used, with treatments replicated 3 times. Plot size 30ft x 9ft, all treatments were applied by a modified van der Weij sprayer with Allman 00 jets. Application rate was 20 gall/acre at 32 psi except for:-

Barban B25 15 gall/acre at 40 psi
Chlorfenprop-methyl and Flamprop-isopropyl (1974 only) 25 gall/acre at 48 psi

The overall infestation of Avena fatua was assessed by counting plant numbers on the 6 control plots in May. Treatment effects were assessed in July by the removal of Avena fatua panicles from a number of quadrats in each plot, the panicles were counted and dry weights taken. Crop yields were taken by a sample harvest technique.

TREATMENTS AND RESULTS

Table 1 1972

Conditions of Treatment Application

Site		1	2	3	4	5
Soil Texture		CL	ZyCL	FSL	ZyCL	ZyCL
Cultivar		Julia	Julia	Tern	Julia	Lofa Abed
Date drilled		30 Mar	30 Mar	16 Mar	22 Mar	28 Mar
A. Fatua plants/yd^2		323	18	18	84	43
on control plots		8 May	8 May	28 April	5 May	8 May
		Treatment Details				
Herbicides - Rates a.i. in lb/ac						
Pre-sowing						
Tri-allate	1.25	23 Mar	27 Mar	15 Mar	22 Mar	17 Mar
Pre-emergence						
Tri-allate gran	1.50	4 Apr	4 Apr	16 Mar	22 Mar	4 Apr
Post-emergence						
(i) Barban 0.31; Barban 'B25' 0.31; Chlorfenprop-methyl 4.3		8 May 3L (1-2½L)	8 May GS3 (1½-3L)	28 Apr GS2-3 (1-3L)†	5 May GS3 (2½L)	8 May* GS4 (2L-GS3)
(ii) Chlorfenprop-methyl 4.3		15 May GS4-5 (1L-GS3)	11 May GS4-5 (2-4L)	9 May GS4-5 (2L-GS3)	10 May GS4-5 (2½-3L)	-
(iii) Benzoylprop-ethyl 1.0		8 June GS7 (GS6)	5 June GS7-8 (GS5-6)	30 May GS7 (GS6)	1 June GS6 (GS5-6)	10 May GS3-4

* Chlorfenprop-methyl applied 10 May. † Rate 3.71 lb/ac a.i. on site 3

Table 2 1972

% Control of A. Fatua as Dry Weight of Panicles

Treatments	Site 1	2	3	4	5	Mean all sites
Control	0	0	0	0	0	0
Tri-allate (pre-sowing)	60	75	88	77	87	77.4
Tri-allate gran (pre-em)	78	68	73	94	85	79.6
Barban (i)	65	96	70	87	96	82.8
Barban 'B25' (i)	66	96	81	84	94	84.2
Chlorfenprop-methyl (i)	18	86	8*	70	47	45.8
Chlorfenprop-methyl (ii)	49	96	97	95	-	84.3
Benzoylprop-ethyl (iii)	76	86	73	84	74	78.6

* 3.7 lb/ai applied instead of 4.3

Table 3 1972

Grain Yield Cwt/Acre

Treatments	Site 1	2	3	4	5	Mean all sites
Control	15.1	43.9	31.3	39.1	35.6	33.0
Tri-allate (pre-sowing)	33.4	45.2	31.4	50.6	44.1	40.9
Tri-allate gran (pre-em)	38.8	45.3	31.1	51.0	47.7	42.8
Barban (i)	29.5	45.8	34.9	51.7	45.7	41.5
Barban 'B25' (i)	30.1	44.3	34.1	48.0	42.8	39.9
Chlorfenprop-methyl (i)	28.7	46.2	32.7	47.7	39.0	38.9
Chlorfenprop-methyl (ii)	28.3	47.6	32.4	-	-	39.9
Benzoylprop-ethyl (iii)	15.3	24.4	17.5	31.1	15.1	20.8
SE diff (a) ±	1.85	2.76	2.70	3.76	3.84	0.77
(b) ±	1.33	1.44	1.57	1.76	3.21	

(a) - for comparison of all treatments

(b) - for comparison of herbicides other than benzoylprop-ethyl

Table 1 1973

Conditions of Treatment Application

Site		2	3	4	5	6	7	8
Soil Texture		CL	SL	SCL	ZyCL	ZyCL	ZyCL	ZyCL
Cultivar		Lofa Abed	Julia	Tern	Julia	Zephyr	Lofa Abed	Julia
Date Drilled		23 Mar	21 Mar	20 Mar	16 Mar	16 Mar	22 Mar	15 Mar
A. fatua Plants/yd^2 on control plots		77 (4 May)	15 (4 May)	-	230 (7 May)	-	162 (7 May)	-

Treatment Details

Herbicides - Rates a.i. in lb/ac	Rate	2	3	4	5	6	7	8
Pre-emergence								
Tri-allate emulsion	1.25	26 Mar	23 Mar	21 Mar	8 Mar	15 Mar	20 Mar	28 Feb
Tri-allate granules) Isoproturon 2.25)	1.50	26 Mar	23 Mar	21 Mar	16 Mar	20 Mar	27 Mar	19 Mar
Post-emergence								
(i) Barban 'B25') Chlorfenprop-methyl)	0.31 4.3	4 May 2½L (1-3L)	3 May 3-4L (2-3L)	7 May 3-4L (2-3L)	26 April 3-4L (1-3L)	7 May GS2 (1-2L)	7 May GS2 (1-3L)	26 Apr 2½-3½L (1½-2½L)
(ii) Chlorfenprop-methyl) Difenzoquat)	4.3 0.67	14 May GS4-5 (3L)	16 May GS4 (3-4L)	11 May GS4 (3-3½L)	7 May GS3-4 (GS1-3)	14 May GS3-4 (1½-3L)	14 May GS3-4 (2-4L)	8 May (2-2½L)
(iii) Chlorfenprop-methyl) Difenzoquat)	4.3 0.67	21 May GS4-5 (GS3-4)	29 May GS5-6 (GS4)	18 May GS5 (GS4)	14 May GS4-5 (GS2-4)	24 May GS6 (GS5)	24 May GS5-6 (GS4-5)	14 May
(iv) Difenzoquat	0.67	30 May GS6-7 (GS4)	6 June GS7-8 (GS6-7)	29 May GS6 (GS5)	1 June GS7-8 (GS4-7)	1 June GS7-8 (GS7)	1 June GS7-8 (GS5-8)	1 June GS6-7 (GS6)
(v) Flamprop-isopropyl	0.88	30 May GS6-7 (GS4)	6 June GS7-8 (GS6-7)	6 June GS7-8 (GS6-7)	15 June GS7-8 (GS4-7)	24 May GS6 (GS5)	1 June GS7-8 (GS5-8)	1 June GS6-7 (GS6)

Table 2 1973

% Control of A. Fatua as Dry Weight of Panicles

Treatments	Site 2	3	4	5	6	7	8	Mean all sites
Control	0	0	0	0	0	0	0	0
Tri-allate emulsion (pre-em)	78	76	58	85	88	93	98	82
Tri-allate granules (pre-em)	96	61	65	79	48	74	98	75
Isoproturon (pre-em)	95	94	24	91	90	91	94	83
Barban 'B25' (i)	97	86	86	78	93	81	93	88
Chlorfenprop-methyl (i)	75	91	37	76	40	82	83	69
Chlorfenprop-methyl (ii)	98	37	33	95	94	92	95	78
Difenzoquat (ii)	100	100	89	98	100	98	99	98
Chlorfenprop-methyl (iii)	82	+3	74	92	81	74	100	71
Difenzoquat (iii)	99	68	97	100	99	92	97	93
Difenzoquat (iv)	98	97	37	94	99	96	100	86
Flamprop-isopropyl (iv)	99	73	93	77	80	81	96	86

Table 3 1973

Grain Yield Cwt/Acre

Treatments	Site 3	4	6	8	Mean all sites
Control	28.8	9.1	36.2	31.4	26.4
Tri-allate (pre-em)	31.7	17.2	40.8	32.1	30.5
Tri-allate gran (pre-em)	34.7	23.8	41.3	33.8	33.4
Isoproturon (pre-em)	29.4	15.1	40.5	29.8	28.7
Barban 'B25' (i)	30.2	26.5	36.7	31.7	31.4
Chlorfenprop-methyl (i)	34.8	19.7	36.8	32.6	31.0
Chlorfenprop-methyl (ii)	27.4	20.6	38.8	32.8	29.9
Difenzoquat (ii)	34.5	27.4	38.9	31.9	33.2
Chlorfenprop-methyl (iii)	26.9	27.0	37.2	32.2	30.8
Difenzoquat (iii)	34.6	28.1	37.0	34.4	33.5
Difenzoquat (iv)	30.2	15.1	40.4	32.7	29.6
Flamprop-isopropyl (iv)	28.2	17.7	36.7	35.2	29.5
SE diff between treatments ±	4.06	2.77	2.38	3.4	1.61
SE diff between control and treatments ±	3.21	2.19	1.89	2.68	1.28

Table 1 1974

Conditions of Treatment Application

Site	3	4	5	6	7	8
Soil Texture	CL	SCL	CL	CL	SCL	CL
Cultivar	Maris Mink	Maris Mink	Tern	Tern	Tern	Tern
Date Drilled	5 Apr	10 Apr	1 Apr	1 Apr	4 Apr	27 Mar
A. fatua plants/yd^2	-	-	112	155	126	-
on control plots			31 May	31 May	29 May	

Treatment Details

Herbicides - Rates ai in lb/ac

		3	4	5	6	7	8
Pre-emergence							
Iso-proturon Chlortoluron	1.88) 2.4)	10 Apr	17 Apr	3 Apr	8 Apr	9 Apr	28 Mar
Post-emergence							
(i) Iso-proturon Chlortoluron	1.5 2.4	28 May GS3-4 (1-3L)	28 May GS3-4 (2-3½L)	21 May GS3-4 (1½-3L)	21 May GS3-4 (2-3½L)	22 May GS3-4 (1½-3½L)	13 May GS3-4 (1-2½L)
(i) Barban 'B25'	0.31	28 May GS3-4 (1-3L)	22 May GS2-3 (1-3L)	14 May GS2 (1-2½L)	13 May GS3 (1-3L)	13 May GS2 (1-2½L)	13 May GS3-4 (1-2½L)
(i) Difenzoquat	1.0	28 May GS3-4 (1-3L)	28 May GS3-4 (2-3½L)	21 May GS3-4 (1½-3L)	21 May GS3-4 (2-3½L)	22 May GS3-4 (1½-3½L)	13 May GS3-4 (1-2½L)
(i) Flamprop-isopropyl	0.88	28 May GS3-4 (1-3L)	28 May GS3-4 (2-3½L)	21 May GS3-4 (1½-3L)	21 May GS3-4 (2-3½L)	22 May GS3-4 (1½-3L)	13 May GS3-4 (1-2½L)
(ii) Chlorfenprop-methyl	4.3	3 June GS4 (2-3L)	28 May GS3-4 (2-3½L)	31 May GS5-6 (2-4L)	21 May GS3-4 (2-3½L)	22 May GS3-4 (1½-3½L)	22 May GS5-6 (2½-3½L)
(iii) Difenzoquat	1.0	10 June GS5 (up to GS4)	10 June GS5 (GS4-5)	31 May GS5-6 (2-4L)	29 May GS5-6 (up to GS5)	29 May GS5-6 (up to GS3)	22 May GS5-6 (2½-3½L)
(iii) Flamprop-isopropyl	0.88	10 June GS5 (up to GS4)	10 June GS5 (GS4-5)	31 May GS5-6 (2-4L)	29 May GS5-6 (up to GS3)	29 May GS5-6 (up to GS3)	22 May GS5-6 (2½-3½L)

Table 2 1974

% Control of A. Fatua as Dry Weight of Panicles

Treatments Site	3	4	5	6	7	8	Mean all sites
Control	0	0	0	0	0	0	0
Isoproturon (pre-em)	27.5	39.9	26.0	15.1	2.5	13.4	15.25
Chlortoluron (pre-em)	37.0	66.0	11.0	17.5	+13.9	40.8	9.03
Isoproturon (i)	56.0	90.0	51.7	51.1	72.1	47.3	58.68
Chlortoluron (i)	56.0	68.8	44.5	24.4	67.1	46.9	43.01
Barban 'B25' (i)	63.0	94.0	66.6	61.9	79.5	95.5	69.53
Difenzoquat (i)	98.0	89.1	67.5	93.8	95.8	99.3	88.41
Flamprop-isopropyl (i)	17.0	34.9	27.4	45.4	57.7	31.8	42.58
Chlorfenprop-methyl (ii)	21.0	85.1	40.0	51.5	84.7	64.5	58.99
Difenzoquat (iii)	100.0	99.8	94.5	86.4	98.6	99.7	92.79
Flamprop-isopropyl (iii)	70.0	83.5	76.0	83.2	83.7	27.7	80.32

Table 3 1974

Grain Yield Cwt/Acre

Treatments Site	3	4	5	6	7	8	Mean all sites
Control	29.6	33.8	12.9	12.5	26.0	36.8	25.3
Isoproturon (pre-em)	34.1	36.3	15.8	15.5	21.7	39.1	27.1
Chlortoluron (pre-em)	32.5	33.5	16.5	14.2	24.8	34.8	26.1
Isoproturon (i)	30.9	38.4	17.5	15.5	28.3	34.8	27.6
Chlortoluron (i)	31.5	33.4	15.2	13.8	22.8	35.8	25.4
Barban 'B25' (i)	32.8	34.8	22.9	20.6	33.7	37.3	30.4
Difenzoquat (i)	32.7	39.1	31.5	20.3	33.2	40.8	32.9
Flamprop-isopropyl (i)	35.6	32.9	16.0	13.7	29.0	37.4	27.4
Chlorfenprop-methyl (ii)	37.2	33.9	24.9	15.4	30.7	38.5	30.1
Difenzoquat (iii)	29.9	37.1	21.5	20.7	34.2	39.7	30.5
Flamprop-isopropyl (iii)	31.8	36.3	23.5	22.1	29.9	37.0	30.1

(Provisional yield results not yet analysed)

DISCUSSION

The results obtained from the use of tri-allate either as emulsion or as granules in the first two years, though reasonably good, are no doubt biased against this material because of the difficulty of applying either formulation realistically on a small plot scale. It also had to be applied to dry cloddy seedbeds at some sites, notably site 1 in 1972 and site 3 in 1973. This being so it was decided not to include this material in the last year of trials. It did appear from the results that even where tri-allate worked well and gave a high percentage control of the wild oats the yields were not consistently higher than from the best of the post-emergence herbicides. This suggests that there is relatively little competition between wild oats and spring barley during the first few weeks after drilling.

Benzoylprop-ethyl proved toxic to barley and its use was not continued beyond the first year of trials. The two herbicides chlortoluron and iso-proturon proved phytotoxic and in 1974 gave poor control of the wild oats; this was probably due in part to the very dry seedbed conditions prevailing at the time of application.

The comparisons between the various post-emergence materials used were complicated by considerable variation between sites and seasons, but applications of difenzoquat at, or soon after crop Growth Stage 5, did appear to give a fairly consistent control of over 90% of the wild oats in the two years it was used, (Table (2) 1973 and 1974), which was rather higher than that from other materials.

Where post-emergence treatments gave a high degree of wild oat control yield responses were also high, and this effect appeared to mask the effects of any yield enhancement that might have been expected due to the early removal of wild oat competition.

It was, however, possible to interpret some of the yield data to suggest that wild oat competition was becoming serious towards the end of May. In 1973 for example the crop yield response, (Table (3) 1973) to the last application of difenzoquat and to flamprop-isopropyl was rather less than the Avena fatua panicle control, (Table (2) 1973) would otherwise lead one to expect. The provisional yields for 1974 (Table 3) also suggest that there was an enhanced response to earlier removal of wild oat competition from the first application of difenzoquat.

It can probably be concluded, however, that most normal post-emergence herbicide applications will be made before Avena fatua competition seriously affects yield and therefore, provided phytotoxicity is not a problem, the herbicide can be chosen and used in such a way as to obtain the maximum control of wild oat panicle numbers.

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THE EFFECTS OF TRI-ALLATE AND BARBAN ON THE CONTROL OF AVENA FATUA IN SPRING BARLEY, ON THE YIELD OF BARLEY AND THE PRESENCE OF A. FATUA SEEDS IN THE HARVESTED GRAIN

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Summary In nine experiments, tri-allate and barban were compared. Each herbicide gave good control of A. fatua at the recommended dose; tri-allate 1.70 kg/ha reduced the numbers of seeds produced/m^2 by an average of 90% and barban 0.35 kg/ha by 91%. At half the recommended dose, control with tri-allate was poorer (77%) but little worse with barban (89%). Tri-allate allowed fewer panicles to be produced, but these were larger and contained more seeds than those which survived barban.

Tri-allate resulted in average barley yield increases of 5.5 and 6.2 quintals/ha and barban 7.5 and 7.2 quintals/ha from the low and high doses respectively. Contamination of the harvested grain by A. fatua seeds was considerably reduced by all treatments.

All treatments gave an economic response, which was greatest with barban applied at the lower dose. Barban increased barley yields when applied to wild oat populations at a wide range of growth stages; at one site less than half of the wild oats had emerged and at two sites over half of the wild oats had more than 2½ leaves when sprayed. In many cases, despite an economic response, herbicide use still permitted a large return of A. fatua seeds to the soil. Possibilities for economising in herbicide use are discussed in relation to the type of control policy being pursued.

INTRODUCTION

Wild oats (Avena fatua and Avena ludoviciana) continue to be the most serious weed problem of cereals, although herbicides have been available for their control for many years. A recent survey (Phillipson 1974) indicates that herbicides have only been used on a relatively small proportion of the infested acreage. Even when herbicides are used annually, on the same land, the problem can remain for many years. Control of severe infestations often results in large increases in crop yields, but there will inevitably be some surviving wild oat plants. The seeds produced by these survivors make eradication, based on annual applications of herbicides, both costly and difficult to achieve. Removal of these surviving plants by a follow up treatment or by hand roguing is necessary if wild oats are to be eliminated.

The cost of such a policy may be impracticable for many farmers (Cussans 1972). The alternative is to reduce wild oat populations to low levels at which crop yields are not affected, and contain these populations at minimum cost. To help define these population levels, information on the relationship between herbicide dose, crop yield response and seed production of the surviving wild oats is needed.

Experiments are reported here in which tri-allate and barban were applied to A. fatua infestations in barley crops. Seeds produced by the surviving plants were recorded, and crop yields measured both quantitatively and qualitatively. The presence of thin barley grain and contaminants such as A. fatua seeds was recorded, as these can affect the value of the harvested grain.

METHOD AND MATERIALS

Nine identical experiments were set up in the spring of 1973 on farms within 60 miles of the Weed Research Organization. Each contained 4 replicates of 4 treatments. Errors due to any uneven distribution of the A. fatua populations were reduced by pairing treated and control plots. Plots were arranged in two rows of two replicates, with a total of 16 treated and 18 control plots at each site. The size of the treatment plots was 4 x 20 m and of the control plots 3 x 20 m, and the total experimental area was 57 x 44 m.

Table 1 shows the barley variety and the dates of drilling, herbicide applications and harvest at each site.

Table 1

Variety of barley and dates of drilling, herbicide application and harvest at each site

	Site	Variety	Drilling date	Tri-allate applied	Barban applied	Harvest date
1.	Bicester	Golden Promise	20 February	27 February	12 April	31 July
2.	Hook Norton	Julia	13 March	15 March	27 April	22 August
3.	Pudlecote	Berac	13 March	16 March	26 April	12 August
4.	Lewknor	Julia	16 March	19 March	9 May	11 August
5.	Stratton Audley	Berac	16 March	19 March	1 May	14 August
6.	Piddington	Vada	19 March	20 March	11 May	29 August
7.	Coln St. Aldwyns	Lofa Abed	20 March	21 March	9 May	13 August
8.	Hardmead	Julia	22 March	23 March	11 May	16 August
9.	Wymington	Julia	28 March	30 March	11 May	17 August

All herbicide treatments were applied with a propane pressuried sprayer fitted with a 4 metre boom, held by two operators. Tri-allate (e.c.) at 0.70 and 1.40 kg/ha was applied shortly after the barley was planted, in 230 l/ha of water and a pressure of 2.07 bars using 6502 Tee-jets and walking at 1 m/sec. The herbicide was incorporated by harrowing with light seed harrows immediately after spraying each plot. When spraying was completed, the whole experiment was cross harrowed. A fine tilth was encountered at Bicester and Pudlecote, otherwise seedbeds were rough and cloddy, particularly so at Hardmead. At Coln St. Aldwyns the tilth was particularly stony. Barban (25%) at 0.175 and 0.35 kg/ha was applied post emergence, usually when the majority of wild oats had emerged, in 120 l/ha of water and a pressure of 2.42 bars using 6501 Tee-jets and walking at 1 m/sec.

All experiments were sprayed at the appropriate time with a commercial mixture of ioxynil and mecoprop for the control of dicotyledonous species.

Assessments

Seedling emergence

Barley and *A. fatua* seedlings were counted in 10 random quadrats of 30 x 30 cm per plot. *A. fatua* seedlings were generally assessed when the majority had emerged. Sixteen fixed quadrats were set up at each site on the control plots, and the seedling emergence of *A. fatua* was recorded at weekly intervals. Coloured rings were used to identify the seedlings counted on each occasion. These quadrats were normally 30 x 30 cm but enlarged to 60 x 60 cm where lighter infestations were anticipated. The emergence pattern recorded was used to estimate the fraction of the total *A. fatua* population which had emerged at the time of the barban treatment. Similarly, the random count was adjusted for the fraction which emerged after the count was taken.

Panicles and seeds

Panicles of *A. fatua* were assessed when fully open but before seed shedding commenced. Four areas of 3 x $\frac{1}{2}$ m, selected at random, were counted on the sprayed plots. On the control plots where panicles were particularly dense, the assessment areas were reduced to 1 x $\frac{1}{4}$ m. Seed production was determined by removing 20 panicles, selected at random from each plot, and counting the seeds on each panicle. Estimates of the total seeds produced per/m^2 were derived from the product of the average number of seeds/panicle and the number of panicles/m^2.

Grain yield and 'quality'

Barley yields were obtained by cutting a single swathe of 1.5 m from the centre of each plot with a small plot combine harvester. The ends of the plots were first removed as discards. At some sites difficulties were experienced in handling badly laid crops. The grain from each plot was weighed, and from this a 250 g sample taken, dried, re-weighed and yields of grain at 85% d.m. derived. *A. fatua* seeds present in the dried sample were counted and weighed. The clean barley was sieved, and weights of the following size fractions obtained: $<$2.0 mm, 2.0-2.5 mm, 2.5-2.7 mm, and $>$2.7 mm.

RESULTS

Seedling populations

Crop and weed seedling populations varied from 223 barley and 15 *A. fatua* seedlings/m^2 at Wymington to 356 barley and 333 *A. fatua* seedlings/m^2 at Bicester (Table 2). With the exception of Bicester, 80% or more of the total *A. fatua* seedlings had emerged when the barban was applied, and a proportion of these seedlings had passed the 2$\frac{1}{2}$ leaf stage at this time. Barban was applied at Bicester relatively early when only 48% of the total *A. fatua* seedlings had emerged, all of which had less than 2$\frac{1}{2}$ leaves when sprayed. The barley had reached 2$\frac{1}{2}$ leaves at Bicester, and 3$\frac{1}{4}$-4 leaves at the remaining sites, when barban was applied.

Control of A. fatua

At most sites good control of panicles was achieved (Table 3). The poorest control with both barban and tri-allate occurred at Bicester. Average values for all sites show that tri-allate 1.40 kg/ha, gave the best control of panicles, followed by barban (both rates), and tri-allate 0.70 kg/ha gave the poorest control. The panicles from plants which survived tri-allate contained twice as many seeds as those which survived barban. The degree of control expressed as seeds produced/m^2 was similar for tri-allate 1.40 kg/ha and for both doses of barban. Tri-allate 0.70 kg/ha allowed over twice as many seeds/m^2 to be produced.

Table 2

Total spring seedling populations, and the stages of growth at which barban was applied

Site	Total seedlings/m^2 on Control plots: Barley	A. fatua	Stage of growth when barban applied — A. fatua — % of total seedlings in four groups: Not emerged	Up to $1\frac{1}{2}$ lvs.	$1\frac{1}{2}$-$2\frac{1}{2}$ lvs.	Over $2\frac{1}{2}$ lvs.	Barley leaves /plant
1	356	333	52	44	4	0	$2\frac{1}{2}$
2	244	38	18	61	19	2	$3\frac{1}{4}$
3	263	58	20	22	53	5	$3\frac{1}{4}$
4	231	118	2	15	29	54	$3\frac{1}{2}$
5	288	111	3	79	14	4	$3\frac{1}{2}$
6	238	31	1	15	43	41	4
7	306	59	2	6	19	73	4
8	315	108	7	11	48	34	4
9	223	15	8	52	10	30	$3\frac{1}{2}$

Table 3

Effect of treatment on the numbers of panicles and seeds of A. fatua

Site	Panicles/m^2: Unsprayed	Tri-allate 0.70 kg/ha	Tri-allate 1.40 kg/ha	Barban 0.175 kg/ha	Barban 0.350 kg/ha	Seeds/m^2: Unsprayed	Tri-allate 0.70 kg/ha	Tri-allate 1.40 kg/ha	Barban 0.175 kg/ha	Barban 0.350 kg/ha
1	192	35	18	52	61	5760	2030	774	1508	1525
2	25	3	1	1	1	1540	306	100	64	65
3	34	8	1	1	1	1666	560	114	39	36
4	85	6	2	21	17	3230	318	124	840	578
5	152	29	12	9	10	10032	2349	1164	423	430
6	74	10	5	1	0	2738	380	210	34	0
7	59	4	1	14	10	3186	268	72	490	370
8	75	15	7	4	1	3375	1035	490	188	25
9	22	3	2	0	0	1100	162	110	0	0
Average /site	80	13	5	11	11	3625	823	351	398	337

Table 4

The effect of treatment on grain yield (quintals/ha at 85 d.m.) and the percentage of A. fatua seeds and thin barley in the harvested grain

	Control plots	Tri-allate 0.70 kg/ha	Tri-allate 1.40 kg/ha	Barban 0.175 kg/ha	Barban 0.350 kg/ha	S.E. (±) A	S.E. (±) B
1. BICESTER							
Grain ex combine	40.6	54.6	56.6	56.5	55.7	3.17	2.45
% A. fatua	8.2	1.0	0.5	1.5	2.1		
% Barley <2 mm	12.7	5.3	4.9	5.5	5.2		
Clean barley >2 mm	31.4	50.8	53.3	52.1	51.5	2.50	1.93
2. HOOK NORTON							
Grain ex combine	38.9	42.4	37.4	43.2	38.3	2.60	2.01
% A. fatua	5.4	0.7	0.3	0.3	0.1		
% Barley <2 mm	16.8	12.9	16.5	12.0	17.0		
Clean barley >2 mm	30.0	36.9	31.1	35.8	31.6	3.01	2.33
3. PUDLECOTE							
Grain ex combine	38.3	41.0	39.7	44.0	40.4	2.00	1.55
% A. fatua	3.2	0.6	0.1	0.1	-		
% Barley <2 mm	34.7	36.2	34.5	33.4	34.8		
Clean barley >2 mm	23.6	25.6	25.4	28.8	25.9	2.66	2.06
4. LEWKNOR							
Grain ex combine	37.4	41.8	45.1	42.0	41.6	3.53	2.73
% A. fatua	4.0	0.8	0.1	1.6	1.1		
% Barley <2 mm	6.9	6.7	5.2	4.8	4.7		
Clean barley >2 mm	33.2	38.7	42.7	39.2	39.1	3.59	2.78
5. STRATTON AUDLEY							
Grain ex combine	24.3	29.9	31.4	32.4	34.6	2.07	1.60
% A. fatua	17.0	4.3	1.8	0.9	0.6		
% Barley <2 mm	29.1	22.4	24.5	26.1	17.4		
Clean barley >2 mm	12.5	21.4	23.4	24.0	28.4	2.25	1.74
6. PIDDINGTON							
Grain ex combine	24.6	29.8	28.7	27.2	25.0	2.46	1.91
% A. fatua	5.6	0.8	0.6	0.1	0.1		
% Barley <2 mm	13.8	17.3	16.5	14.8	19.2		
Clean barley >2 mm	18.9	22.5	22.5	22.1	19.7	2.08	1.61
7. COLN ST ALDWYNS							
Grain ex combine	42.1	40.0	39.2	46.8	50.3	3.57	2.77
% A. fatua	3.0	0.2	0.1	0.5	0.3		
% Barley <2 mm	3.0	2.0	3.6	2.3	1.3		
Clean barley >2 mm	39.3	39.1	37.5	45.5	49.2	3.60	2.79
8. HARDMEAD							
Grain ex combine	35.6	39.4	40.9	41.7	41.5	1.90	1.47
% A. fatua	3.9	0.8	0.3	0.1	-		
% Barley <2 mm	10.0	12.9	8.5	12.5	11.1		
Clean barley >2 mm	29.9	33.4	36.9	36.0	35.9	1.95	1.51
9. WYMINGTON							
Grain ex combine	38.0	36.7	39.4	40.5	40.2	1.77	1.37
% A. fatua	0.8	0.2	0.1	0.1	-		
% Barley <2 mm	9.5	10.1	10.5	9.6	11.0		
Clean barley >2 mm	33.6	32.9	35.0	36.2	35.2	1.64	1.31

S.E. A - differences between treatments
B - differences between treatments and controls

Effects on yields

The control of A. fatua by the herbicide treatments resulted in increased crop yields at most sites (Table 4). Significant increases occurred with all treatments at Bicester, Stratton Audley and Hardmead. Average yields for all sites of clean barley > 2 mm were increased by 5.3 and 6.2 quintals/ha following the low and high doses of tri-allate, and by 7.5 and 7.2 quintals/ha following the low and high doses of barban.

The main contaminants of the harvested grain were A. fatua seeds. The numbers of seeds occurring in the grain were considerably reduced at all sites by both doses of tri-allate and barban. Grain from the unsprayed areas was highly contaminated on some sites, with a maximum of 17% being recorded from Stratton Audley. At a few sites, notably Piddington where the barley was badly laid, there was also marked contamination by soil and broken straw. The proportion of thin barley < 2 mm in the harvested grain was less affected by treatment, and only substantially reduced by spraying at Bicester and Stratton Audley, the two most heavily infested sites. The content of thin grain differed greatly between sites, varying from less than 4% at Coln St. Aldwyns to over 30% at Pudlecote.

Yield response to herbicide treatment was always greater in terms of clean barley > 2 mm than when measured ex combine. Because the harvested grain from the unsprayed plots contained more A. fatua seeds and sometimes more thin barley than from the treated plots, cleaning the sample increased the differences between the unsprayed and treated plots.

DISCUSSION

The higher doses of tri-allate and barban used were those currently recommended, and at most sites each herbicide gave a commercially acceptable control of A. fatua with a resulting increase in barley yield. Relatively poor control was obtained at Bicester with barban, probably as a result of the early date of application at that site. When the barban was sprayed, fewer than half of the final total of A. fatua seedlings had emerged. Despite the poor control at this site crop yield response was high, which illustrates the importance of controlling the early germinating and most competitive wild oats.

At all sites other than Bicester, a proportion of the A. fatua seedling population was more advanced than 2½ leaves when sprayed with barban. Because of the often protracted emergence of wild oat seedlings in the spring, only a proportion are generally in the most susceptible 1-2½ leaf stage at any one time. In these experiments, an average of 60% of the final total populations had less than 2½ leaves when sprayed, the remainder were either more advanced or not emerged at this time. Control with barban at Lewknor and Coln St. Aldwyns, where over half of the seedlings were more advanced than 2½ leaves when sprayed was relatively poor.

The recommended dose of tri-allate reduced the seed production of A. fatua by an average of 90% to 351 seeds/m^2, and that of barban by 91% to 337 seeds/m^2. (Table 5). Some seeds were removed in the grain (Table 4), others would normally have been removed in the straw, but most would have reached the ground, either directly by shedding before harvest or indirectly through the combine. Previous work (Wilson 1970) indicated that where the majority of seeds had shed at harvest only a low proportion of the total seeds produced was removed in the grain and straw. In these experiments it is probable that the average seed return to the stubble where these doses of tri-allate and barban were used, was of the order of 300 seeds/m^2.

Table 5

Yield response of barley (clean grain >2 mm) and reduction in seeds produced by A. fatua

Site	Percentage reduction of seeds: Tri-allate 0.70 kg/ha	Tri-allate 1.40 kg/ha	Barban 0.175 kg/ha	Barban 0.35 kg/ha	Percentage increase in yield: Tri-allate 0.70 kg/ha	Tri-allate 1.40 kg/ha	Barban 0.175 kg/ha	Barban 0.350 kg/ha
1	65	87	74	74	62	70	66	64
2	80	94	96	96	23	4	19	5
3	66	93	98	98	8	8	22	10
4	90	96	74	82	17	29	18	18
5	77	88	96	96	71	87	92	127
6	86	92	99	100	19	19	17	4
7	92	98	85	88	-	-	16	25
8	69	85	94	99	12	23	20	20
9	85	90	100	100	-	4	8	5
	Mean seeds of A. fatua/m^2				Mean increase in yield quintals/ha			
	823	351	398	337	5.5	6.2	7.5	7.2

A lower yield response was obtained with tri-allate when used at half the recommended dose, when more than twice as many A. fatua seeds/m^2 were produced. With barban, a slightly higher yield response was obtained with half compared with the full recommended dose, although slightly more seeds were produced at this lower dose. The full dose of barban caused a temporary check to the crop at some sites. Although symptoms had disappeared by harvest, this data suggests that this effect may have influenced yield.

The average yield response from tri-allate was less than that from barban. This was largely due to the results from one site, Coln St. Aldwyns, where there was no response to tri-allate but a significant response to barban. The absence of any yield response to tri-allate at this site is difficult to explain in view of the good control of A. fatua and the absence of any obvious symptom of herbicide toxicity to the crop.

The adjustments of a combine such as used in these experiments are somewhat subjective, and the operator can choose between achieving maximum yield, and obtaining a sample free from contamination. If all A. fatua seeds are removed by the separating mechanism, smaller crop grains will also be lost. In these experiments, the aim was to harvest as much grain as possible, accepting the high resulting levels of contamination. It was considered that clean barley >2 mm was the parameter least likely to be affected by variations in combine settings. Contamination of the combined grain by A. fatua seeds, soil and straw was sufficiently high (over 3% by wt) on all sites except one, to reduce the saleable value of the grain from the control plots. A. fatua seeds were the major contaminant and these were reduced in nearly all cases to an acceptable level by spraying.

Competition from severe infestations at Bicester and Stratton Audley appeared to increase the proportion of thin grain but on other sites treatments had little effect. The large differences between sites appear to be related to particular varieties with Berac having the highest and Lofa Abed having the lowest proportion of thin grain. If high levels of *A. fatua* seeds and thin barley are removed by post harvest cleaning, the saleable yield can be reduced considerably from the grain that is harvested. This was seen at Stratton Audley where the unsprayed yield was reduced by half when these fractions were removed.

These results demonstrate the considerable financial advantage from spraying *A. fatua* infestations in terms of increased yields of higher quality grain. With either herbicide there may be a greater risk of poor weed control under sub optimal conditions if doses are reduced. This risk might well be acceptable where low populations are being sprayed and a policy of containment followed. Where high infestations are likely to lead to appreciable crop losses, the economic advantages of reducing the doses of these herbicides may not be justified in view of the increased risk of failure. The short term economic advantages should not be considered in isolation from the longer term benefits of weed control. However, the numbers of *A. fatua* seeds returned to the soil by the survivors suggests that the level of control achieved in these experiments is inadequate if an eradication policy is being pursued.

Acknowledgements

We are grateful to the farmers for their co-operation in providing the experimental sites, and to J R Aldridge, J A Carrington, S J Godding and P A Phipps for their technical assistance in carrying out these experiments.

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CHEMICAL CONTROL OF AVENA SPP. IN WINTER WHEAT

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Summary Twenty-three replicated trials included a total of nine herbicides with some variations in timing and rates of application. Crop yields and Avena spp. panicle weights were recorded. Most consistent good control was from benzoylprop-ethyl applied at early growth stage 7. Where A. myosuroides was present, the herbicides controlling both weed species tended to give the higher crop yields.

INTRODUCTION

ADAS Agronomy Department in Cambridge has continued to compare as many as possible of the herbicides available for the control of Avena spp. under a wide range of field conditions in order to provide information for use in advisory work.

METHODS AND MATERIALS

Experimental techniques were similar to those used previously; full details and the effects of treatments on A. myosuroides and broad leaved weeds are reported elsewhere.

Barban was applied at 40 lb/in^2: at 15 gal/ac in 1973 and 20 gal/ac in 1974. Benzoylprop-ethyl, chlorfenprop-methyl and difenzoquat were applied at 25 gal/ac at 48 lb/in^2. All other applications were at 20 gal/ac at 32 lb/in^2.

Herbicidal doses in both seasons, expressed as ai/ac were as follows:- tri-allate emulsion and granules 1.5lb pre-emergence, granules 2.0lb post-emergence; Chlortoluron 3.2lb pre-em, 2.8lb early post emergence: 2.4lb in spring; isoproturon 2.3lb pre-emergence and 1.9lb all post-emergence; barban 0.3lb; metoxuron/simazine 3.2 + 0.2lb; metoxuron 3.2lb; chlorfenprop-methyl 4.3lb; benzoylprop-ethyl 1.0lb and difenzoquat 0.9lb.

In the tables of site details, tables 1, 4 and 7, stages of growth are abbreviated:- number of leaves as 'L', Feekes - Large Growth Stage as G.S. Growth stages for the crop without brackets, for the Avena spp. within brackets.

Avena spp. survival is expressed in terms of dry weight of panicle gm/m^2. This gives a better indication of level of control than panicle numbers done since it reflects panicle size and seed return. For example in the 1972/73 trials the average panicle weights on the controls was 0.3 gms at site 3 and 3.1 gms at site 2.

Table 1

1972/73 EXPERIMENTS, SITE DETAILS (For treatment details, see Result Tables)

Site	1	2	3	4	6	7	8	9	10
Soil	VFSL	ZyCL	CL	OrgZyl	CL	ZyCL	Pty L	Zyl	SCL
Variety	Cappelle	Cappelle	Bouquet	M Huntsman	Bouquet	Cappelle	M Ranger	Cappelle	M Ranger
Sown	9/10	12/10	12/10	24/11	25/10	14/11	18/11	23/11	30/11

Conditions at times of treatments

Treatments, dates of applications, and stages of growth of wheat and (in brackets) *Avena spp*(L = no. leaves; GS = Growth stage - Feekes scale)

Site numbers

1	2	3	4	6	7	8	9	10
Treatments 1, 2 and 4								
11 Oct	12 Oct	13 Oct	27 Nov	31 Oct	17 Nov	22 Nov	24 Nov	7 Dec
Treatment 5								
13 Nov 2L(1L)	28 Dec 1-2½L(1L)	18 Dec 1-2½L(1L)	4 Jan 1L(1L)	21 Dec 1L(1L)	1 Jan 1L(1L)	29 Dec 1-1½L(1L)	4 Jan 1L(1L)	9 Jan 1L
3 & 7 8 Jan 2½L (1½L)	3 12 Jan 2-2½L (1-1½L)	3 10 Jan 1½-2½L (1½)	3 25 Jan 1½-2½L (1L)	3 11 Jan 1-2½L (1½L)	3 10 Jan 1½L (1L)	3 12 Jan 1½-2L (1L)	3 25 Jan 1½L (1L)	3 8 Feb 2L (1L)
6,8,9,10 & 13 27 Feb GS4-5 (2-4L)	6,7,8 & 9 8 Mar 3L-GS3 (2-3L)	6,7,8 & 9 1 Mar GS2 (2-2½L)	6,7,8 & 9 8 Mar GS3 (2-2½L)	6,7,8,9 & 13 2 Mar 3-4L (2-3L)	6,7,8,9 & 10 1 Mar & 13 GS2 (2L-GS2)	6,7,8 & 9 7 Mar GS3 (2-3L)	6,7,8 & 9 8 Mar GS2 (2-3L)	6,7,8 & 9 9 Mar 3L (1-3L)
	10 & 13 15 Mar 3L-GS3 (2½L-GS2)	10 & 13 13 Mar GS2 (2L-GS2)	10 & 13 19 Mar GS3 (3-4L)	10 13 Mar 3L-GS2 (2-3L)		10 & 13 19 Mar GS3 (2-4L)	10 & 13 19 Mar GS3 (1L-GS3)	10 & 13 27 Mar GS2-3 (1L-GS2)
Treatment 11								
11 Apr GS5-6 (GS3)	1 May GS5-6 (GS4-5)	4 May GS6 (GS5-6)	1 May GS5-6 (GS3-4)	25 Apr GS5 (GS5)	25 Apr GS5 (GS2-5)	7 May GS6 (GS4-5)	25 Apr GS5-6 (2L-GS5)	7 May GS5 (GS3-5)
Treatment 12								
8 May GS8 (GS6)	11 May GS7 (GS5-6)	14 May GS7 (GS6-7)	11 May GS7 (GS4-5)	18 May GS7 (GS7)	8 May GS6-7 (GS5-6)	16 May GS7-8 (GS5-7)	9 May GS7 (GS3-7)	16 May GS6-7 (GS4-5)

TABLE 2

Percentage Control of Avena spp as Dry Weight of Panicles 1972/73

	Sites									
Mean Weight Panicles	1	2	3	4	6	7	8	9	10	Means
g/m^2 on controls	37.9	80.7	82.0	3.8	124.0	325.0	50.7	19.8	13.6	81.9
Treatments										
1. Tri-allate ec pre-em	80	97	89	88	33	58	82	74	97	83
2. Tri-allate granules pre-em	79	98	79	92	32	58	85	84	63	80
3. Tri-allate granules post-em	82	81	85	61	+70	61	19	79	89	70
4. Chlortoluron pre-em	89	77	93	82	+ 7	60	70	38	99	76
5. Chlortoluron post-em	94	78	91	99	8	60	79	66	100	83
6. Chlortoluron early Spring	69	77	81	32	+15	66	77	32	100	67
7. Barban (March except Site 1)	94	93	84	53	22	87	90	59	81	80
8. Metoxuron-simazine (early S)	56	93	92	94	33	54	56	58	94	75
9. Metoxuron (early S)	70	95	83	67	40	61	27	67	62	67
10. Chlorfenprop-methyl (early S)	83	91	43	100	46	60	97	87	96	82
11. Benzoylprop-ethyl (crop GS5-6)	90	88	79	96	19	87	99	94	100	92
12. Benzoylprop-ethyl (crop GS7)	99	94	92	87	64	93	91	90	100	93
13. Difenzoquat early spring	99	91	84	79	39	70	97	99	99	90
SE diff ± (between herbicide comparisons)	22.3	31.9	13.9	62.5	23.3	16.0	30.5	22.5	43.4	11.9
A. myosuroides present (length heads, m/m^2)	14.7		15.7		20.0					

TABLE 3

Grain Yield Cwt/Acre 85% DM 1972/73

	Site								Mean Yields	% effect on yield
Treatment										
Control	27.5	36.5	18.8	35.2	6.7	26.9	31.6	32.1	26.9	100
1. Tri-allate ec pre-em	36.5	39.5	36.3	37.3	15.9	29.5	28.9	29.8	31.7	118
2. Tri-allate gran pre-em	35.1	38.2	32.3	38.9	18.5	28.9	34.2	35.0	32.6	121
3. Tri-allate gran post-em	29.5	41.9	28.9	32.5	10.1	29.5	31.8	31.8	29.5	110
4. Chlortoluron pre-em	27.5	38.2	41.1	36.6	15.5	28.6	38.1	32.4	32.3	120
5. Chlortoluron post-em	30.9	38.8	42.6	36.8	17.5	28.5	34.3	36.8	33.3	124
6. Chlortoluron (early S)	32.5	38.8	36.7	38.9	17.5	27.3	34.9	28.0	31.8	118
7. Barban (March) except site 1	34.7	44.7	40.7	41.3	27.9	25.6	33.3	36.7	35.6	132
8. Metoxuron Simazine (early S)	30.7	40.3	38.8	37.1	16.7	28.8	32.2	33.9	32.4	120
9. Metoxuron (early S)	26.0	43.4	41.2	37.6	18.7	32.2	35.0	33.9	33.5	125
10. Chlorfenprop-methyl (early S)	26.8	38.2	22.2	33.9	14.9	29.5	37.6	39.4	30.3	113
11. Benzoylprop-ethyl (crop GS 5-6)	34.4	38.0	30.3	37.1	28.3	31.1	32.1	33.7	30.1	112
12. Benzoylprop-ethyl (crop GS7)	33.5	41.3	31.5	37.9	33.2	32.6	31.9	31.1	34.1	127
13. Difenzoquat (early S)	30.1	40.8	37.3	33.3	25.2	26.5	33.0	33.5	32.5	121
SE diff for herbicide comparisons	±3.32	±4.01	±2.80	±3.49	±2.98	±4.53	±3.43	±2.86	±1.23	±4.57%

TABLE 4

1973-74 Autumn Treatment Trials - Site Details

(For treatment details, see Result Tables)

Site	1	2	3	4	5	6	7
Soil	CL	CL	Org.ZyCL	SCL	SCL	CL	SCL
Variety	Bouquet	M Ranger	Bouquet	Cappelle	Armentieres	West Desprez	M Nimrod
Sown	8 Oct	8 Oct	13 Oct	6 Oct	24 Oct	31 Oct	30 Oct

Dates of applications of each treatment and stages of growth of wheat and (in brackets) of *Avena spp*. (L = number of leaves; GS = growth stage)

	Sites						
Treatment	1	2	3	4	5	6	7
1 and 2	12 Oct	15 Oct	17 Oct	18 Oct	31 Oct	6 Nov	7 Nov
3 and 4	8 Nov 1-1½L (1L)	9 Nov 1-1½L (1L)	9 Nov 1L (Nil)	15 Nov 2L (1L)	23 Nov 1L (½L)	26 Nov 1L (1½L)	6 Dec 1L (-)
5 and 6	10 Dec 2½L (1-2½L)	10 Dec 2½L (1½L)	11 Dec 2½L (1-1½L)	17 Dec 3L (2½L)	18 Dec 1½L (1-1½L)	19 Dec 1-1½L (1-2L)	22 Jan 2-2½L -
7	9 May GS7 (GS5-7)	13 May GS7 (<GS6)	9 May GS7 (GS6)	8 May GS8 (GS4-5)	9 May GS7 (GS5-6)	15 May GS6-7 (<GS6)	9 May GS6 (2L-GS5)

TABLE 5

Percentage Control of Avena Spp: as Dry Weight of Panicles 1973/74

Autumn Treatment Trials

	Sites							
	*1	2	3	4	5	*6	7	Means
Mean Weight Panicles g/m^2 on controls	47.7	1.9	12.1	14.4	41.4	72.2	56.1	35.1
Treatments								
1. Chlortoluron (pre-em)	86	69	79	92	100	90	68	83
2. Iso-proturon (pre-em)	85	18	86	87	100	67	74	74
3. Chlortoluron (crop 1 leaf)	97	97	83	98	100	66	53	85
4. Iso-proturon (crop 1 leaf)	86	87	92	98	100	49	62	82
5. Chlortoluron (crop 2½ leaf)	91	98	59	95	100	78	19	77
6. Iso-proturon (crop 2½ leaf)	95	99	47	94	100	72	58	81
7. Benzoylprop-ethyl (crop GS7)	92	92	97	99	97	94	94	95
A. myosuroides length heads m/m^2	7.0	5.9		8.4	1.3	22.6		

* Sites 1 and 6, approx. 40% and 70% *Avena ludoviciana*.

TABLE 6

Grain Yield Cwt/Acre 85% DM. 1973-74 Autumn Treatment

Treatment	Site 1	2	3	4	5	6	Mean yields	% effect on yield
0. Untreated	54.2	38.7	56.1	47.0	50.9	41.9	48.1	100
1. Chlortoluron (pre-em)	59.2	44.0	56.8	58.3	55.2	55.6	54.9	114
2. Iso-proturon (pre-em)	60.9	45.6	56.3	55.7	55.8	53.1	54.6	114
3. Chlortoluron (Crop 1 leaf)	59.1	44.1	59.0	54.1	57.7	55.9	55.0	114
4. Iso-proturon (Crop 1 leaf)	62.3	45.8	59.0	55.4	55.1	50.7	54.7	114
5. Chlortoluron (Crop 2½ leaf)	60.4	41.7	58.0	55.8	54.3	54.0	54.0	112
6. Iso-proturon (Crop 2½ leaf)	56.0	40.9	58.5	56.7	56.7	47.8	52.8	110
7. Suffix (Crop GS7)	55.1	39.1	55.3	53.9	54.8	46.2	50.7	105

TABLE 7

1973-74 Spring Treatment Trials - Site Details and Conditions at times of Treatment

Site	8	9	10	11	12	13
Soil	CL	CL	SCL	SL	SCL	CL
Variety	Bouquet	West Desprez	Bouquet	Cappelle	Cappelle	M Ranger
Sown	8 Oct	31 Oct	26 Oct	27 Oct	6 Oct	24 Oct

Treatment, dates of application, and stages of growth of wheat and (in brackets) *Avena spp*. (L = no. leaves, GS = growth stage)

SITES

8	9	10	11	12	13
19 Nov 1 & 2 2-2½L 1-1½L	19 Dec 1 & 2 1½L (1-2L)	5 Dec 1 & 2 1L (1L)	27 Feb 3.4.6 & 7 4L (1-1½L)	22 Feb 3.4.6 & 7 GS3 (1L)	1 Apr 3.4.5.6.7.8 & 12 GS4 (1L-GS2)
4 Jan 5 & 8 3-3½L (1-3L)	25 Feb 3.4.5.6.7 & 8 4L (2½L-GS2)	25 Feb 3.4.5.6.7 & 8 3-4L (2L)	12 Mar 5 & 8 GS2 (2-2½)	8 Mar 5 & 8 GS3 (2-2½)	19 Apr 9 & 13 GS5 (1L-GS3)
20 Feb 3.4.6.7 & 12 GS3 (GS2)	20 Mar 12 GS3 (1-GS3)	20 Mar 12 GS3 (3-GS2)	21 Mar 12 GS3 (GS2)	20 Mar 12 GS3-4 (GS3)	14 May 10 & 14 GS7 (up to GS5)
11 Apr 9 & 13 GS5 (GS4)	19 Apr 9 & 13 GS5 (2-GS4)	18 Apr 9 & 13 GS5 (GS4)	11 Apr 9 & 13 GS4-5 (GS3)	10 Apr 9 & 13 GS5-6 (GS4-5)	28 May 11 GS8 (up to GS6)
9 May 10 & 14 GS6-7 (GS5-7)	15 May 10 & 14 GS7 (up to GS7)	9 May 10 & 14 GS7 (GS4-5)	9 May 10 & 14 GS7 (GS4)	9 May 10 & 14 GS7 (GS6)	
21 May 11 GS8 (GS7-8)	28 May 11 GS7-8 (up to GS7)	28 May 11 GS7-8	28 May 11 GS8	21 May 11 GS8 (GS6-7)	

TABLE 8

Percentage Control of *Avena* Spp: As Dry Weight of Panicles 1973/74

Spring Treatment Trials

	Sites						
	*8	*9	10	11	12	13	Means
Mean Weight Panicles g/m^2 on controls	42.6	45.0	22.7	65.3	27.8	19.8	37.2
Treatments							
1. Chlortoluron (Dec)	95	82	86				
2. Iso-proturon (Dec)	95	56	83				
3. Chlortoluron (early spring)	86	45	79	97	74	65	74
4. Iso-proturon (early spring)	31	80	97	99	97	85	81
5. Barban (March: Site Jan)	77	64	84	93	83	49	75
6. Metoxuron-Simazine (early Sp)	89	32	87	98	88	96	82
7. Metoxuron (early spring)	77	49	63	98	66	95	75
8. Chlorfenprop-methyl (early Sp)	44	0	85	93	59	93	62
9. Benzoylprop-ethyl (crop GS5-6)	94	57	85	65	92	64	76
10. Benzoylprop-ethyl (crop GS7)	92	96	90	84	96	97	93
11. Benzoylprop-ethyl (crop GS8)	0	94	91	85	88	81	73
12. Difenzoquat (early spring)	86	93	76	88	97	97	90
13. Difenzoquat (crop GS5-6)	20	97	99	88	98	94	83
14. Difenzoquat (crop GS7)	59	94	52	90	94	91	80
A. myosuroides length heads m/m^2	6.2	22.6			8.0		

* Sites 8 and 9, approx 45% and 75% *Avena ludoviciana*

TABLE 9

Grain Yield Cwt/Acre 85% DM. 1973-74 Spring Treatment

Treatment	9	Site 11	12	13	Mean yields	% effect on yield
0. Untreated	41.7	43.9	42.9	47.7	44.1	100
1. Chlortoluron (December)	47.9					
2. Iso-proturon (December)	48.6					
3. Chlortoluron (early spring)	47.1	48.3	51.6	49.1	49.0	111
4. Iso-proturon (early spring)	51.2	50.7	52.1	47.4	50.4	114
5. Barban (March)	43.0	47.1	46.1	47.2	45.9	104
6. Metoxuron-simazine (early spring)	44.5	50.4	54.2	46.3	48.9	111
7. Metoxuron (early spring)	49.2	51.8	51.7	49.6	50.6	115
8. Chlorfenprop-methyl (early spring)	39.7	51.4	46.8	48.3	46.6	106
9. Benzoylprop-ethyl (crop GS 5-6)	48.0	44.8	51.6	46.3	47.7	108
10. Benzoylprop-ethyl (crop GS 7)	44.5	48.8	45.8	48.3	46.9	106
11. Benzoylprop-ethyl (crop GS 8)	44.6	42.5	40.9	49.3	44.3	100
12. Difenzoquat (early spring)	42.7	49.1	47.3	49.6	47.2	107
13. Difenzoquat (crop GS 5-6)	49.5	48.4	48.4	51.8	49.5	112
14. Difenzoquat (crop GS 7)	46.9	48.1	45.9	47.9	47.2	107

DISCUSSION

A. myosuroides were present at many sites in both years in numbers sufficient to effect crop yields, and excellent control of Avena spp. alone did not always result in best crop yields. Wild oat populations were lighter in 1973-74 trials. Avena ludoviciana was present in quantity at sites 1, 6, 8 and 9 in 1973-74 but it was not possible to accurately assess differential effects of treatments.

In 1972-73 triallate emulsion and granular used pre-emergence gave good control of A. fatua and moderate of A. myosuroides resulting in good yield increases. Difficulty in applying this herbicide on small plot trials (incorporation, even application etc) led to it being omitted from 1973-74 trials.

In both years early post-emergence application of chlortoluron gave better control of both weed species than pre-emergence (possibly due to cloddy seed beds) and this in turn proved more effective than when used in spring and this is reflected in crop yields.

Metoxuron/simazine gave better control than an equal rate of metoxuron alone but the yield order was reversed in each year.

Iso-proturon was compared closely with chlortoluron in 1973/74 at four different times of application. Both herbicides were extremely effective against both weed species, chlortoluron being slightly better in Autumn and iso-proturon better in Spring.

Yields from some December applications of iso-proturon were dramatically lower than those from both earlier and later applications in spite of good weed control; this is considered to be related to the very low temperatures experienced at this time.

Barban in 1972/73 gave good control of Avena fatua but modest control of A. myosuroides. It considerably checked crop growth at six of ten sites but gave highest mean crop yields. Barban was less effective in 1973/74.

Chlorfenprop-methyl gave good control of Avena fatua on most occasions, but appeared to be ineffective on Avena ludoviciana. Benzoylprop-ethyl gave excellent control of Avena spp. applied at crop GS 6-7 and difenzoquat performed best when applied GS 4-6. None of the latter three herbicides were effective against A. myosuroides and this was reflected in yields.

Site 3 in 1972/73 had high populations of both A. fatua and A. Myosuroides and yield increases were strongly in favour of herbicides giving control of both species. Site 6 also had extremely high populations of both weeds and good control of one species usually led to a high increase in the density of the other species. Site 7 had an extremely high population of A. fatua alone, control yields being 6.7 cwts against 33.2 cwts of the best treatment, and here even 90% control of weed plants resulted in only 60% reduction of panicle weights. In other words, where populations are extremely high, a normally effective herbicide must be expected still to leave a sufficiently high population of the weed that maximum yield cannot be expected to be achieved with a single application of a wild oat herbicide.

The mainly soil acting herbicides, chlortoluron, iso-proturon, metoxuron and metoxuron/simazine are noticeably most effective in grass and broad leaved weeds on the lighter mineral soils (sites 1, 5 and 10 in 1972/73; 11 and 13 in 1973/74) and would seem a case for considering whether dosage should be varied with soil type.

Acknowledgements

The authors wish to thank especially the farmers who provided the experimental sites, ADAS colleagues who assisted, and Rothamsted Experimental Station for the statistical analysis. In addition we would like to thank those who provided us with experimental materials.

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THE CONTROL OF AVENA FATUA IN WINTER SOWN CEREALS WITH CHLORTOLURON

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Summary It has been demonstrated in replicated small and large plot trials during 1968 to 1974, and in commercial use that chlortoluron (N'-(3-chloro-4-methylphenyl)-NN-dimethylurea) applied pre or early post crop emergence at 3.58 kg ai/ha has given good control of *Avena fatua*.

INTRODUCTION

Chlortoluron was first tested in the United Kingdom in 1968 and the results reported in the Proceedings of the 10th British Weed Control Conference 1970 (Smith and Tyson). They reported good control of *Alopecurus myosuroides*, other annual grasses, and some broad-leaved weeds, with a promising effect on *A. fatua* (in half the trials 85-100% control).

The herbicide was introduced commercially in 1970, primarily for application in the spring to winter sown cereals for the control of *A. myosuroides* and several broad-leaved weeds.

It was observed in CIBA Limited trials from 1968-71 (mostly unpublished) that pre-emergence use was equally effective in controlling *A. myosuroides* but consistently good results were achieved on *A. fatua* compared with spring application.

The results of the pre 1973/74 trials conducted by ADAS Eastern Region (Proctor, ADAS 1970/71/72/73) or by CIBA-GEIGY (UK) Limited, are summarised in Table 1. These trials were located in the Eastern Counties of the United Kingdom. In 1973 ACAO approved chlortoluron for the control of the mixed populations of *A. fatua* and *A. myosuroides* in the Eastern Counties of the United Kingdom.

As pre-emergence techniques became more acceptable to the farmer, and an increasing number of results showed good activity against *A. fatua*, it was decided that an extensive trials programme should be carried out in 1973/74 to confirm the acceptability of this new use of chlortoluron. The main objective of these trials reported in this paper was to gather information from other important winter cereal areas, with particular attention to adverse soil drainage or compaction, conditions which previous experience suggested could reduce herbicidal performance.

Table 1

Control of *Avena fatua*
with 3.58 kg ai/ha chlortoluron applied pre-crop and weed emergence

Year	Conducted by	Number of experiments	*A. fatua* population		Range % Control		Average % reduction /year
			Plants m^2 (Jan)	Heads m^2 (July)	by No. heads	by dry wt.	
1968/69	CIBA	1		160	94		94
1969/70	CIBA	6		31-54	60-97		86
	ADAS	5	29-60			31-100	77
1970/71	CIBA	12		14-58	57-100		88
	ADAS	4	2-152			67-96	81
1971/72	CIBA-GEIGY	4		5-9		67-98	81
	ADAS	7	32-75			51-99	92
1972/73	CIBA-GEIGY	3		75-206		71-99	88
	ADAS	10	2-1091			7-99	76

MATERIALS AND METHODS

Chlortoluron was applied as a pre-emergence treatment using the commercial 80 WP formulation at the dose used to control *A. myosuroides* (3.58 kg ai/ha). Sixty three unreplicated trials were installed using conventional farm sprayers on plots up to 2 hectares. A Land-Rover fitted with an Evers and Wall sprayer was used to spray an additional ten trials, operating at a pressure of 2.9 kg cm^2 with an output of 260 litres/hectare: these trials had six replicates with plots of 6 x 20 m.

All sites were treated during the period 1st October to 28th November although the majority were sprayed during the first half of October. Table 2 lists some of the important site characteristics.

Table 2

Summary of trial site data

Cereal varieties	No. of sites	Drilling date	No. of sites	Soil texture types	No. of sites
Wheat					
Armentieres	1	October 1 - 7	5	Loamy sand	1
Atou	4	8 - 14	7	Loamy very fine sand	2
Bouquet	15	15 - 21	9	Sandy loam	8
Cappelle Desprez	13	22 - 28	16	Fine sandy loam	5
Champlein	5	29 - 4 Nov.	6	Very fine sandy loam	2
Chalk	2	Nov. 5 - 11	5	Loam	4
Flinor	2	12 - 18	3	Sandy clay loam	12
Maris Ranger	7	19 - 25	2	Clay loam	14
Maris Widgeon	2			Silty clay loam	1
				Calcareous soils	4
Barley					
Astrix	2				

The seventy three sites were located in the major arable areas of the United Kingdom with the following distribution (divided here according to ADAS regions) :-

Region	No. of sites
Eastern	27
East Midland	14
South East	18
South West	3
West Midland	4
Yorkshire and Lancashire	3
Scotland	4

Observations were made 4 to 6 weeks after drilling to determine the degree of soil compaction at seed depth and plough depth using the Peerlkamp scale (1967) in an endeavour to correlate between soil compaction and control of A. fatua.

Counts of A. fatua plants were made in January and again in April to establish the respective numbers of autumn and spring germinating plants.

Fifty three sites survived until July 1974, the other twenty sites being discarded for a variety of reasons, the commonest being no wild oats (6 sites), treated area oversprayed by the farmer (4 sites) and insufficient untreated areas to make meaningful comparisons (8 sites).

Panicle counts were made at these sites in July (16 × 1/4 m^2 quadrat counts per treatment).

The replicated trials were harvested by a modified CLAAS Compact combine harvester, cutting an area of 2.3 m by 12 m from each plot.

The unreplicated trials were harvested by hand sampling, six quadrats of 50 cm^2 were cut from each treatment followed by individual bench threshing of the quadrat samples, winnowing and weighing.

RESULTS

The sites treated covered a wide range of soil types from loamy sand through to silty clay loams, although clay loams and sandy clay loams predominated (Table 2). Soil structure/compaction determinations in November/December using the Peerlkamp method indicated that all sites had loose, friable seedbeds with no more than moderate compaction below.

Plant counts in January and April 1974 established that, at the sites under review, the majority of wild oats germinated in the spring. A. fatua control in April averaged 69% (in terms of plant numbers) and surviving A. fatua plants exhibited progressive toxicity symptoms. Comparison of panicle counts in July, on treated and untreated areas, showed substantial further improvement in control averaging 89%. Table 3 illustrates the distribution of weed control levels achieved.

Table 3

Frequency distribution of reduction in *Avena fatua* panicles (1973/74 trials)

% reduction of *A. fatua* panicles	No. of sites in each category
0 - 25	1
26 - 50	1
51 - 75	2
76 - 85	8
86 - 90	6
91 - 95	8
96 - 100	27

Control of *A. fatua* exceeded 96% on nearly half of the sites and better than 86% control was achieved at three quarters of all the sites treated in 1973/74. Situations where chlortoluron failed to give an adequate control of *A. fatua* reflected only the dominant features of winter cereal production in general, i.e. most failures occurred in the Eastern counties and where the soil compaction measurements were too similar at all sites to permit testing of the hypothesis that differences in percolation rate of water through the soil might affect the activity of chlortoluron against *A. fatua*.

Yield

Harvesting of five of the replicated trials, and sample harvesting of thirty of the unreplicated trials is currently in progress, and results will be reported elsewhere.

CONCLUSIONS

The 1973/74 trials programme has confirmed previous evidence from CIBA-GEIGY and independent trials and from extensive commercial use that chlortoluron applied at 3.58 kg ai/ha pre crop emergence is an effective herbicide for the control of moderate populations of wild oat. Results have been equally reliable throughout the United Kingdom.

Acknowledgements

We would like to express our gratitude to all those farmers who have co-operated in the trials, and especially to the Agronomy Section of ADAS Eastern Region for allowing us to use results of their trials.

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TRIALS ON WILD OAT (AVENA LUDOVICIANA, DURIEU) CONTROL IN WINTER WHEAT COMPARING NEW HERBICIDES

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Summary Two trials carried out in Italy, in the Bologna area, are reported. The aim of one of the trials was to evaluate the effectiveness of Tri-allate, Chlortoluron, Barban, Metoxuron and Difenzoquat on artificially caused Avena ludoviciana infestations at different rates. The object of the other trial was to evaluate the possibility of extending the application period of Benzoyl-prop-ethyl and Difenzoquat.
The results can be summarized as follows:

- the herbicides effectiveness on wild oat control tended to decrease with the increase in the wild oat population.
- Among the various products tried, Benzoyl-prop-ethyl and Difenzoquat gave good control of wild oats; it would also appear that these herbicides can be applied earlier without substantially changing their selectivity towards the crop but with reduction in their control capacity on the wild oats.
- Barban's effectiveness on wild oats was good but not accompanied by high selectivity towards the wheat crop.

INTRODUCTION

In 1973 the wheat-growing area in Italy was 3.5 million ha, including 2 million ha of soft wheat and 1.5 million ha of hard wheat. (ISTAT 1974).

One of the major economical problems of Italian wheat cultivation is the control of annual weeds and, especially, wild oats. Recent studies (Cesari and Sgarzi 1974, Antonelli et al. 1974) showed that the most widely spread species of wild oats infesting wheat fields in Italy are A.ludoviciana Durieu, A.sterilis L., A.barbata Pott. and A.fatua L., and the first listed is the most widely spread.

The reduction of yield of soft wheat due to A.ludoviciana is variable, depending on the length of time it is present in the crop, on the amount of the weed population, on nitrogen fertilization and on wheat sowing density and methods (Toderi and Catizone 1974). However, under most practical conditions, treatments for wild oat control are justified even though they are fairly expensive. For this reason, a research programme on A.ludoviciana control in wheat crops was set up at the Dept. of Agronomy and Field Crops, University of Bologna. Some of the results obtained in two field trials are reported in this paper.

The object of one of the trials was to evaluate the effect of several herbicides on increasing rates of A.ludoviciana populations. In another trial, the aim was to estimate the wild oat control by the two most promising post-emergence herbicides applied at different stages of wheat and wild oat growth. The application dates were chosen in order to be able to evaluate the possibility of extending the application period for the two herbicides.

METHODS AND MATERIALS

The two trials were conducted in the Bologna area, one in 1972-1973 at Cadriano and one in 1973-1974 at Ozzano.

The characteristics of the soil at Cadriano were as follows: sand 40%, silt 24%, clay 36%, o.m. 1.8%, $CaCO_3$ traces, pH 7.6; and at Ozzano they were: sand 55%, silt 14.5%, clay 30.5%, c.m. 1.29%, $CaCO_3$ 5%, pH 7.7.

Cadriano Four A.ludoviciana infestation rates, caused artificially by using 0, 130, 260 and 390 seeds/m^2, were combined with the five herbicides given in Table 1 plus a control, arranged in a split-plot design with 4 replications. The various wild oat populations were in the plots and the herbicides in the sub-plots, which were 2,64 x 6 m.

Details on the trials are given in Table 1.

In the field used for the trials, which had formerly been sown to a wheat-maize cropping system and weeded with Terbutryn and Atrazine respectively, a uniform infestation of A.myosuroides Huds, and of various broad-leaved weeds had been noted, but no wild oats were observed.

On October 30th artificial infestation was carried out with seeds collected in the summer 1972 by a combine in a wheat crop. The germinability of the seeds, tested in pots, was 42% (Data from Lovato and Viggiani, I974, gives greater details on the seeds). Immediately after sowing, the wild oat seeds were buried in the first 10 cm of soil using a rake. The wheat was sown on October 31st using the variety 'Resistente' at a rate of 500 seeds/m^2, with the help of a precision drill on continuous rows 22 cm apart. This method was chosen in order to get different populations of A.ludoviciana. With the same experimental conditions, infact, the amount of the wild oat population and its dry weight was directly correlated with the number of seeds sown (I.A.B. 1971).

Spraying was done with a precision sprayer at a pressure of 2 Kg/cm^2. The volume of the water used was 600 l/ha.

April 2, 1973, the whole trial was treated with Dinotreb in order to eliminate the broad-leaved weed infestation.

The determination of the amount of A.ludoviciana was carried out on June 22nd over the whole plot area, harvesting the wild oats by hand. The wheat was harvested with a plot-combine on July 3rd eliminating 2 border rows in each plot.

Ozzano 2 x 2 m plots were marked off on January 30, 1974, in a hard wheat crop (IAB 3TD variety), at a uniform stage of growth and where there was an infestation of A.ludoviciana. The wild oat plants in each plot were marked with plastic rings, the plots where the wild oat infestation differed greatly from the average field infestation were excluded from the trial; the number of plots used was such that, the treatments were possible according to a randomized block design with 4 replications. Details on the trial are given in Table 1.

The spraying was carried out with the same technique used for Cadriano.

April 15th, the whole trial was treated with Ioxynil plus Mecoprop in order to control the broad-leaved weeds present.

On June 25th, two weeks before the probable complete ripening of the wheat, the plastic rings which marked the wild oat plants were found and notes were taken as to whether each one was alive or dead, plus the number of stems per plant, these were considered to be alive if they had produced even one seed.

<u>Table 1</u>

<u>Products, dosages, application method and times</u>

	formulation type	formulation a.i. %	rate a.i. kg/ha	application method and date		Growth stage (Keller Baggiolini scale) Wild oat	wheat
Cadriano trial 1972-73							
chlortoluron	w.p.	80	2.24	pre-em.	Dec. 31		
tri-allate	granules	10	1.70	post-em.	Jan. 26	E	E
barban	e.c.	w/v 12.5	0.35	post-em.	Feb. 6	E	E
metoxuron	w.p.	80	3.60	post-em.	Mar. 14	F	F
difenzoquat (*)	a.c.	w/v 40	0.80	post-em.	Mar. 28	F	G
Ozzano trial 1973-74							
				post-em.VE:	Feb. 13	E	E
benzoyl prop-ethyl	e.c.	w/v 20	1.40	post-em.E :	Mar. 12	F	G
				post-em.N :	Apr. 1	G	I
				post-em.E :	Feb. 13	E	E
difenzoquat (*)	a.c.	w/v 40	0.80	post-em.N :	Mar. 12	F	G
				post-em.L :	Apr. 1	G	I

Notes: (*) Wetting agent (2 kg a.i./ha was added in the spray tank).
Growth stages of wild oat and wheat were observed on more than 50% of the total plants.
VE, E, L: very early, early and late application in comparison to normal time (N).

RESULTS AND DISCUSSION

<u>Cadriano</u> The wheat emerged during the first two weeks of November together with <u>A.myosuroides</u>. The wild oat emergence proved to be spaced over a period of time and continued for the whole month of December.

The high germinability of the material used in order to cause the infestation, determined a strong infestation of wild oats even at the rate of 130 seeds/m^2, Table 2.1. Under these conditions (130 seeds/m^2), only Difenzoquat and Barban succeeded in maintaining wild oat development at negligible levels, whereas Tri-allate Chlortoluron and Metoxuron reduced the quantity of wild oats by 52.5%, 35.5% and 12.4% respectively as compared to the control plot.

Going from the lowest seed rate to the highest one, there was an increase in the amount of the wild oat population to different extents depending on the herbicides used. As an average of the different wild oat rates, all of the herbicides reduced the infestation significantly compared to the control. In particular Difenzoquat and Barban were the most effective and gave similar results. Among the other products Tri-allate was more effective than Chlortoluron and Metoxuron which gave poor control.

Table 2

Cadriano Trial: Effects on grass weeds (dry weight: q/ha)

Levels of W.O. artificial infestation seeds/m²	treatments					
	check	chlortoluron	tri-allate	barban	metoxuron	difenzoquat
2.1 Avena ludoviciana **						
0	2.2	2.1	2.3	0.0	0.3	0.0
130	68.1	43.9	32.4	2.9	59.7	0.4
260	106.7	76.8	57.9	4.6	82.2	3.8
390	130.6	100.1	60.7	9.1	84.1	8.5
mean *	(*)101.8a	76.6b	50.3c	5.5d	75.3b	4.2d
2.2 Alopecurus myosuroides **						
0	37.2	12.9	32.4	14.6	16.4	31.8
130	24.6	4.0	32.1	18.8	6.4	28.6
260	15.9	4.5	16.7	16.4	5.5	27.3
390	9.4	3.0	14.6	14.6	2.2	19.0
mean *	21.7a	6.1c	23.9a	16.1b	7.6c	26.7a

Notes: * means countersigned by different letters are significantly different at $P = 0.01$

** Interaction W.O. density level x treatments is statistically significant at $P = 0.01$

(*)Statistical analyses and means for sown plots only

With regard to the various herbicides' effectiveness on A.myosuroides this weed was significantly controlled by Chlortoluron, Metoxuron and Barban. In the field there was a low population of L.italicum A.Br. which was resistant to Difenzoquat, susceptible to Barban and Chlortoluron, and intermediate in response to the other compounds.

The depressive effect exercised by A.ludoviciana on A.myosuroides appears to be sufficiently clear from the data in Table 2 (the correlation coefficient was significant for all the herbicides except for Barban).

The grain yields (Table 3.1) proved to be inversely correlated, for all the herbicides with the total quantity of weeds present at harvesting. As an average of the various infestation levels, all of the trial herbicides permitted higher yields under the trial infestation conditions, than in the control plot.

The 1000 grain weight (Table 3.2) for the various herbicides, proved to be inversely correlated with the total quantity of infestation except for Barban, and this can be attributed to the toxic effects on the wheat due to this herbicide. These effects appeared in the form of a reduction in the number of wheat stems/unit area and with the reduction in the height of the wheat stem at harvesting (Table 3.3). However the good wild oat control and the greater unit weight of the caryopses due to the low plant density/unit area compensated sufficiently for the toxic effect on the wheat.

Table 3

Cadriano Trial: Effect on grain yield, weight of 1,000 grains and stem height of wheat at harvesting time

Levels of W.O. artificial infestation seeds/m^2	treatments					
	check	chlortoluron	tri-allate	barban	metoxuron	difenzoquat
3.1 Grain yields, 13% humidity (q/ha) **						
0	32.8	43.5	36.5	31.3	41.6	36.7
130	20.7	37.5	29.7	31.4	30.1	32.0
260	13.3	30.8	26.1	32.3	23.2	29.7
390	15.8	24.5	24.7	32.2	21.9	28.7
mean *	20.6a	34.0b	29.2b	31.8b	29.4b	31.8b
3.2 Weight of 1,000 grains, 13% humidity (g) **						
0	39.2	39.7	39.5	41.4	41.4	39.1
130	37.2	37.3	37.5	42.0	36.7	38.6
260	34.6	36.8	36.7	39.3	35.0	38.1
390	34.9	36.7	35.2	40.9	35.9	37.9
mean *	36.5c	37.6bc	37.2bc	40.9a	37.2bc	38.4ab
3.3 Stem height at harvesting time (cm)						
0	85	84	86	75	84	81
130	86	86	86	75	88	85
260	83	83	85	78	86	83
390	86	85	85	79	86	85
mean *	85.0b	84.5b	85.5b	76.7a	86.0b	83.5b

Notes: * means countersigned by different letters are significantly different at $P = 0.01$

** Interaction W.O. density levels x treatments is statistically significant at $P = 0.01$

Ozzano In Italian conditions the recommended stage for treatment with Benzoyl-prop-ethyl is when the first node of the stem is visible in wheat (Perugia and Gallizia, 1973). Application of Difenzoquat is recommended at the 3-5 leaf stage in wild oats (Cyanamid 1973, Sisto 1973) i.e.: when the tillers of the wild oats are already formed. Both herbicides reduced the number of wild oat plants significantly when applied in the recommended stages, as compared to the control (Table 4).

Benzoyl-prop-ethyl, was less effective at the earlier time of application. This is shown in table 4 with respect to the number of plants and stems and the wild oat tillering index. From the data given in Table 5, it is possible to note that by treating earlier, the wild oat plants which had not tillered or which only had one tiller decreased from 51.5% for the normal treatment date to 24.4% at the earlier date.

Table 4

Ozzano Trial: Effects on wild oat and wheat crop

treatments	wild oat: surviving plants % (1)	wild oat: surviving plants No./m² (2)	wild oat: stems No./m² (2)	wild oat: stems % reduction (3)	wild oat: stems No./plant tillering index	wheat: date of evaluation	wheat: phytotoxicity index (4)
untreated	95.8	33.8a	256.7a	——	7.6a	——	——
benzoyl prop-ethyl							
1st appl.time (VE)	65.8	10.5ab	45.2b	82.4	4.3bc	febr.25	0
2nd appl.time (E)	51.8	8.9ab	33.9b	86.8	3.8bc	mar. 25	0
3rd appl.time (N)	35.1	3.6b	13.3b	94.8	3.7bc	apr. 26	+
difenzoquat							
1st appl.time (E)	30.7	5.7ab	28.7b	88.8	5.0bc	febr.25	+
2nd appl.time (N)	12.7	1.9b	11.0b	95.7	5.7ab	mar. 25	+
3rd appl.time (L)	28.7	2.7b	7.4b	97.1	2.7c	apr. 26	1.5

Notes: (1) % in comparison to total W.O. population present before the application (2) number of plants and stems present at harvesting – (3) % in comparison to untreated – (4) scoring system of visual evaluation: 0 (no phytotoxicity) to 5 (max.); + : transient traces. In each vertical column, figures marked with different letters are significantly different at P = 0.01.
VE, E, L: very early, early and late application in comparison to the normal time (N).

Table 5

Ozzano Trial: Final effects of treatments on survival percentage of wild oat plants

	survival % of W.O. plants (a)	Tillering index of survived wild oat plants – frequency % by class (number of tillers per plant): 1	2	3	4	5	6	7	8	9	>9
untreated	95.8	1.2	7.5	9.4	9.4	9.4	8.8	6.5	8.8	4.4	34.6
bezoyl prop-ethyl											
1st appl.time (VE)	65.8	19.8	14.6	15.6	14.6	8.3	4.2	4.2	7.2	2.1	9.4
2nd appl.time (E)	51.8	25.8	20.7	17.2	6.9	8.6	5.2	3.5	6.9	1.7	3.4
3rd appl.time (N)	35.1	27.3	24.2	9.2	15.1	6.1	3.0	3.0	3.0	0.0	9.1
difenzoquat											
1st appl.time (E)	30.7	30.2	11.6	11.6	2.6	7.0	4.6	4.6	4.6	0.0	23.2
2nd appl.time (N)	12.7	13.3	20.0	13.3	0.0	0.0	6.7	13.3	6.7	6.7	20.0
3rd appl.time (L)	28.7	33.3	23.3	13.3	3.4	10.0	16.7	0.0	0.0	0.0	0.0

Notes: (a) compared to total number of plants present before the application
VE, E, L: very early, early and late application in comparison to the normal time (N)

The results obtained with early treatments of Difenzoquat were similar to those mentioned above. Earlier treatment gave poorer control of wild oat plants (Table 4). Later application reduced the tillering index giving a superior overall effect compared to early treatment even though the number of wild oat plants/m^2 was similar. The data in Table 5 shows, infact, that at the later date no plants with more than six stems were found and among these, 56.6% either had not tillered or only had one tiller. Some sensitivity on the late application of Difenzoquat was shown by the tested hard variety (Tab. 4).

CONCLUSIONS

From the results obtained and considering the conditions under which the trials were carried out, characterized by a heavy artificial or natural wild oat infestation, we can conclude that among the herbicides tried, those that furnished satisfactory control of the wild oats, along with good selectivity towards the crop were Benzoylprop-ethyl and Difenzoquat. With these herbicides, the results also showed that earlier application gave poorer control of wild oats. With Difenzoquat, a later treatment compared to the recommended date improved wild oat control, on condition that crop safety be investigated further especially for hard varieties.

Among other herbicides experimented Barban showed high effectiveness in controlling wild oats, but not high selectivity towards the wheat. In the author's view this degree of damage would not be acceptable to farmers even though good recovery occurred in this experiment. The wild oat control tended to diminish with the increase in the wild oat seed rate and thus with the increase in the wild oat population.

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Acknowledgements

Thanks are due to Mr. P.Viggiani for his technical assistance.

Proceedings 12th British Weed Control Conference (1974)

THE EFFECT OF A SINGLE FIELD APPLICATION OF VERY HIGH RATES OF LINURON AND SIMAZINE ON CARBON DIOXIDE EVOLUTION AND TRANSFORMATION OF NITROGEN WITHIN SOIL

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Summary. A single application of very high rates of linuron (130 kg/ha) and simazine (133 kg/ha) having been made to field plots, the opportunity was taken to study their effect on microbial activities in the soil. CO_2 evolution and mineral nitrogen were determined in the laboratory on soil samples from these plots during the ensuing three years. Initially large reductions in CO_2 were observed on treated as compared with untreated soils, the difference becoming less with time. Indirect as well as direct antimicrobial effects may have been involved. A reduction in mineral nitrogen occurred in the spring of two consecutive years. The amounts used here may occur only as a result of an overdose.

INTRODUCTION

Pollution of the air and water have been studied and discussed extensively but that of soil has received less attention. Whether pesticides, including herbicides, contribute to soil pollution depends on application rates and persistence. The effect of repeated annual applications of field rates has been under investigation at the Weed Research Organization (WRO) since 1963 (Fryer and Kirkland, 1970), two of the microbial activities being examined by Grossbard (1971). Other work on the influence of repeated application of herbicides on micro-organisms has been reported by Spiridonov and Spiridonova (1973) and other workers.

To investigate the degradation of a single application of excessively high doses of herbicides Fryer, Ludwig and Hance of this Organization laid down a field experiment in 1971 using linuron and simazine. The establishment of these plots provided the authors with the opportunity to examine the effects of these high rates in the field on microbial activities. Samples were brought into the laboratory and tested for CO_2 output and the formation of mineral nitrogen. The results of these investigations are described in this report.

METHODS AND MATERIALS

In April 1971 randomised plots (8.3 m x 2.3 m; 4 replicates) of spring barley on a coarse sandy loam field at WRO were sprayed pre-emergence with linuron (130 kg/ha) and simazine (133 kg/ha). Soil characteristics of this field are described by Fryer and Kirkland (1970). The barley together with 314 kg/ha fertilizer (13.13.20) was drilled over the whole of the experimental area in 1971. However, as the crop together with any weeds died soon after germination on the herbicide-treated plots only the control plots were harvested. The following year only the control plots were cultivated, fertilized and sown with barley. These plots were not cropped in 1973 or 1974. Prior to the first sampling in June 1972 two areas 1 m^2 were set aside on each control plot for microbial activity investigations. These were cleared of all vegetation and were subsequently kept free of weeds by hand. Weeding in 1972 and early 1973 caused disturbance of the soil in the metre square sub-plots in comparison with the herbicide-treated plots which remained weed free and compacted. To restore similar physical conditions the metre square areas were compacted in mid-1973.

Two samples per plot, each of 15 cores 2.5 cm diameter by 5 cm deep were taken from the metre squares of each control plot, and the overall area of the treated plots in spring and autumn 1972 and 1973 and also in spring 1974. In spring 1972 only controls and linuron treatments were sampled, but subsequently simazine was included. After removal to the laboratory, the soils were sieved and the moisture content of three replicates (100 g) per sample, i.e. six replicates per plot, were adjusted to field capacity using tension tables (Clements, 1966). These were then transferred to Kilner jars and incubated at 23^{o}C as described by Grossbard (1971). At the end of the two-week incubation period the NaOH, used to absorb CO_2, was titrated against 0.1 N H_2SO_4 between pH 8.3 and 3.8 to determine the CO_2 evolved from the soils, which were then stored at -15^{o}C for subsequent analysis for nitrogen present as NH_4^+, NO_2^- and NO_3^-. NH_4^+ was determined in a K_2SO_4 extract of the soil by the steam distillation method of Bremner and Keeney (1965), and NO_2^- and NO_3^- on the same extract using a modification of Litchfield's method (1967) on a Technicon AutoAnalyzer. The organic C content of the soil samples was determined by an adaptation of Walkley and Black's method (1934), replacing the final titration by an estimation of colour intensity on a Technicon AutoAnalyzer (J.A. Varley, pers. comm.). Herbicide residues in a separate series of soil samples were determined by the Chemistry Group at WRO. Linuron was measured by electron-capture gas chromatography of a 2,2,4-trimethylpentane solution after the herbicide had been extracted with methanol, and the solvent evaporated off (McKone, 1969), and simazine by alkali flame ionisation chromatography of a methanol soil extract (McKone et al., 1972).

RESULTS

The results for CO_2 evolution, residue analyses and nitrate-N are given in Figures 1, 2 and 3. CO_2 output on linuron-treated plots was less than in the control in all samplings (Fig. 1) although the herbicides had broken down to a relatively low level by 1973 (Fig. 2). Linuron degraded more rapidly than simazine (Fig. 2) but had longer-lasting effects on CO_2 output. After an initial period of lower CO_2 production from the simazine-treated plots the mean showed a recovery to the control level by September 1973. The higher standard error on this occasion results from a stimulation of more than 20% on two plots, while output on the others was still less than with the control (Table 1). In 1973 the simazine-treated plots with higher CO_2 output were covered in moss and were found to have lower residues than the other replicates. No moss was observed on the linuron or control plots. Differences in organic C in the plots were negligible, the overall range being 1.0-1.1% organic C. Theoretically breakdown of 0.01% organic C could release 100 ppm carbon as CO_2.

The herbicides had no significant effect on mineral-N in the soil in autumn samplings, but in April 1973 and 1974 NO_3^--N was significantly lower with both treatments (Fig. 3). Only very small amounts of NH_4^+-N were detected (< 1 ppm), and NO_2^- was not recorded at any time.

Figure 1.
Evolution of CO_2 over 14 days from soil treated with linuron and simazine in April 1971.

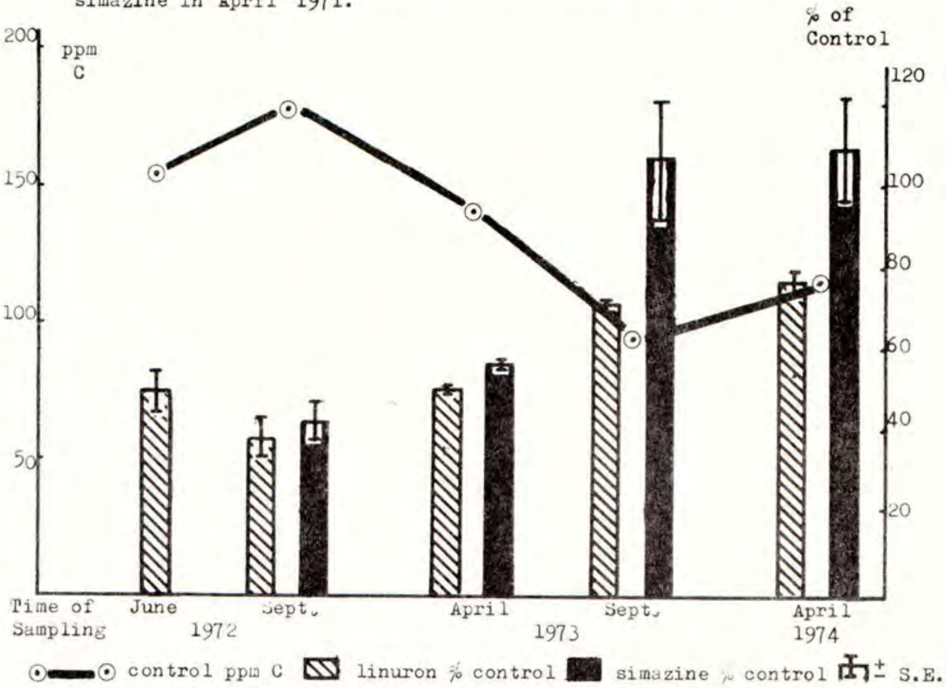

Figure 2.
Amount of linuron and simazine in top 5 cm of the field after treatment in April 1971 (kg/ha)

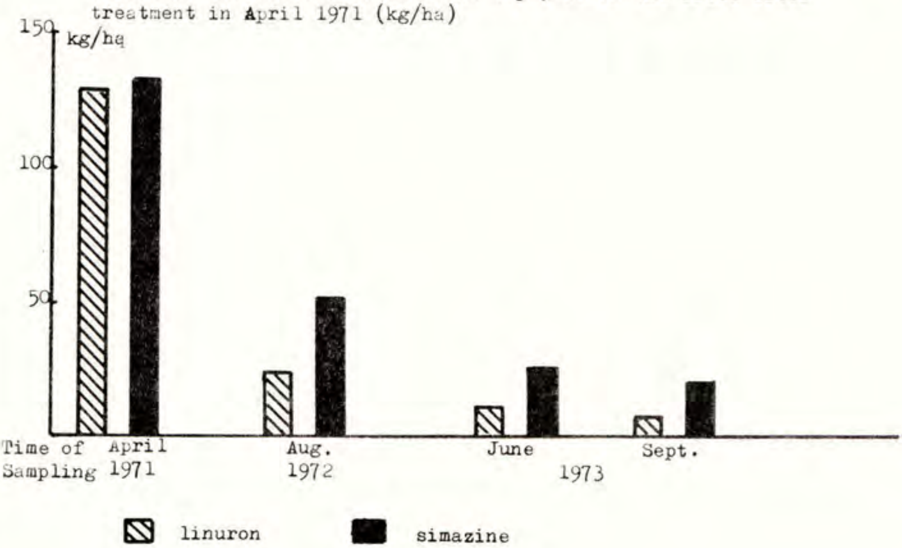

Figure 3.

The effect of linuron and simazine on nitrate production in soil treated with linuron and simazine in April 1971.

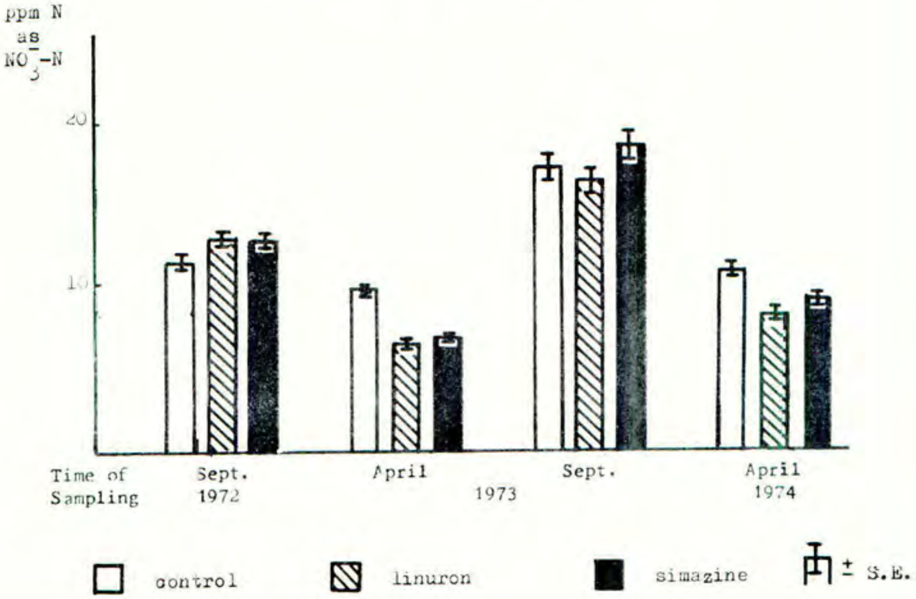

Table 1

Individual plot means of CO_2 output (ppm C) for control and simazine-treated plots sampled in September 1973, showing presence of moss on two plots

Block	I	II	III	IV
Control	101 ± 2.1	91 ± 2.1	93 ± 2.7	94 ± 1.7
Presence of moss	-	-	-	-
Simazine	133 ± 2.3	84 ± 2.4	74 ± 1.6	115 ± 10.2
Presence of moss	+	-	-	+

DISCUSSION

CO_2 output was lower for both herbicides in relation to control although this was longer-lasting with the less persistent herbicide linuron. Inhibition of CO_2 production by linuron and simazine in field experiments at much lower rates has previously been reported (Grossbard, 1971). She interpreted this result as a response to the larger amounts of plant remains on the control plots as compared with the treated, rather than to a direct action of the herbicides on the microflora. Similar conclusions have been drawn by Kruglov et al., (in press). However, in the experiment described here particular attention was paid to removal of root material in addition to aerial parts of plants during the hand-weeding operation, although inevitably some small roots will have been left behind. Before mid-1973 the results may have been influenced by cultivation and removal of the barley crop from the control plots, thus providing more substrate for CO_2 evolution, and also by the greater compaction on the herbicide-treated plots. However, a direct suppression of microbial activity may also have contributed, especially in the case of linuron since the effect still continued with this treatment even after compaction. This influence might also be expected to apply to simazine which in September 1972 and April 1973 showed a similar degree of inhibition to linuron. The higher output of CO_2 from simazine-treated soil between April and September 1973 was possibly due to a contribution of respiratory CO_2 by the moss on the plots where the residues had decreased most, rather than to an increase in microbial activity. The antimicrobial effect of linuron at high rates has been demonstrated in laboratory experiments (Bartha et al., 1967; Grossbard and Marsh, 1974), however, the comparable data on simazine are less conclusive, both inhibitions and stimulations being reported (Chandra et al., 1960; Eno, 1962; Bartha et al., 1967).

The microbial populations responsible for mineralisation of nitrogen (the conversion of organic nitrogen to ammonium-N) show some sensitivity to high rates of linuron and simazine during the winter months, but not during the summer when they are more active. Since only traces of ammonium-N were detected in this work, high rates of these herbicides did not have any effect on nitrification of the soil (oxidation of NH_4^+-N to NO_3^--N). This agrees with data from many laboratory experiments where neither herbicide exerted an influence on mineralisation of N and nitrification in unamended soil (Spiridonov and Spiridonova, 1973; Grossbard and Marsh, 1974).

The interpretation of the data from this experiment is made more difficult since it was not laid down for microbial investigation, and involved procedures which resulted in the control and treated plots not being directly comparable.

The rates used in this experiment are far in excess of any which farmers apply to crops in the field. Thus it could well be that such effects as were found would only occur as a result of severe accidental spillage of these herbicides, or overdosing in non-selective usage.

Acknowledgements

We wish to thank Mr. J.D. Fryer and Dr. K. Holly for guidance and advice in this work; Mr. Fryer, Dr. R.J. Hance, Mr. J.W. Ludwig and Mr. P.D. Smith for allowing us to use plots from their experiment, and also for permission to quote unpublished residue data; Mrs. S. Ridge and Mr. C.J. Marshall of the joint Letcombe/WRO Statistics Section for statistical analyses, and Miss C.J. Standell for technical assistance.

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Proceedings 12th British Weed Control Conference (1974)

SOME ENVIRONMENTAL ASPECTS OF THE USE OF ASULAM FOR BRACKEN CONTROL IN UPLAND AREAS

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Summary Ecological studies of flora and fauna, on land and in water, have been carried out in upland areas treated with asulam for the control of Pteridium aquilinum (bracken).

No more than 0.5 ppm asulam was detected in ground or surface water immediately after spraying and none after two weeks. An extensive range of aquatic fauna was found unaffected in streams flowing through and beyond the sites.

A wide range of plant species showed no or little reaction to direct sprays of asulam at 4 lb a.i./ac. In the case of the sensitive flowering species, where some kill was noted, re-establishment occurred from seeds or roots and the appearance of the plant communities showed little visible change twelve months after spraying.

Résumé Des études sur l'écologie de la flore et de la faune, sur la terre ainsi que dans l'eau, ont été effectuées en hautes terres traitées à l'asulam pour lutter contre la fougère (Pteridium aquilinum).

Un maximum de 0.5 ppm d'asulam fut détecté dans les eaux souterraines et de surface immédiatement apres pulvérisation. Aucunes traces ne furent trouvées après deux semaines. Une faune aquatique tres diversifiée fut découverte intacte dans les cours d'eau traversant, et en dela, des lieux d'essais.

Une large gamme de plantes d'espèces diverses ne réagirent que peu ou pas du tout aux pulvérisations directes d'asulam à 4.48 kg/ha. Dans les cas des espèces à fleurs sensibles, parmi lesquelles il y eut des pertes, elles repousserent des graines ou des racines et l'aspect général des populations de plantes ne montra que peu de changements visibles, douze mois après la pulvérisation.

INTRODUCTION

In 1972 asulam was marketed in the U.K. for the control of Pteridium aquilinum and it is officially approved for this use on hill and agricultural land, on non-crop areas and in forestry.

In the U.K. bracken is found primarily on hills and moorlands and, because of the steep and often boulder strewn terrain, application by ground sprayers is not always practicable and aerial application is often the only feasible means of applying the chemical. Since much of the bracken-infested land is in areas of scenic beauty, with a diverse flora and fauna, and in catchment areas of Water Boards and River Authorities, the effect of spray drift or accidental direct application outside the target areas is of considerable interest.

Extensive laboratory studies on asulam have shown that the chemical has little or no effect on a wide range of animals and micro-organisms and that the hazards to the environment are likely to be negligible (May & Baker 1971). Nevertheless, during 1973 further studies were undertaken to confirm this by monitoring both commercially and experimentally sprayed areas.

The investigations reported in this paper primarily cover the effects of asulam on the indigenous flora, the decline in ground and surface waters, together with some observations on the associated aquatic fauna.

METHODS AND MATERIALS

(a) Site details

Site	Location	Date sprayed	Method of application	Area sprayed
A	South Middleton moor, Northumberland	21.8.73	Fixed wing aircraft	100 ac
B	Redesdale Experimental Husbandry Farm, Northumberland	31.7.73	Motorized knapsack sprayer	0.5 ac
C	Rippon Tor, Dartmoor, Devonshire	5-8.8.73	Helicopter	40 ac

(b) Materials

The commercial formulation 'Asulox', containing 40% w/v asulam as the sodium salt was used at all sites. A dose of 4 lb asulam (8 pints of commercial formulation) per acre was applied, with a lower rate of 3 lb also included at Site B. The treatments were applied in 4 gallons of water per acre (Sites A and C) and 12 gallons per acre at Site B.

(c) Assessments

Site A Levels of asulam in surface water were monitored at three locations. Sampling point 1 was at the junction of two streams, both flowing through the sprayed area, point 2 was approximately 300 yards downstream where a further stream, bordering the sprayed area, joined the original, and sampling point 3 was three quarters of a mile further downstream.

In mid-June 1974 duplicate samples of mud, gravel, scrapings from under rocks within the streams, and moss samples at the edge of the streams were taken from each of the above water sampling areas. Where necessary, the fauna were preserved in a suitable fixative before returning to the laboratory for identification.

Site B Levels of asulam in surface water were monitored in a small stream bordering the lower slope of the area sprayed with 4 lb asulam. Levels in ground water were determined by sampling from specially dug sumps, in a natural hollow within the plot sprayed with 4 lb asulam.

Similar samplings of aquatic fauna were carried out, at intervals along the stream, as for Site A. At this site, observations on the effect of the spray on the flora are being taken by the Nature Conservancy Council.

Site C The site was surveyed before spraying and observations on the reaction of the flora were taken at three weeks, two months and twelve months after spraying. No monitoring of the levels of asulam in water was undertaken at this site.

(d) Analysis of water samples Analysis of asulam in water was by a colorimetric method sensitive to 0.05 ppm. The water samples were filtered to remove suspended matter, acidified, and any asulam present was diazotised and coupled with N-1-naphthylethylenediamine to obtain a coloured derivative suitable for quantitative estimation.

RESULTS

(a) Water studies

The results of the analyses of the water samples from Sites A and B are shown in Table I. Rainfall records, from Redesdale Experimental Husbandry Farm (approximately 1½ miles from Site B), were obtained and are included in the table.

Table 1

Asulam in water samples

Time after treatment	Asulam concentration (ppm) Site A Location 1	Site A Location 2	Site A Location 3	Site B Stream	Site B Sump	Rainfall (mm) since previous sampling
1 hr	0.50	0.36	0.22	<0.05	<0.05	
6 hrs	-	-	-	<0.05	<0.05	
27 hrs	-	-	-	<0.05	0.09	0.4
41 hrs	-	-	-	<0.05	0.08	1.7
72 hrs	<0.05	<0.05	<0.05	<0.05	0.23	7.1
1 week	<0.05	<0.05	<0.05	<0.05	0.10	37.1
2 weeks	<0.05	<0.05	<0.05	<0.05	<0.05	23.5
4 weeks	<0.05	<0.05	<0.05	<0.05	<0.05	9.8
16 weeks	<0.05	<0.05	<0.05	<0.05	<0.05	118.5
26 weeks	<0.05	<0.05	<0.05	<0.05	<0.05	196.5
39 weeks	<0.05	<0.05	<0.05	<0.05	<0.05	187.9
52 weeks	<0.05	<0.05	<0.05	<0.05	<0.05	111.9

The highest concentration of asulam in surface water was 0.50 ppm which, as expected, was found at the junction of two streams both flowing through the sprayed area in site A. This site was sprayed by fixed wing aircraft and the asulam detected in the water is almost entirely due to adventitious spray contamination. At Site B there was only a short 40 yard stretch of water adjacent to the sprayed area and the very small amount of drift was insufficient to produce detectable levels of asulam in the surface water. Concentrations in the ground water at this site rose briefly to a maximum of 0.23 ppm, but were below the level of detection by the second week after spraying.

A list of the aquatic fauna found at both sites is given in Table 2. Although the streams in the two areas were similar in size there were significant differences in their nature, which accounts for the differences in the range of species encountered. The streams in Site A had patches of fine gravel, silt and mud at intervals, which provided a wide range of habitats for aquatic life. In contrast, the stream at Site B has only coarse gravel and no silt or mud. Neither area had any significant amount of aquatic plants.

(b) Plant studies

The reaction of the major plant species at Rippon Tor (Site C) is shown in Table 3. This site included an area of valley bog with a rich diversity of plant species. It was possible to establish that a corner of this, which included a small pond and its marshy surrounds, was exposed to the spray.

Of the sixty species monitored, over fifty showed no or only very slight reaction to asulam. As was expected, the monocotyledons, and in particular the grasses, were more sensitive than the dicotyledons. Some kill of Agrostis, Holcus and Poa spp. was noted, but re-generation from seed or from unaffected rhizomes was widespread twelve months after spraying.

Of the dicotyledons, Plantago spp. showed the greatest initial reaction, and kill of some plants occurred. There was good re-generation from seed within twelve months. Ulex europaeus and Ulex gallii also showed a fairly severe initial reaction, damage consisting of a yellowing of new growth, the tips of which became brittle and were easily broken off. Die-back was evident twelve months after spraying, mainly to a length of about 3-6", but re-growth was vigorous. Two trees of Betula pubescens showed severe defoliation, at the twelve month assessment, of the parts exposed to the spray. This provides some confirmation of the observations by the Nature Conservancy Council (Robinson, N.A. 1974) that this species is sensitive to asulam. Slight die-back of the tips occurred on some trees of Crataegus monogyna.

The other shrubs and trees showed little or no reaction, and mosses were completely unaffected by direct sprays of asulam.

Table 2

Aquatic fauna found in (or near) streams at Sites A & B

Order		Species	Site A	Site B
Nematoda		Alaimus sp.	-	A,J
		Chromadorid sp.	A,J	-
		Dorylaimus sp.	A,J	-
		Eudorylaimus sp.	A,J	J
		Monhystera spp.	A,J	A,J
		Mononchus sp.	A,J	-
		Plectus sp.	A,J	A,J
		Prismatolaimus spp.	A,J	A,J
Annelida		Enchytraeids (unidentified)	-	J
		Octolasion lacteum	A,J	-
Mollusca		Ancylastrum fluviatile	A	-
Crustacea		Cyclops sp.	-	A,J*
		Gammarus sp.	A,J	A,J
Insecta	Ephemeroptera	Baetis sp.	-	J
		Ecdyonurus sp.	J	J
	Odonata	Pyrrhosoma nymphula	-	A
	Plecoptera	Leuctra sp.	-	J
		Sailis fuliginosa	-	A
	Hemiptera	Orthezia sp.	-	A,J
		Velia caprai	A,J	A,J
	Trichoptera	Glossosoma ap.	-	J
		Leptostomatid sp.	-	J
		Limnephilid sp.	J	-
		Odontocerum albicorne	J	-
	Diptera	Chironomid spp.	J	J
		Pedicia sp.	J	-
		Other unidentified sp.	J	-
	Coleoptera	Agabus bipustulatus	-	A*
		Aleocharinid spp.	-	A
		Anacaena globulus	-	A
		Dyschirius globosus	A	-
		Elmis maugei	A,J	A,J
		Haliplus fluviatilis	A	-
		Helodid sp.	J	-
		Helophorus sp.	A	A*
		Hydraena gracilis	A	-
		Hydroporus sp.	A	A*
		Lesteva heeri	A	A
		Limnebius truncatellus	A,J	A,J
		Limnius tuberculatus	A,J	A,J
		Platambus maculatus	-	A

* Found in ground water sump
A = adult stage
J = juvenile stages (larvae, nymphs, juveniles)

Table 3

Reaction of plant species to direct sprays of 4 lb asulam per acre. Score, on scale 1-5*

Species	Reaction after 3 weeks	2 months	12 months
A SPERMATOPHYTES - Dicotyledons			
Achillea millefolium	1	1	1
Anagallis tenella	1	1	1
Betula pubescens	1	1	3-4
Callitriche stagnalis	1	1	1
Calluna vulgaris	1	1	1
Cirsium arvense	1	1-3	1
Cirsium palustre	3	3	1-2
Cirsium vulgare	2	2	1
Crataegus monogyna	1	1	1-2
Digitalis purpurea	1	1	1-2
Drosera rotundiflora	1	N.S.	1
Erica cinerea	1	1	1
Erica tetralix	1	1	1
Euphrasia anglica	2	N.S.	N.S.
Hypericum elodes	1	2	1
Ilex aquifolium	1	1	1
Leontodon autumnalis	2	1	1
Lonicera periclymenum	N.S.	N.S.	1
Lotus corniculatus	1	N.S.	1
Lotus pedunculatus	1	2	1
Menyanthes trifoliata	1	1	1
Narthecium ossifragum	1	1	1
Pedicularis palustris	1	N.S.	1
Plantago lanceolata	4	4-5	1
Plantago major	4	4-5	1
Potentilla spp.	1	1	1
Ranunculus flammula	3	2	1
Ranunculus omiophyllus	1	1	1
Ranunculus repens	2	1	1
Rubus spp.	1	1	1
Rumex acetosa	2	1	N.S.
Rumex acetosella	2	N.S.	1-2
Salix spp.	2	2	1
Stellaria graminea	1	1	1
Taraxacum officinale	1	1	1
Ulex europaeus	3	2	1-2
Ulex gallii	3	3	2-3
Urtica dioica	1	1	1
Vaccinium myrtillus	1	1	1
Veronica chamaedrys	2	1	1

Cont'd.....

Table 3 (Cont'd.)

Reaction of plant species to direct sprays of 4 lb asulam per acre. Score, on scale 1-5*

Species	Reaction after 3 weeks	2 months	12 months
B SPERMATOPHYTES - Monocotyledons			
Agrostis setacea	2	2	1
Agrostis stolonifera	4	4-5	3
Agrostis tenuis	4	4-5	1-3
Anthoxanthum odoratum	2	1	1
Cynosurus cristatus	2	2	1
Dactylis glomerata	3	2	1-2
Festuca ovina	2	3	1
Glyceria fluitans	4	3	2
Holcus lanatus	4	4-5	1-2
Holcus mollis	4	4-5	1
Juncus acutiflorus	2	1	1
Juncus bufonius	2	N.S.	1
Juncus bulbosus	1	2	1-2
Juncus effusus	1	2	1-2
Lolium perenne	2	1	1
Molinia caerulea	1	1	1
Poa annua	4	5	1
Poa trivialis	4	4	1
Potamogeton polygonifolius	3	4-5	1-2
Scirpus fluitans	1	1	1
Scirpus setaceus	1	N.S.	1
C BRYOPHYTES			
Fontinalis antipyretica	1	1	1
Polytrichum commune	1	1	1
Rhytidiadelphus squarrosus	1	1	1
Sphagnum spp.	1	1	1

* Scoring 1 = no visible reaction
2 = slight discolouration, at twelve months slight check to growth
3 = moderate discolouration, with moderate check to growth at twelve months
4 = severe discolouration or growth check
5 = plants dead
N.S. = not seen

DISCUSSION

The results of this study show that the use of asulam for the control of bracken in upland areas should not give rise to any significant hazard to other plant communities which may accidentally be sprayed. Of over 60 species observed at the Dartmoor site, kill of some plants was confined to six species of grass and two dicotyledons. In almost every case re-generation, by seed or from surviving root fragments, has resulted in little apparent change in the population twelve months after spraying. It must be stressed that the reactions shown in Table 3 are those of plants exposed to the full spray, and many of the most sensitive species were unaffected when shielded by the bracken canopy. It is particularly gratifying to note that a large range of marsh and aquatic plants were unharmed, since these will not be protected by bracken, which does not colonise wet ground.

Although the initial reaction of some species appears to have been more severe than has been reported by the Nature Conservancy Council (Robinson 1974), the lack of effect at twelve months is in good agreement with their findings. There was far less initial reaction, particularly of grass species, at Sites A and B. The spraying on Dartmoor was carried out after a period of dry hot weather, whereas conditions were less severe at the Northumberland sites, and this could account for the differences observed.

No asulam (<0.05 ppm) was found in any flowing waters apart from initial adventitious contamination during aerial spraying ($\ngtr 0.5$ ppm). Some asulam ($\ngtr 0.25$ ppm) appeared briefly in the ground water in the sump at Site B, but this had all disappeared within two weeks.

The highest concentration of 0.5 ppm was many thousand times lower than the LC50 levels of 5,500 ppm for rainbow trout, 17,000 ppm for the freshwater shrimp and more than 31,600 ppm for Chironomid larvae and Tubificid worms (May & Baker 1974). The safety to the aquatic environment was confirmed by the wide variety of fauna found in the streams at Sites A and B in the year following spraying.

Since it is improbable that spraying will need to be repeated for at least 3 or 4 years, asulam is unlikely to have any significant effect, apart from the removal of bracken, on upland plant communities or aquatic life.

Acknowledgements

Thanks are due to Dr. D.C. Twinn and his colleagues in the Entomology Department on Ongar Research Station for their assistance in the collection and identification of the many species listed in Table 2.

The co-operation and help of Mr. J.P. Wray in providing the facilities for the experiment at the Redesdale Experimental Husbandry Farm is gratefully acknowledged.

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CHEMICAL CONTROL OF ALOPECURUS MYOSUROIDES IN WINTER WHEAT

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Summary A number of herbicides were compared at a total of eighteen centres in the harvest years 1973 and 1974. The use of materials giving good control of blackgrass resulted in considerable yield increases in the winter wheat particularly where dense infestations of the weed were present. Chlortoluron and iso-proturon proved particularly effective especially when used in the autumn. Because of dry soil conditions on some sites in both seasons there was a tendency for early post-emergence applications of these materials to be more effective than applications applied pre-emergence. Iso-proturon proved markedly more effective than other post-emergence treatments in the dry spring of 1974.

INTRODUCTION

There have been a large number of herbicides introduced in recent years and the ADAS Agronomy Department in Cambridge has continued to examine them under a range of field conditions to obtain information for use in advisory work.

Previous reports, North and Livingston (1970) Baldwin and Livingston (1972), have given comparative data on many of these herbicides and in 1973 treatments were confined to the more promising herbicides. By the following season the problem of lack of tolerance by some of the more popular wheat varieties to chlortoluron and metoxuron was thought to justify a re-examination of the full range of available herbicides. Tri-allate was dropped from the treatments because of difficulties of using this material on a small plot scale in such a way that realistic results could be obtained.

METHOD AND MATERIALS

Ten experiments were completed in 1973 and eight in 1974. All the experiments were superimposed on commercial crops where naturally occurring infestations of A. myosuroides were expected.

The herbicides used are listed in Table 1 below. Site details, treatment application dates, stage of growth of the winter wheat and A. myosuroides are given in Tables 2 and 3.

Plot size was 30 ft x 9 ft and all treatments were applied using a modified van der Weij sprayer with size 00 fan jets at a pressure of 32 lb/sq in. Application rate was 20 gal/ac. A randomised block design was used with three replications.

Treatment effects were assessed by removing all the A. myosuroides plants in a number of quadrats from each plot in late May/June. The total length of seed heads was then measured to give some indication of seed return. Crop yields were measured by a sample harvest technique in the remainder of the plot.

The density of the original weed population was measured by counting plants at various times.

The assessment of length of seed head gives a measure of seed return. In relation to degree of infestation more than 30 m/m^2 is considered heavy, 10-30 m/m^2 moderate and less than 10 m/m^2 as light infestation. In most circumstances with reasonable crop competition 10 m/m^2 relates to a spring plant population of about 50 m^2, a level at which an economic response to herbicide application is likely. These figures are average and will vary with degree and vigour of tillering which in turn is affected by crop density and vigour.

Table 1

Treatments

		lb/ac a.i.	Year applied Treatment number used in subsequent tables ( )	
Tri-allate emulsion	pre emergence	1.5	1973(1)	
Tri-allate granules	pre emergence	1.5	1973(2)	
Trietazine + linuron	"	1.0 + 1.5	1973(3)	
Chlortoluron	pre emergence	3.2	1973(4)	1974(1)
Chlortoluron	very early post emergence	2.8		1974(6)
Chlortoluron	early post emergence	2.8	1973(5)	1974(9)
Chlortoluron	post emergence	2.4	1973(6)	1974(11)
Iso-proturon	pre emergence	2.25	1973(10)	1974(2)
Iso-proturon	very early post emergence	1.9		1974(7)
Iso-proturon	early post emergence	1.9		1974(10)
Iso-proturon	post emergence	1.0	1973(11)	1974(12)
Barban	post emergence	0.3	1973(7)	
Terbutryne	pre emergence	2.5		1974(3)
Trifluralin/linuron	pre emergence	1.20/0.60		1974(4)
WL 29226	pre emergence	0.36		1974(5)
Methabenzthiazuron	very early post emergence	2.8		1974(8)
Metoxuron	post emergence	3.6 1973 (9) 4.0 1974 (13)		
Metoxuron/Simazine	post emergence	3.0/0.19 1973 (8) 3.63/0.23 1974(14)		
Chlortoluron/Metoxuron	post emergence	1.2/1.8	1973(12)	
Cyanazine	post emergence	1.66		1974(15)

Table 2 - Site details

1973										
Site	1	2	3	4	5	6	7	8	9	10
Soil texture	SL	SCL	Pty.L	Org.ZL	CL	FSL	SL	ZyCL	ZyL	ZyL
Variety	Maris Ranger	Cappelle	Cappelle	Cappelle	Maris Ranger	Maris Huntsman	Maris Nimrod	Cappelle	Cama	Bouquet
Date drilled	7.10.72	20.10.72	23.10.72	23.10.72	20.10.72	31.10.72	2.11.72	9.11.72	18.11.72	25.11.72
Seedbed at first spray	Dry Cloddy	Dry very cloddy	Dry good	Dry, hard cloddy	Good	Good	Dry, fine dusty	Sticky cloddy	Fine sticky	Dry cloddy
Treatment dates										
1 2 3 4 & 10 (pre-em)	18/10	25/10	24/10	24/10	26/10	1/11	6/11	17/11	20/11	30/11
5	14/11	11/12	18/12	18/12	29/12	22/12	22/12	28/12	28/12	29/12
6 8 & 9	20/2	20/2	7/3	7/3	27/2	9/3	9/3	12/3	13/3	13/3
7	14/11	11/12	8/1	8/1	8/1	10/1	10/1	9/1	9/1	11/1
11 & 12	16/3	16/3	7/3	7/3	27/2	9/3	9/3	12/3	13/3	13/3
Growth stage of crop	Early Post-em treatments									
	14/11 1½-2 lf	11/12 2 leaf	18/12 60% 2 lf	18/12 80% 2 lf	29/12 1½ lf	22/12 1½ lf	22/12 1 lf	28/12 1 lf	28/12 1 lf	29/12 1 lf
	Post-em treatments									
	20/2 3½ lf	20/2 3 lf	8/1 2 lf	8/1 2-2½ lf	8/1 2 lf	10/1 2 lf	10/1 2 lf	9/1 1½ lf	9/1 1¼ lf	11/1 1 lf
	Spring treatments									
	16/3 4½ - tiller	16/3 GS 4	7/3 3½ lf	7/3 tiller GS 3	27/2 3-4 lf 21/3 GS 3	9/3 GS3	9/3 GS3	12/3 4 lf	13/3 4½ lf	13/3 4½ lf
Growth stage of *A. myosuroides*	Early Post-em treatments									
	14/11 1-2 lf	11/12 up to 2 lf	18/12 1 lf	18/12 1-2 lf	29/12 1 lf	22/12 1 lf	22/12 1 lf	28/12 1 lf	28/12 1 lf	29/12 1 lf
	Post-em treatments									
	20/2 4 lf	20/2 3½ lf	8/1 1½ lf	8/1 1-2 lf	8/1 1 lf	10/1 1½ lf	10/1 1½ lf	9/1 1 lf	9/1 1 lf	11/1 1 lf
	Spring treatments									
	16/3 Tillered	16/3 Tillered	7/3 Tillered	7/3 7½ lf	27/2 3 lf tillered 21/3 tillered	9/3 tiller (5 lf)	9/3 tiller (5 lf)	12/3 3½ lf	13/3 3½ lf	13/3 3½ lf

lf = Leaf
GS = Feekes-large growth stage

Table 3 - Site details

1974								
Site	1	2	3	4	5	6	7	8
Soil texture	CL	ZyCL	CL	CL	ZyCL	SCL	CL	SCL
Variety	Joss Cambier	Cappelle	Maris Ranger	Bouquet	Joss Cambier	Cappelle	Bouquet	Maris Ranger
Date drilled	6.10.73	6.10.73	15.10.73	29.10.73	29.10.73	30.10.73	29.10.73	23.11.73
Seedbed at first spray	Good tilth moist	Sl. Cloddy dry	Cloddy dry	Good tilth moist	Good tilth dry	Variable wet	Good tilth moist	Cloddy moist
Dates of application								
Treatment dates								
1 2 3 4 & 5 (pre-em)	11/10	12/10	18/10	6/11	31/10	7/11	1/11	28/11
6 7 & 8	8/11	9/11	15/11	21/11	23/11	6/12	4/12	21/1
9 & 10	10/12	11/12	17/12	19/12	18/12	23/1	3/1	11/4
11 12 13 14 & 15	20/2	26/2	4/3	14/3	21/2	27/3	6/3	21/3
Growth stage of crop	Early Post-em treatments							
	8/11 1½ lf	9/11 1½ lf	15/11 1¼ lf	21/11 1 lf	23/11 1 lf	6/12 1 lf	4/12 1 lf	21/1 1 lf
	Post-em treatments							
lf = Leaf GS = Feekes large growth stage	10/12 3 lf	11/12 2½ lf	17/12 2¼ lf	19/12 1¼ lf	18/12 1¼ lf	23/1 2¼ lf	3/1 2 lf	21/3 GS 2-3
	Spring treatments							
	20/2 GS 3	26/2 GS2-3	4/3 6 tiller	14/3 2 tiller	21/2 1-2 tiller	27/3 2 tiller	6/3 6½ lf	11/4 GS 5
Growth stage of *A. myosuroides*	Early Post-em treatments							
	8/11 1½ lf	9/11 1 lf	15/11 1 lf	21/11 1 lf	23/11 few B/G	6/12 1 lf	4/12 none	21/1 1 lf
	Post-em treatments							
	10/12 2¼ lf	11/12 2 lf	17/12 2 lf	19/12 1 lf	18/12 1 lf	23/1 2 lf	3/1 1 lf	21/3 2 lf tiller
	Spring treatments							
	20/2 up to 10 tiller	26/2 3 lf-7 tiller	4/3 3 tiller	14/3 3 tiller	21/2 2 lf to 8 tiller	27/3 up to 6 tiller	6/3 up to 4 tiller	11/4 tillered

Table 4

1973 *A. myosuroides* control

(Total length of flowering heads in m/m^2)

Treatment	Site 1	2	3	4	5	6	7	8	9	10	Mean % control
Control	143.3	28.7	7.5	42.6	165.9	31.1	24.8	3.1	6.2	15.0	0
1. Tri-allate emulsion	164.7	17.8	4.8	45.0	112.3	11.7	5.9	0.4	7.7	6.0	20
2. Tri-allate granules	108.7	13.8	5.1	21.1	65.7	7.9	10.6	0.2	4.2	8.2	48
3. Trietazine + linuron	153.8	4.6	2.6	24.4	62.7	13.3	1.5	0.4	2.2	1.8	43
4. Chlortoluron	40.5	0.3	0.2	0.8	10.7	0.0	7.5	0.2	1.4	0.2	87
5. Chlortoluron	10.5	1.4	0.7	0.8	3.7	1.6	0.0	0.1	0.4	0.0	96
6. Chlortoluron	39.2	5.8	3.0	22.8	31.5	3.4	0.0	0.8	1.4	1.1	77
7. Barban	78.8	7.8	1.6	18.2	98.4	4.5	5.5	0.3	1.1	9.5	52
8. Metoxuron + simazine	47.1	4.3	1.6	8.7	20.7	3.5	0.0	0.2	1.5	2.3	81
9. Metoxuron	36.4	6.5	0.6	9.3	33.5	3.4	0.0	0.7	0.1	1.8	80
10. Iso-proturon	51.0	0.9	0.2	0.3	24.8	6.0	2.8	0.1	0.3	0.0	82
11. Iso-proturon	30.5	5.7	1.4	6.5	24.5	1.0	0.0	1.0	1.2	0.0	85
12. Chlortoluron/metoxuron	59.8	12.3	0.8	7.6	30.6	5.8	0.0	1.2	0.6	0.5	75
SE diff for herbicide comparisons	±37.53	±8.33	±1.70	±11.60	±17.81	±6.81	±4.80	±0.66	±3.35	±5.93	

Table 5

1974

Treatment	Site 1*	2	3	4	5*	6	7*	8	Mean % control
Control	58.7	4.0	13.0	2.4	31.7	43.7	1.3	2.4	0
1. Chlortoluron	4.4	1.9	0.7	0	0.4	0	0	0	95
2. Iso-proturon	4.4	0.8	1.0	0	0	1.1	0	0	95
3. Terbutryne	48.7	0.9	2.0	0.1	3.7	4.4	0	0.1	62
4. Trifluralin/linuron	33.3	2.4	2.9	0.2	4.5	6.3	0	0.3	68
5. WL29226	26.9	0.9	1.4	0.1	1.9	3.2	0	0	78
6. Chlortoluron	1.8	0.4	0.2	0	0.2	2.3	0	0	97
7. Iso-proturon	0.1	0.1	0.2	0	0.2	2.2	0	0	98
8. Methabenzthiazuron	16.4	1.2	2.1	0.2	1.6	16.6	0	0.2	76
9. Chlortoluron	4.6	0.4	0.5	0	0.4	3.8	0	0.8	93
10. Iso-proturon	0.6	0.4	0.1	0	0	1.1	0	0.5	98
11. Chlortoluron	24.8	1.2	5.1	0.7	3.0	14.6	0.4	1.1	68
12. Iso-proturon	10.2	0.9	1.9	0.5	0.3	6.30	0	0.7	87
13. Metoxuron	37.0	2.5	3.2	0.6	18.5	7.6	0.4	1.3	55
14. Metoxuron/simazine	54.6	3.2	2.8	0.7	7.5	30.3	0.1	1.5	36
15. Cyanazine	31.3	3.4	7.3	1.6	10.0	44.4	0.5	1.9	36
Avena spp - dry wt of panicles gm/m^2	58.7	-	-	-	10.4	-	31.2	-	-

*Sites 1, 5 and 7 contained considerable numbers of *Avena* spp

Table 6 - Grain yield cwt/ac 85% D.M.

1973

Treatment	Site 1	2	3	4	5	6	7	8	9	10	Mean	%
Control	6.2	20.5	35.5	8.6	27.1	33.9	37.5	32.8	25.3	41.6	26.9	100
1. Tri-allate emulsion	12.3	25.2	33.6	18.4	39.9	37.3	44.3	29.9	25.1	41.9	30.8	114
2. Tri-allate granules	18.1	26.9	40.3	19.0	38.8	38.9	44.2	34.4	23.6	47.1	33.1	123
3. Trietazine + linuron	17.0	20.2	35.4	8.4	31.9	35.2	45.6	36.5	22.0	46.5	29.9	111
4. Chlortoluron	29.5	34.1	33.4	24.4	49.0	38.2	43.4	30.4	28.5	42.6	35.4	132
5. Chlortoluron	27.3	34.8	36.2	21.6	53.9	42.9	44.1	34.0	26.6	44.1	36.6	136
6. Chlortoluron	22.9	33.6	32.5	21.6	38.6	34.5	32.8	34.3	32.5	44.9	32.8	122
7. Barban	21.9	17.7	37.8	31.3	31.3	33.9	42.8	32.5	28.3	42.3	32.0	119
8. Metoxuron + simazine	21.5	31.9	36.7	23.2	46.3	43.2	34.6	37.9	27.0	41.2	34.4	128
9. Metoxuron	26.1	25.8	34.1	25.9	41.4	43.7	37.5	33.4	28.2	43.9	34.0	126
10. Iso-proturon	29.9	34.1	36.4	31.5	39.9	36.3	40.9	34.8	31.3	41.4	35.7	133
11. Iso-proturon	25.6	23.0	37.3	23.5	39.9	35.7	42.0	37.0	27.0	48.1	33.9	126
12. Chlortoluron/metoxuron	23.1	30.9	32.3	28.9	39.0	39.8	39.2	31.3	25.4	42.3	33.2	123
SE diff for herbicide comparisons	±2.16	±4.40	±4.44	±3.29	±5.00	±4.36	±2.91	±3.40	±3.73	±3.00	±1.19	±4.42

Table 7 - Grain yield cwt/ac 85% D.M.

1973/1974

Treatment	Site 1*	2	3	4	5*	8	Mean	%
Control	28.9	57.4	48.4	55.3	45.2	57.7	48.8	100
1. Chlortoluron	50.1	59.6	52.1	53.5	54.4	63.0	55.5	114
2. Iso-proturon	56.4	57.9	57.4	59.0	49.5	57.3	56.2	115
3. Terbutryne	28.4	56.7	51.3	55.3	57.4	63.1	52.0	107
4. Trifluralin/linuron	37.2	60.0	57.3	54.5	55.3	57.5	53.6	110
5. WL29226	25.4	60.8	55.6	56.4	49.8	59.5	51.3	105
6. Chlortoluron	61.2	60.6	58.3	52.1	58.8	54.3	57.5	118
7. Iso-proturon	60.6	61.2	57.1	59.4	55.4	65.2	59.8	123
8. Methabenzthiazuron	42.7	59.8	52.6	59.6	57.2	64.0	56.0	115
9. Chlortoluron	64.1	58.6	56.5	56.4	58.1	59.9	59.0	121
10. Iso-proturon	60.9	56.8	55.4	57.7	47.2	52.7	55.1	113
11. Chlortoluron	37.2	62.1	51.8	55.4	50.2	63.1	53.3	109
12. Iso-proturon	50.0	63.4	53.1	53.8	56.6	58.9	56.0	115
13. Metoxuron	32.6	60.2	53.9	57.6	56.8	58.0	53.2	109
14. Metoxuron/simazine	44.9	57.0	54.1	50.9	52.5	57.6	52.8	108
15. Cyanazine	34.2	58.4	52.5	51.0	52.6	55.8	50.7	104

*Sites 1, 5 and 7 contained considerable numbers of *Avena spp*

Sites 6 and 7 not harvested

DISCUSSION

There is some variation in the performance of herbicides for A. myosuroides control both as regards level of control and resultant yield response. This is inevitable because of the varying levels of infestation, variations in site conditions, timing of application and the differing margins of selectivity or activity of the chemicals. Nevertheless the large spread of trials do give reasonably consistent results on which to base advice on choice of herbicide in Eastern Region.

On the heavy soils of East Anglia A. myosuroides very often occurs in association with Avena spp. which clearly creates problems of competition interactions when some herbicides are used. Although Avena spp. are not so competitive as A. myosuroides the removal of one enhances the competitive effect of the other. For example at Site I chlortoluron, iso-proturon, metoxuron and tri-allate all of which show some considerable activity against Avena spp., gave considerably greater yield responses compared with methabenzthiazuron even though A. myosuroides control was reasonable with the latter herbicide. A herbicide weed spectrum which includes both A. myosuroides and Avena spp. is clearly an advantage on many soils in East Anglia.

The spread of sites included some varieties which are reported not to be tolerant of chlortoluron and metoxuron. In the 1973 series these varieties were severely scorched and thinned by all timings of chlortoluron and metoxuron but the weed control and subsequent recovery and compensatory growth was such that yields from the pre-emergence and early post-emergence treatments were better than any other treatment. In the 1974 series varieties showed far more tolerance to chlortoluron and metoxuron. In both series there was no evidence of varietal susceptibility to iso-proturon.

Timing of application of chlortoluron and iso-proturon has been a main feature of both series of trials. In both years pre-emergence and early post-emergence application of both chemicals gave excellent weed control which was reflected in high yield responses. The spring applications of chlortoluron, whilst giving a moderate weed control, were not nearly so effective as spring application of iso-proturon. This coupled with apparent varietal tolerance illustrates the flexibility of iso-proturon.

The weed control achieved with metoxuron and metoxuron/simazine in the 1973 series was in keeping with previous experiences (Baldwin and Livingston 1972, North and Livingston 1970) but in the 1974 series weed control with these chemicals was disappointing. This was probably due to the unprecedented advanced stage of growth of A. myosuroides at the time of application.

With all chemicals there was a close association between degree of weed control and yield response. Even at moderate levels of weed control such as with tri-allate in the 1973 series and metoxuron in the 1974 series yield response was economic.

Acknowledgements

The authors wish to thank especially the farmers who provided the experimental sites, ADAS colleagues who assisted and Rothamsted Experimental Section for the statistical analysis in the 1973 series. In addition we would like to thank those who provided the experimental materials.

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NOTES

ISOPROTURON, A NEW SELECTIVE HERBICIDE FOR CONTROL OF ALOPECURUS MYOSUROIDES IN WINTER CEREALS

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Summary Isoproturon, N-4-isopropylphenyl-N',N'-dimethylurea, is a new selective herbicide for the control of *Alopecurus myosuroides* in winter cereals. In seventy field trials carried out in the U.K. during 1972 - 1974, over 90% control of *A. myosuroides* was obtained at rates of 2.3 lb/ac a.i. pre-emergence, and 1.9 lb/ac a.i. post-emergence up to the early-tillering stage. Applications made in the autumn or winter, however, were generally the most effective both in terms of weed control and increase in crop yield. A useful control of *Avena* spp., other annual grasses and many broad-leaved weeds was also obtained, but *Galium aparine*, *Lamium* spp., *Veronica hederifolia* and *Viola arvensis* were resistant. Isoproturon was found to be safe on all varieties of winter wheat and winter barley tested, even at double the commercial rates of application.

Résumé Isoproturon, N-4-isopropylphenyl-N',N'-dimethylurée, est un nouvel herbicide séléctif pour la destruction de l'*Alopecurus myosuroides* dans les céréales d'hiver. Un contrôle de plus de 90% a été obtenu dans les 70 essais réalisés entre 1972 et 1974 en Grande Bretagne. Le produit a été utilisé à 2.3 lb/ac m.a. en pré-émergence et 1.9 lb/ac m.a. en post-émergence jusqu'au début du tallage. Toutefois les traitements exécutés en automne ou bien en hiver ont été en général les plus efficaces, non seulement à l'égard de l'activité herbicide mais aussi à l'égard de l'augmentation du rendement. Un contrôle satisfaisant a été obtenu également contre *Avena* spp., d'autres graminées annuelles et un grand nombre de dicotylédones sauf *Galium aparine*, *Lamium* spp., *Veronica hederifolia* et *Viola arvensis* qui se montraient résistants. L'application de l'Isoproturon n'a pas causé de dégâts aux varietées testées, même à double dose.

INTRODUCTION

Isoproturon is the common name for N-4-isopropylphenyl-N',N'-dimethylurea, which is formulated by Hoechst AG as a wettable powder containing 75% a.i. The code number during development was Hoe 16410, and the trade name is 'Arelon' (formerly 'Alon').

The chemical structure, physical and toxicological properties have been described by Rognon *et al* (1972) and Thizy *et al* (1972), who also reported selective control of *Alopecurus agrestis* (= *A. myosuroides*), other annual grasses, and some broad-leaved weeds pre- and post-emergence in wheat.

Although a number of materials for A. myosuroides control are commercially available, some are not selective on certain of the newer, high-yielding winter wheat varieties (eg. Maris Huntsman, M. Nimrod and M. Templar). In view of their popularity there is a need for an effective material which can safely be applied pre- and post-emergence to these and other varieties.

In glasshouse studies with isoproturon, varietal susceptibility was not evident while excellent control of a number of annual-grass and broad-leaved weeds was obtained. The object of the work described in this paper was therefore to confirm the weed susceptibility and crop selectivity under field conditions in the U.K.

METHOD AND MATERIALS

A total of seventy small plot trials was carried out over the period 1972 - 74. Fifty of these (twenty pre- and thirty post-emergence) were replicated trials in which isoproturon was applied at five rates on a range of commercially grown winter wheat and winter barley varieties in areas of the country where A. myosuroides is a serious problem. Soil types were generally clay or sandy-clay loams, with medium organic-matter content.

Fourteen replicated trials involved separate applications of isoproturon at different times within each site. This enabled a comparison of crop selectivity and weed susceptibility to be made at different stages of growth. In two of these trials, four rates of isoproturon were applied at each of eight successive crop stages from immediately post-drilling to late tillering, while in the other twelve, three separate applications (pre-emergence in autumn, post-emergence in winter and spring) were made with normal and double rates.

In the above trials, chlortoluron (80% w.p.) was included pre- and post-emergence, and metoxuron (80% w.p.) post-emergence only; there was also an untreated control. Plot size was 2.5 by 6 yards, and the plots were arranged in a randomised block design with three replicates. All applications were made with a Van der Weij 'AZO' sprayer at a pressure of 40 lb/in^2 using fan jets delivering 40 gal/ac.

Six unreplicated variety trials were also carried out to study the effect of the chemical on a range of winter cereal varieties under identical soil and weather conditions. Normal and double rates of isoproturon were sprayed across strips of different varieties pre- and post-emergence and, in all, fifty individual winter wheats and fourteen winter barleys were treated.

Pre-emergence treatments were generally made during the week after drilling, which occurred between the second weeks of October and November. Winter applications were made in mid December at the 1 - 3-leaf stage of both the crop and A. myosuroides, while spring treatments were applied between the last week of February and first week of April. At this time both crop and grass-weeds had 3 leaves to 2 - 3 tillers, and the broad-leaved weeds were mostly at the young-plant stage.

Crop vigour was assessed at intervals during the season by scores on a 1 - 9 scale. Counts of annual-grass and broad-leaved weeds were made in April, A. myosuroides seed heads in June and Avena spp. panicles in July. Crop yields were measured by a sample harvest technique. The data were analysed using a multiple range test (Duncan, 1955). Comparisons are in the vertical columns only, where values with the same letter(s) are not significantly different at P = 0.05.

RESULTS

Control of A. myosuroides

The mean results obtained in each series of trials are given in Tables 1 and 2 for pre- and post-emergence treatments respectively. At rates of 2.3 lb/ac a.i. pre- and 1.9 lb/ac a.i. post-emergence isoproturon gave excellent control which was equivalent to that obtained with the standard materials and there was little advantage in increasing the rates above these values.

Table 1

Percentage control of A. myosuroides plants and seed heads from pre-emergence applications

Compound	lb/ac a.i.	Autumn 1972 (16 trials) plants	Autumn 1972 (16 trials) seed heads	Autumn 1973 (10 trials) plants	Autumn 1973 (10 trials) seed heads
Isoproturon	1.5	73 a	90 a	-	-
"	2.3	87 ab	95 a	94 a	96 a
"	2.7	89 ab	96 a	-	-
"	3.0	91 ab	98 a	-	-
"	4.5	95 b	99 a	98 a	99 a
Chlortoluron	3.2	86 ab	96 a	93 a	96 a
Range of A. myosuroides/ft^2 on control plots		0.6 - 110	0.8 - 200	2.0 - 34	0.9 - 56
(Mean)		(27)	(33)	(8.2)	(15)

Table 2

Percentage control of A. myosuroides seed heads from post-emergence applications

Compound	lb/ac a.i.	Spring 1972 (7 trials)	Spring 1973 (19 trials)	Winter 1973 (10 trials)	Spring 1974 (10 trials)
Isoproturon	1.5	90 a	90 ab	-	-
"	1.9	-	94 ab	97 a	91 a
"	2.3	96 a	96 ab	-	-
"	3.8	-	99 a	99 a	98 a
Chlortoluron	2.4	85 a	89 ab	-	78 b
"	2.8	-	-	94 a	-
Metoxuron	3.8	-	84 b	-	85 ab
Range of A. myosuroides/ft^2 on control plots		0.3 - 16	0.7 - 200	0.9 - 56	0.9 - 56
(Mean)		(7.7)	(29)	(15)	(15)

Control of Avena spp. and other annual grasses

In some of the trials a mixed population of grass weeds occurred. Isoproturon generally gave good control of Avena spp. when applied pre-emergence or post-emergence in winter (Avena spp. emergence to 1-leaf stage) or spring (2 - 3 leaves) (Table 3). Pre- and post-emergence applications of isoproturon also gave complete kill of Lolium spp., Poa annua and P. trivialis.

Table 3

Percentage control of Avena spp. panicles

Compound	lb/ac a.i.	Pre-emergence Autumn 1972 (8 trials)	Pre-emergence Autumn 1973 (5 trials)	Post-emergence Spring 1973 (10 trials)	Post-emergence Winter 1973 (5 trials)	Post-emergence Spring 1974 (5 trials)
Isoproturon	1.5	65 b	-	78 ab	-	-
"	1.9	-	-	82 ab	81 a	68 ab
"	2.3	74 ab	85 a	87 ab	-	-
"	3.0	83 ab	-	-	-	-
"	3.8	-	-	92 a	89 a	79 b
"	4.5	91 a	94 a	-	-	-
Chlortoluron	2.4	-	-	69 b	-	59 a
"	2.8	-	-	-	75 a	-
"	3.2	79 ab	78 a	-	-	-
Metoxuron	3.8	-	-	70 b	-	67 ab
Range of Avena spp./ft^2 on control plots		0.2 - 31	0.1 - 4.0	0.2 - 30	0.1 - 4.0	0.1 - 4.0
(Mean)		(10.5)	(1.1)	(9.7)	(1.1)	(1.1)

Control of broad-leaved weeds

Information on the susceptibility of a number of broad-leaved weeds was obtained from some of the trials, and the data are summarised in Table 4. For clarity, only results obtained with normal and double commercial rates of isoproturon are included.

Although Galium aparine, Lamium spp., Veronica hederifolia and Viola arvensis were resistant, and control of Myosotis arvensis and Veronica persica was variable, only G. aparine was a problem at harvest.

Time of application

In the two trials in which separate applications of isoproturon were made at eight different times, good control of A. myosuroides was obtained up to late tillering, although pre- or early post-emergence treatments were the most effective (Table 5). It is interesting to note that there was no visible crop damage on either variety (Maris Ranger, M. Otter) with isoproturon at any rate or time of application. With both varieties however, chlortoluron caused slight damage when applied at the 1- or 2-leaf stage.

In later trials where spraying at the same site was done on three separate occasions, applications in autumn and winter 1973 were more effective than those made in the following spring (see Tables 1 and 2).

Table 4

Percentage control of broad-leaved weeds

Species	No. of Sites	Pre-emergence (lb/ac a.i.) Iso-proturon 2.3	Pre-emergence Iso-proturon 4.5	Pre-emergence Chlor-toluron 3.2	No. of Sites	Post-emergence (lb/ac a.i.) Iso-proturon 1.9	Post-emergence Iso-proturon 3.8	Post-emergence Chlor-toluron 2.4	Post-emergence Met-oxuron 3.8
Aphanes arvensis	3	93	98	99	3	92	98	95	100
Capsella bursa-pastoris	-	-	-	-	1	84	90	-	-
Galium aparine	2	0	0	0	2	5	12	7	46
Lamium spp.	1	0	0	0	1	0	0	0	11
Myosotis arvensis	1	44	100	95	2	82	76	92	92
Papaver rhoeas	1	100	100	100	1	100	100	100	100
Senecio vulgaris	-	-	-	-	1	95	99	-	-
Sinapis arvensis	2	78	96	87	3	99	99	99	99
Spergula arvensis	1	100	100	100	1	100	100	98	100
Stellaria media	4	82	88	95	6	96	99	92	98
Tripleurospermum Maritimum spp. inodorum	5	98	100	100	5	100	100	91	100
Veronica persica	4	18	37	53	5	25	26	35	76
Veronica hederifolia	4	10	16	7	4	9	8	21	23
Viola arvensis	1	0	7	1	1	0	69	27	93

Varietal tolerance

No crop damage has been observed on the following varieties with double the commercial rates of application pre- or post-emergence (4.5 and 3.8 lb/ac a.i., respectively). The development of some new varieties which were sprayed with isoproturon has subsequently ceased, and these have been omitted.

Winter wheats			Winter barleys
Armentieres	Maris Freeman	Tommy	Astrix
Atou	Maris Fundin	Trio	Athene
Bouquet	Maris Hobbit	Val	Banteng
Cama	Maris Huntsman	West Desprez	Cossack
Cappelle Desprez	Maris Nimrod	FD 2915/253	Hoppel
Chalk	Maris Ranger	MH 24/8/9	Igri
Champlein	Maris Templar	RPB 15/69	Malta
Clement	Maris Widgeon	RPB 36/69	Maris Otter
Derwent	Mega	RPB 145/69	Maris Trojan
Flinor	Pride	RPB 155/69	Mirra
Joss Cambier	Reso	RPB 181/70	Senta
Mantle	Score		Sonja

Table 5

Percentage control of A. myosuroides seed heads with isoproturon applied at different times

Compound	lb/ac a.i.	Date	3.11.72	23.11.72	22.12.72	19.1.73	6.2.73	12.3.73	3.4.73	19.4.73
		Crop Stage	Pre-em.	Pre-em.	1 lf	2 lf	3 lf	1 tiller	3 - 4 tillers	Late tillering
		Weed Stage	Pre-em.	Em.	"	"	"	3 lf - 1 tiller	2 - 3 tillers	Late tillering
Isoproturon	1.5		-	-	-	-	90	86	80	77
"	2.3		97	100	99	96	94	96	91	87
"	2.7		98	100	98	100	97	97	95	90
"	3		100	100	98	100	100	98	99	93
"	4.5		100	100	100	100	-	-	-	-
Chlortoluron	3.2		100	99	100	97	-	-	-	-
"	2.4		-	-	-	-	90	88	84	74

Table 6

Crop yields expressed as a percentage of the untreated control

Compound	lb/ac a.i.	Pre-emergence Autumn 1972 (11 trials)	Pre-emergence Autumn 1973 (8 trials)		Post-emergence Spring 1973 (13 trials)	Post-emergence Winter 1973 (8 trials)		Post-emergence Spring 1974 (8 trials)	
Isoproturon	1.9	-	-	-	131	144	(148)	129	(132)
"	2.3	144	147	(156)	-	-	-	-	-
"	3.8	-	-	-	135	154	(156)	136	(140)
"	4.5	163	152	(156)	-	-	-	-	-
Chlortoluron	2.4	-	-	-	129	-	-	119	(128)
"	2.8	-	-	-	-	122	(135)	-	-
"	3.2	148	128	(138)	-	-	-	-	-
Metoxuron	3.8	-	-	-	121	-	-	121	(129)

The percentages in brackets are the means of five trials only; the data from those on varieties for which chlortoluron and metoxuron are not recommended and where damage occurred (Maris Templar, Mega and Val) having been omitted.

Crop yield

Yield assessments were made in most of the trials, and the results are summarised in Table 6.

DISCUSSION

Effective control of A. myosuroides was obtained with isoproturon either pre- or post-emergence up to early tillering, although applications made early generally produced the best response. Thus, spraying in the autumn or winter gave, on average, a greater weed kill (Tables 1, 2 and 5) and increase in crop yield (Table 6) than did spring treatment. Results with other products (North and Livingston, 1970; Baldwin and Livingston, 1972) have also shown that yield increases from early treatments are higher than from those made late in the spring. In the present trials this appeared to be due to a combination of better weed control and competition between weeds and crop during the winter months, since in some cases where the percentage control of A. myosuroides was identical with autumn and spring applications, yields were less where spraying was delayed until the spring. In agreement with other workers (eg. North and Livingston, 1970), yield increases as a result of spraying were highest in trials where the unweeded controls had high densities of A. myosuroides and thus produced low yields.

Rates of 2.3 lb/ac a.i. pre-emergence and 1.9 lb/ac a.i. post-emergence were found to be necessary to consistently give an average of over 90% control of A. myosuroides. In field trials carried out in the U.K. (Hubbard and Livingston, 1974) results obtained with isoproturon at 2.3 and 1.5 lb/ac a.i. pre- and post-emergence, respectively, were very similar to those achieved with standard materials even though the post-emergence rate was lower than is now commercially recommended (1.9 lb/ac a.i.). Rognon et al (1972) obtained good control of annual-grass weeds with 2 kg/ha a.i. pre- or post-emergence in field trials in France, while Thizy et al (1972) reported a complete kill in glasshouse tests with 1 kg/ha a.i.

Although the seedbeds were good in most trials, 'cloddy' conditions occurred occasionally but did not appear to cause any reduction in the performance of the chemical. There was also no loss of activity on seedbeds with a relatively high organic-matter content, and in one trial reported by Hubbard and Livingston (1974) 97% kill of A. myosuroides was obtained following pre-emergence application of isoproturon to a soil with 15.5% organic-matter content. As with chlortoluron, the persistence of isoproturon following pre-emergence application was sufficient to control annual grasses germinating in early spring.

Control of Avena spp. was more variable than with A. myosuroides, although kill of both species was lower when applications were made in the dry spring of 1974 (Tables 2 and 3). However, the control obtained was equivalent to that obtained with the standard materials. Lower amounts of a.i. of isoproturon than of chlortoluron and metoxuron are needed to achieve comparable control of both Avena spp. and A. myosuroides (Tables 1, 2 and 3), and this is also demonstrated by the post-emergence data of Rognon et al (1972).

The other annual-grass weeds found in the present trials (Lolium spp., P. annua and P. trivialis) were also controlled by isoproturon, and kill of these together with Avena spp. can provide a useful bonus to the A. myosuroides control. Rognon et al (1972) and Thizy et al (1972) also found that Lolium spp., Avena spp. and Agrostis spica venti (= Apera spica-venti) were susceptible, pre- or post-emergence, at 1 - 2 kg/ha a.i.

Many broad-leaved weeds were controlled by autumn or spring applications of isoproturon (Table 4), although some species were more susceptible post-emergence especially at the seedling stage. In addition to the species reported in this paper, Rognon et al (1972) found that Centaurea cyanus and Matricaria recutita (= M. chamomilla) were controlled at 1 - 2 kg/ha a.i. and Polygonum aviculare at 3 kg/ha a.i., and in plot tests (Thizy et al, 1972) Sinapis alba and Chenopodium album were found to be susceptible at 0.5 - 1.0 kg/ha a.i. pre- and post-emergence.

One of the outstanding features of isoproturon is its safety on all varieties of winter cereals currently being commercially grown in the U.K., especially since a number of the newer varieties, which now constitute a significant part of the acreage, cannot be treated with some of the existing products. There was no crop damage with double the rate of isoproturon even when spraying was carried out in mid December at which time some varieties had only one or two leaves. Although there was no 'hard' winter during the three seasons when these trials were conducted, spraying before or after short periods of frost did not affect the crop nor did it appear to influence the level of grass control.

Acknowledgements

I am grateful to the National Institute of Agricultural Botany, R.H.M. Arable Services Ltd. and Twyford Plant Breeders for the variety trials, and to the many farmers who kindly provided trials' sites. I would also like to express my sincere thanks to Dr. B. Sebestyén (Hoechst AG) for the statistical analyses, to H. R. Pinckney and M. R. Redbond for assistance at various times; and to Miss S. M. Tilsley for typing this paper.

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DEVELOPMENT WORK WITH METOXURON FORMULATED AS A MICROGRANULE FOR WEED CONTROL IN WINTER CEREALS

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Summary A microgranular formulation containing 40% metoxuron (normal dosage rate 8-10 kg of product/ha) proved to be encouraging from the biological point of view. Compared with the w.p. formulation, this microgranule was normally equally effective though occasionally slightly less active particularly when the application was made to dry foliage in conjunction with dry soil. In these cases, the crop tolerance was slightly better. Application tests with different equipment proved that this formulation can be applied with sufficient accuracy. The existing equipment though scarce should prove adequate.

Résumé La formulation microgranulée contenant 40% de métoxuron (dose d'application 8-10 kg/ha) a montré une activité biologique très satisfaisante. Son efficacité était généralement comparable à celle de la formulation W.P., sauf lors de quelques applications sur feuillage et sol secs (en même temps) où elle semblait légèrement moins active dans l'état actuel de la technique. En contre partie la sélectivité était dans ces cas sensiblement meilleure. L'épandage de ce microgranulé est réalisable dans la pratique avec suffisamment de précision pour autant qu'un equipement adequat (encore peu répandu) soit utilisé.

INTRODUCTION

The experiments reported in this paper were carried out to compare the efficacy of a microgranule with the wettable powder formulation of a herbicide for winter cereals.

The microgranular formulations show several advantages, the main one being a substantial rationalisation of the application, particularly by eliminating the large quantities of water normally associated with sprays. For metoxuron, which is a foliar and soil acting herbicide, the foliar retention of the microgranules is an interesting property.

In this investigation, emphasis was particularly given to a comparison in greenhouse experiments and field trials of the microgranular formulations with the 80% w.p. formulation of metoxuron (DOSANEX®) which is registered in many countries for the control of grass weeds and broad-leaved weeds in winter cereals.

The problem of application was also partially examined in large scale tests with some of the applicators available at present.

METHOD AND MATERIALS

The development of metoxuron formulated as a microgranule was begun in 1972 with an 80% formulation (metoxuron m.g. 80), then from 1973 on continued with a 40% formulation (metoxuron m.g. 40). Main characteristics of the actual formulation:

Appearance: light brown, fine, spheric granule;
granule size range : 80-200 µ
number of granules per g : 800,000

Normal dosage rate: (equal to the recommended rate of metoxuron w.p.)

metoxuron m.g. 80: 4-5 kg/ha product)
metoxuron m.g. 40: 8-10 kg/ha product) = 3.2 - 4 kg/ha a.i.

The biological performance was partly examined in the greenhouse on 2 plant species, i.e. beans (Phaseolus vulgaris) and blackgrass (Alopecurus myosuroides), and partly in the field on winter wheat against the common annual grasses and broad-leaved weeds.

Application of the microgranules (m.g.) was made in most of the field trials and in all greenhouse trials with a portable pneumatic small plot microgranule applicator.

The large scale application tests were conducted with 3 pneumatic microgranule applicators, and with 2 aerial spreaders. The distribution pattern was assessed by counting the number of microgranules per cm^2 on pieces of red coloured adhesive tape (3.8 cm x 10 cm) placed prior to the applications, across the swath at 1-2 m intervals.

RESULTS

1. Greenhouse experiments The experiments in the greenhouse under relatively controlled conditions indicate that in the field, environmental variables may be more important in governing the activity of the m.g. as compared with the w.p. formulation. The results can explain the somewhat weaker activity of the m.g. compared with the w.p. obtained in the field. The m.g. caused less phytotoxicity to the susceptible wheat varieties and gave slightly less consistent weed control (tables 3, 4 and 5). The application in the greenhouse took place at the 2 leaf stage of the beans and at the 2-3 leaf stage of A. myosuroides.

Table 1 shows that the moisture status of the leaves at the time of application was more important for the beans than for A. myosuroides. Five days after the application, the activity of the w.p. on the beans was practically not affected by leaf moisture, while the m.g. was significantly less active on dry bean plants than on the wet ones.

In the case of A. myosuroides, 14 days after the application, there was very little difference between the application on wet and dry leaves. Five and 14 days after application of the beans and of A. myosuroides, respectively, the w.p. was significantly more active than the m.g. on both dry and wet leaves.

All these differences for the normal and double rate became smaller with time and were no longer significant 20 days after treatment.

Table 2 shows the residues of metoxuron on the leaves immediately after application. It can be seen that the retention of the w.p. was practically not influenced by the moisture of the leaves. In contrast, the retention of the m.g. was much greater on wet leaves than on dry ones; approximately six times greater for A. myosuroides and 10 times greater for beans.

Table 1

Activity differences of metoxuron depending on:

1. formulations
   microgranule (m.g.) wettable powder (w.p.)

2. moisture status of the leaves
   dry - wet

% effectiveness, visually assessed according to a linear percent scale; mean values of 4 replications, pots of 170 cm² surface

	formu-lation	kg/ha a.i.	% effectiveness leaves dry		leaves wet	leaves dry		leaves wet
No. days after treatment			5			20		
Bean	m.g.	2	10 ± 0		10 ± 0	53 ± 6		67 ± 6
		4	17 ± 6	**	27 ± 6	97 ± 6	n.s.	100 ± 0
		8	17 ± 6		40 ± 10	100 ± 0		100 ± 0
			***		***	n.s.		n.s.
	w.p.	2	37 ± 6		37 ± 5.8	97 ± 6		93 ± 6
		4	40 ± 10	n.s.	37 ± 5.8	97 ± 6	n.s.	100 ± 0
		8	60 ± 0		30 ± 0	100 ± 0		100 ± 0
No. days after treatment			14			20		
A. myosuroides	m.g.	2	23 ± 6		30 ± 0	40 ± 21		53 ± 6
		4	63 ± 6	n.s.	67 ± 11.6	90 ± 0	n.s.	90 ± 10
		8	77 ± 6		80 ± 0	100 ± 0		100 ± 0
			*		***	n.s.		n.s.
	w.p.	2	53 ± 6		77 ± 6	63 ± 6		86 ± 10
		4	73 ± 6	n.s.	83 ± 6	90 ± 10	n.s.	93 ± 6
		8	80 ± 0		93 ± 6	100 ± 0		100 ± 0

Statistical analysis: stratified Wilcoxon's Rank Sum Test' over three dosages

*** significant difference $P < 0.01$
** " " $P < 0.02$
* " " $P < 0.05$
n.s. not significant

Table 2

Retained quantities of metoxuron immediately after application on the leaves, in p.p.m. Dosage 4 kg/ha a.i.

	Alopecurus leaves			bean leaves		
	dry		wet	dry		wet
m.g.	28.0 ± 4.4	***	147.3 ± 56.0	23.7 ± 3.2	***	263.7 ± 51.2
	***		n.s.	***		n.s.
w.p.	238.0 ± 98.9	n.s.	195.3 ± 76.1	222.3 ± 73.7	n.s.	281.0 ± 59.1

Statistical analysis: Wilcoxon Test

*** significant difference $P < 0.01$

n.s. not significant

2. Field trials

Comparison of metoxuron m.g. and metoxuron w.p.

Crop tolerance. One winter wheat variety trial, including 2 varieties known as resistant to metoxuron w.p. and 2 varieties known as susceptible, was carried out in Switzerland in 1972 on a weed-free light-medium loamy soil with gravel. The application took place at the tillering stage of the crop.

Table 3

Phytotoxicity score in % (means of 2 assessments, 4 and 10 weeks after application; 5 replicates)

		metoxuron m.g. 80 kg/ha a.i.		metoxuron w.p. 80 kg/ha a.i.	
varieties		3.2	6.4	3.2	6.4
Splendeur	(resistant)	2.5_b	7.5_a	2.5_b	8.2_a
Champlein	(resistant)	5.0_a	4.0_a	8.7_a	10.0_a
Zenith	(susceptible)	9.0_c	65.0_a	49.0_{ab}	61.0_{ab}
Tapro	(susceptible)	3.2_c	27.0_b	25.0_b	76.0_a

Means followed by the same letter are not significantly different at the 5% level (Duncan's-Test). Comparisons valid only horizontally.

On the two resistant varieties, the results do not indicate any significant difference between m.g. and the w.p. formulation.

On the two susceptible varieties the microgranular formulation of metoxuron proved to be significantly safer than the w.p. formulation. As can be seen in table 2, the m.g. formulation was less retained by the dry leaves than the w.p. This may be a possible explanation for the observed better tolerance of the m.g.

Weed Control. The comparison of the m.g. and w.p. formulation in respect of weed control was carried out in Switzerland in 1972 with the 80% microgranular formulation and in 1973 in several countries with the 40% formulation. The applications were generally made at the following development stages:

- Crop : stage: tillering
- *Alopecurus myosuroides* : beginning of tillering to full tillering-stage
- *Avena fatua* : 2-3 leaf stage

The trials were visually assessed according to a linear percent scale. Plot size: 20 m^2, 3 replicates.

Table 4

Results obtained in Switzerland in 1972

Treatments	Dose kg/ha a.i.	Effectiveness in % A. myosuroides 7 trials	A. fatua 3 trials	Galium aparine 7 trials	Papaver rhoeas 3 trials
metoxuron m.g. 80	3.2	92 ± 14	63	82 ± 13	94
metoxuron w.p. 80	3.2	95 ± 8	68	86 ± 11	98

Table 5

Results obtained in Italy, Spain and England

Treatments	Dose kg/ha a.i.	A. sterilis Spain 4 trials	A. ludoviciana Italy 4 trials	A. fatua GB 5 trials	broad leaf weeds Italy 3 trials
metoxuron m.g.	4.0	59 ± 15	73 ± 12	70 ± 22	85
metoxuron w.p.	4.0	62 ± 6	73 ± 13	83 ± 9	89

The results included in Tables 4 and 5 indicate that there is no significant difference between the w.p. and m.g. formulation of metoxuron. In a few trials there was a very slight tendency in favour of the w.p. formulation in respect of performance and regularity.

Influence of moisture on the foliage at the time of application. Two trials were carried out in Switzerland to determine the possible effect of the moisture status of the foliage at application. Applications were made early in the morning on dew wet foliage at midday on dry foliage, and in the evening on dew moist foliage.

Table 6

Influence of the moisture status of the foliage

dosage 3.2 kg/ha a.i.

Effectiveness in % (2 trials)

Weeds	Morning application w.p.	m.g.	Midday application w.p.	m.g.	Evening application w.p.	m.g.
A. myosuroides	95	95	97	94	96	93
G. aparine	92	87	92	88	92	89

No significant difference could be found, either between the two formulations at any of the 3 times of application, or between the 3 different times of application. These results are surprising in the sense that a stronger activity (stronger foliar absorption) of the microgranular formulation could have been expected when applied on moist foliage.

APPLICATION

Application tests with different types of applicators, were carried out with both formulations, metoxuron m.g. 80 and m.g. 40, to assess whether such microgranules can be broadcast with adequate uniformity of distribution. In some cases comparison was made with the metoxuron w.p. in respect of biological activity.

Ground application tests. Three different pneumatic microgranule applicators were used for the application tests. Their main characteristics were as follows:

Applicator 1 (prototype) : Introduction of the microgranules metered by a screw conveyor in the fan.

Applicator 2 : Introduction of the microgranules displaced by an adjustable orifice after the fan in the air flow; only one air supply for several nozzles.

Applicator 3 : Introduction of the microgranules displaced by a rotor driven by a land wheel in the air flow; all pipes having an individual air supply.

Test results

- The 80% formulation, which is to be applied at the 4-5 kg/ha rate, appeared to be too concentrated; the calibration of such a low rate is indeed difficult, even impossible for the less sophisticated machines. In that respect the 40% formulation, to be applied at a rate of 8-10 kg/ha, proved to be suitable.
- Both microgranular formulations, being relatively susceptible to mechanical stress, were severely damaged by the fan of applicator type 1.
- The results obtained with the 40% formulation in the field with applicators 1 and 2 were good in respect of weed control and crop tolerance and was comparable to

the conventional application of metoxuron w.p. The uniformity of distribution for applicator 3 was well within acceptable limits of 15% deviation from the mean. The distribution pattern of applicator 2 was not satisfactory since some points of the distribution curve showed 30 to 40% deviation and one deviated 80% from the mean. The main source of the lack of uniformity was certainly due to uneven displacement through the adjusting orifice, and also due to the uneven distribution of the microgranules in the different air pipes.

Aerial application tests

Several aerial application tests were carried out with a normal granular fertilizer spreader and with a more sophisticated dust and seed spreader.

The calibration of the fertilizer spreader appeared to be very delicate, and the uniformity of application was not satisfactory, i.e. dosage deviations of up to 70% from the mean were obtained.

The other spreader was also difficult to calibrate, but gave good distribution curves; the maximum dose deviation being 12% from the mean.

DISCUSSION

The preliminary results obtained with the microgranular formulation of metoxuron are promising in respect of both biological performances and suitability for application.

Biological performance. The amount of metoxuron residues in the leaves of both bean and *A. myosuroides* shortly after the application indicated that:

- the m.g. was substantially less retained on dry leaves than on moist ones

- the m.g. was substantially less retained than the w.p. on dry leaves.

This means that when the m.g. was applied on dry leaves the main part of the metoxuron reached the soil and consequently the main uptake occurred through the roots. This is true for the beans, where the m.g. on dry leaves showed a much lower initial activity than on moist leaves. This is however not true for *A. myosuroides* where the different amount of metoxuron on the leaves did not influence significantly the degree of the initial activity.

Finally, both the m.g. and the w.p. formulation applied at the normal rate on both dry and moist leaves of both bean and *A. myosuroides* showed practically the same degree of activity. This was also confirmed by the majority of field trial results.

The possible weaker foliar activity of the m.g. seems thus to have been compensated by the higher dosage which reached the soil. In the cases, however, of soil with high adsorption capacity, or of soil with moisture deficiency, the compensation could not be fully achieved. This is possibly what happened in the few field trials where the m.g. did not perform quite as well as the w.p. formulation.

In conclusion, it can be said that at the present stage of the technique, the microgranule compared to the w.p. formulation can give less reliable results in certain unfavourable circumstances. This disadvantage is however minor and is largely compensated for by the obvious advantages of the microgranule.

Application. The application tests proved that the 40% microgranular formulation of metoxuron (8-10 kg/ha) can be applied accurately with correct equipment. This correct equipment is however still scarce, the main reason being of course the rarity of microgranular products, and also the fact that the rather sophisticated use of microgranules has not yet been fully accepted by the majority of farmers. A very interesting future can no doubt be expected for microgranules, provided reliable easy to handle economic equipment is developed parallel with microgranular formulations. An effective cooperation between machinery manufacturers and agro-chemical firms is surely the only way to speed up development in this field.

Acknowledgements

We wish to thank all our co-workers, particularly Mr van Hoek who has contributed his analytical results.

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Proceedings 12th British Weed Control Conference (1974)

WEED CONTROL IN WINTER WHEAT WITH AC 92,553 ALONE AND IN COMBINATION WITH OTHER HERBICIDES

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Summary The results of 15 randomized block trials carried out in Italy in 1972/73 and 73/74 show that AC 92,553 [N-(ethylpropyl)-3,4-dimethyl-2,6-dinitrobenzenamine] STOMP* 330 E controls most of the dicots and grasses in winter wheat. Preemergence applications of 500 g a.i./ha performed well against broadleaf weeds and fairly well against Alopecurus myosuroides. Preemergence applications of 2.0-2.5 kg a.i./ha were necessary for excellent control of A. myosuroides. With the higher rates the number and height of young wheat plants were reduced. However, no other visual signs of phytotoxicity were noted nor was there a negative effect on the yield. Tank mixes of AC 92,553 with either terbutryne or linuron at very low rates applied preemergence gave good control without phytotoxicity.
Postemergence applications of 0.6 to 2.5 kg a.i./ha gave better dicot control than preemergence applications; however, A. myosuroides control was poorer.
Tank mixes of AC 92,553 (0.75 to 0.79 kg) with difenzoquat (0.73 to 0.75 kg) controlled with one postemergence treatment Avena spp. and other grass and broadleaf weeds. Chlormequat can also be added to this mixture.

Resumé Les résultats de 15 essais effectués en Italy en blocs randomizés en 1972/73 et 73/74, démontrent que AC 92,553[N-(éthyl propyl)-3,4-diméthyl-2,6-dinitrobenzènamine]STOMP* 330 E, contrôle la plupart des adventices dicotylédones et graminées dans le blé d'hiver. Les applications en préémergence en raison de g 500 m.a/ha ont donné des bons résultats contre les dicotylédones et assez bons vis à vis d'Alopécurus myosuroïdes. Des applications en pré-émergence de 2,0-2,5 kg m.a/ha ont été nécessaires pour un excellent contrôle de l'Alopecurus m. Avec les doses les plus hautes ont été reduits nombre et hauteur des jeunes

* Trademark American Cyanamid Company

plantes de blé. Toutefois aucun autre symptome de phytotoxicité n'a été noté ni ont eu lieu des effets negatifs sur la récolte. Les mélanges "tank mixes" de AC 92,553 avec terbutryne ou bien linuron appliqués à des doses très basses en pré-émergence ont donnés un bon contrôle sans phytotoxicité.
Les applications en post-émergence de 0,6 jusqu'à 2,5 kg m.a./ha ont donné un contrôle des dicotylédones meilleur de ce des applications en pré-émergence. De toute façàn , le contrôle d'*A. myosuroïdes* a été moins bon.
Les mélanges "tank mixes" de AC 92,553 (de 0,75 jusqu'à 0,79 kg/ha) avec difenzoquat (de 0,73 jusqu'à 0,75 kg/ha) ont contrôlé avec une seule application, Avena spp. et d'autres adventices graminées et dicotylédones. A ce mélange peut être additioné aussi le chlorméquat.

INTRODUCTION

Hormone herbicides are not used much in Italy because of potential drift hazard, as vines are nearly ubiquitous. This may be one of the reasons grass weeds, except *Avena* spp., in wheat, are not so predominant as in many other European countries.

Herbicides other than phenoxy compounds, e.g., terbutryne, metoxuron, nitrofen, linuron, neburon, chlortoluron, methabenzthiazuron, and trifluralin, applied either pre or postemergence alone or in mixtures are widely used in the good wheat growing areas. In the dry regions the extremely low yield does not pay for the treatment with expensive herbicides. As the winter and spring climate is very irregular, wet or dry weather may occur in the same area in different years. Thus herbicide performance is also very irregular. New herbicides may have a place if they are safe in various conditions and if they have a large spectrum of activity.

Wild Oats (mostly *A.ludoviciana*) are a problem mostly in Southern and Central Italy, but it is spreading now towards the North. Benzoylprop ethyl is now introduced but very often farmers would prefer to treat once only for the control of *Avena* spp. and other weeds.

In our trials we proposed to look for a safe herbicide with a large spectrum of activity which would be miscible with a postemergence wild oat herbicide.

METHODS AND MATERIALS

During 1972 and '73 we have carried out 15 randomized block trials with four replications on winter wheat. The plot size was 5 x 10= 50 m^2

Applications were made pre or postemergence using an engine driven plot sprayer with a pressure of 2.5 atm. and a spray olume of 650 or 800 l./ha.

In most of the trials trifluralin was applied as standard. Trifluralin, indeed, is largely used in those areas where Brassica and other cruciferous weeds are not a problem.

Trials were made on both Triticum vulgare and T. durum varieties.

Weed control and crop tolerance were assessed with a scale of 0-9 where 0 means no effect and 9 is a complete kill. Coverage is expressed by %.

Mixtures applied in the trials are tank mixes prepared immediately before spraying. Experimental plots were combine harvested and the yield determined soon after harvest. No fungicide or insecticide treatment was carried out in the trials.

Statistical evaluation was made with Duncan's multiple range test. The wheat growth stage was reported by the Baggiolini-Keller scale.

Most of the trials were situated in the Po Valley, (i.e. in an important wheat growing area of Italy) or in Central Italy.

RESULTS

(a) Timing

In three trials (Table 1) AC 92,553 applied at pre and early post-emergence (stage "D" of the Baggiolini-Keller scale) produced no visual signs of phytotoxicity. There was a reduction in the number of emerged plants following pre-emergence applications in all three trials, though this was not statistically significant. Also a small bùt significant reduction in the height ofthe young plants occurred which later disappeared.

Dicots were controlled equally in pre- and post-emergence treatments. Alopecurus myosuroides control was better in pre- than post-emergence treatments.

Yield was determined only in one trial: Post-emergence application of AC 92,553 gave the highest yield. The yield increase obtained with the pre-emergence treatment was also significantly different from the untreated control.

(b) Rate

Different dosages were tried at pre-emergence only (Table 2): we

Table 1

Effect of timing on the activity and safety of AC 92,553

Herbicide	Dose g/ha a.i.	Timing days after sowing	Wheat plants/ 10 m²	Length in cm X of 25 plants	% ground coverage	Control of *Veronica* spp.	Control of *Capsella bursa pastoris*	Control of *Alopecurus myosuroides*	Yield kg/ha
			Trial No 1						
AC 92,553	500	5	337	8.29 c	2.3	9.0	7.75	7.0 ab	--
Trifluralin	667	5	327	8.27 a	3.8	6.8	5.25	8.00a	--
AC 92,553	687	49 D*	--	--	--	8.8	7.25	8.25a	--
Trifluralin	890	49 D*	--	--	--	8.3	5.25	6.50 b	--
Untreated			321	8.81 a	11.0	0	0	0 c	--
			Trial No 2						
AC 92,553	500	0	472	5.10 c	2.3 a	--	8.0	7.8	--
Trifluralin	667	0	442	4.93 b	2.3 a	--	5.8	7.3	--
AC 92,553	687	47 D*	--	--	2.0 a	--	8.8	7.3	--
Trifluralin	890	47 D*	--	--	3.0 b	--	6.0	5.3	--
Untreated			516	5.21 a	9.3 c	--	0	0	--
			Trial No 3						
AC 92,553	500	3	348 ab	5.64 c	6.2 a	9.0	8.3	7.8	5490 c
Trifluralin	667	3	292 b	5.80 b	10.0 ab	8.0	1.3	7.8	5802 b
AC 92,553	687	47 D*	--	--	12.5 b	9.0	8.5	6.3	6130 a
Trifluralin	890	47 D*	--	--	13.8 b	8.8	6.0	6.3	5740 b
Untreated			355 a	5.94 a	47.5 c	0	0	0	4520 d

Note: Values followed by the same letter in the same column are not significantly different at the 5% level of significance using Duncan's Multiple Range Test.

* Stage D of the Baggiolini-Keller Scale

Table 2

Influence of dosage on performance of AC 92,553

Herbicide	Dose kg/ha a.i.	No of wheat plants/10 m^2	Height in mm, X of 25 plants	% ground cover	Control of *Alopecurus* spp.	Control of *Veronica* spp.	Control of *Papaver rhoeas*	Phytotoxicity	Control of *Fumaria officinale*	Control of *Lolium* spp.
Trial No 1										
AC 92,553	0.6348	2865	20.0	5.0	6.8	9.0	9.0	0	--	--
AC 92,553	1.2696	2407	20.4	3.3	8.5	9.0	9.0	1.0	--	--
AC 92,553	1.9044	2302	19.9	3.3	8.5	9.0	9.0	1.5	--	--
AC 92,553	2.5392	2272	20.7	2.3	9.0	9.0	9.0	1.5	--	--
Untreated		2737	21.4	16.3	0	0	--	0,5	--	--
Trial No 2										
AC 92,553	0.6348	4530	84.7	7.0	--	9.0	--	0	9.0	5.0
AC 92,553	1.2696	4492	86.8	6.3	--	9.0	--	0	9.0	6.0
AC 92,553	1.9044	4530	85.7	6.3	--	9.0	--	0	9.0	6.0
AC 92,553	2.5392	4020	87.3	5.3	--	9.0	--	0	9.0	6.8
Untreated		4860	87.9	21.3	--	--	--	--	--	--

Treatment in Trial No 1 : one day after seeding
" " " " 2 : three days after seeding

Table 3

Performance* of AC 92,553 alone and in mixture with other herbicides

Herbicide	Dose g/ha a.i.	Timing, days after sowing	Wheat plants /10 m^2	Height of plants in cm	% ground coverage	Control of *Alopecurus myosuroides*	Yield kg/ha
AC 92,553	526	3-5 **	1420	6.69	6.48	6.40	5175
AC 92,553	1052	3-5	1467	6.50	5.92	6.08	5310
Trifluralin	578	3-5	1452	6.43	7.88	6.23	5230
AC 92,553+linuron	394+500	3-5	1466	6.58	7.12	6.20	5471
AC 92,553+terbutryne	394+500	3-5	1480	6.57	6.28	6.38	5156
Methabenzthiazuron	2100	3-5	1372	6.46	14.38	5.30	5361
AC 92,553	790	40-52 ***	—	—	9.00	4.10	5389
Untreated	—	—	1396	6.59	29.76	—	4843

* Mean values from 5 trials

** Herbicides applied 3 to 5 days after sowing

*** Herbicide applied 40 to 52 days after sowing (Stages C or D of Baggiolini-Keller Scale) know from previous trials that AC 92,553 in post-emergence applications is very safe and that six times overdosage does not damage the wheat. With increasing rates from the normal rate (0.63 kg a.i./ha) to 4 times (2.54 kg a.i./ha), a progressive reduction of the number of emerged plants was observed in both trials. The same is true also for height of the plant; however, the difference disappeared completely during the tillering stage.

As far as efficacy is concerned, the weed coverage was low also at the low rate and no significant reduction of coverage was obtained with increased rates. Control of Alopecurus myosuroides was improved clearly with higher rates whereas Lolium reacted poorly at the increased rates.

(c) Mixtures

In Table 3 the results of different rates of AC 92,553 alone and the reduced rate mixed with linuron or with terbutryne are reported. Here too no significant difference was observed in the performance between the normal and double rates of AC 92,553.

The mixtures (tank mix) of AC 92,553 + linuron and AC 92,553 + terbutryne are very promising. The reduced efficacy of the post-emergence treatment against Alopecurus myosuroides, already noted in the timing trials, was confirmed in this series too.

The mixture of AC 92,553 with 3 different formulations of difenzoquat (Table 4) performed well: no significant efficacy reduction of either of the components, or phytotoxicity was observed. The compatibility of difenzoquat + chlormequat and the the three-way mixture difenzoquat + AC 92,553 + chlormequat (Table 5) was good. In this trial in spite of the very low rate of chlormequat a significant reduction of shoot height (ca. 8-10 cm) was noted.

In trial No 2 of Table 5 a very high yield increase was obtained owing to the good control of the heavy Wild oat infestation.

In order to simplify and reduce the Tables detailed results of AC 92,553 against a series of dicots are not reported. Papaver, Sinapis arvensis, Stellaria media, Thlaspi arvense, Polygonum convolvulus were controlled with low rates (750 g a.i./ha) in both pre and post-emergence treatments, whereas Ranunculus spp. and Vicia spp. were relatively resistant.

DISCUSSION

AC 92,553 performed well against a wide range of dicots at low rates (750 g a.i./ha) both pre and post-emergence, i.e., with lower rates than in other European countries. For the control of grass weeds higher rates are necessary, especially when applied postemergence.

A special advantage of AC 92,553 is that this herbicide can be mixed with difenzoquat Wild oat herbicide and so with one treatment all weeds infesting winter wheat can be controlled. Difenzoquat seems to improve the activity of AC 92,553 against Alopecurus myosuroides, although a higher rate (1,5 kg a.i./ha) is necessary because of reduced activity against grass weeds when it is applied postemergence. AC 92,553 and difenzoquat can be used only as a tank mix and it will probably not be easy to formulate the two active substances as a ready for use mixture.

Table 4

Compatibility of AC 92,553 25%EC with 3 different difenzoquat formulations

Herbicide	Dose g/ha a.i.	%Ground Coverage 18.4.74	Control of Wild Oats 18.4.74	Control of Black grass 18.4.74	%Ground Coverage 14.5.74	Control of Wild Oats 14.5.74
Difenzoquat Form."A"	750	50.0 b	8.0	3.3	53.8 c	7.5
Difenzoquat Form."B"	750	50.0 b	8.0	2.0	46.3 c	7.5
Difenzoquat Form."C"	750	48.8 b	8.0	1.0	46.3 c	7.0
Difenzoquat Form."A" + AC 92,553 25% EC	750+ 750	22.5 a	8.0	2.5	10.3 a	7.0
Difenzoquat Form."B" + AC 92,553 25% EC	750+ 750	23.8 a	8.0	4.8	16.3 a	6.8
Difenzoquat Form."C" + AC 92,553 25% EC	750+ 750	22.5 a	8.0	4.3	10.0 a	6.8
Untreated		76.3	—	—	85.0 d	—

Table 5

Compatibility of difenzoquat with herbicides and with chlormequat

Herbicide	Dose g/ha a.i.	Trial No 1		Trial No 2		
		%Ground Coverage 8.5.74	Control of Wild Oat 8.5.74	%Ground Coverage 17.5.74	Control of Wild Oat 17.5.74	Yield kg/ha 17.5.74
Difenzoquat	750	9.0 a	8.0 a	22.5 d	7.8	2053
Difenzoquat+chlormequat	750+250	11.3 a	7.8 a	21.3 cd	8.0	1883
Difenzoquat+AC 92,553	750+793	6.0 a	8.0 a	8.8 b	7.3	1968
Difenzoquat+AC 92,553+ chlormequat	750+793+ 750	9.0 a	8.0 a	6.3 a	8.0	2041
Difenzoquat	1000	10.5 a	8.0 a	20.0 c	8.0	1842
Untreated		45.0 b	0 b	85.0 e	—	901

Note: Values followed by the same letter in the same column are not significantly different at the 5% level of significance using Duncan's Multiple Range Test.
Treatment at stage "F" of the Baggiolini-Keller Scale.

BIOLOGY AND CULTURAL CONTROL OF (POA TRIVIALIS) IN CEREAL CROPS

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Summary Mature plants of rough-stalked meadow grass, Poa trivialis, which are allowed to reestablish in the seed beds of winter wheat and spring barley are able to produce seed. Seedlings of Poa trivialis germinating in winter wheat are also capable of producing seed because they are vernalized during the winter period. Seedlings germinating in spring barley however, are not vernalized and are incapable of producing seed. Successive crops of spring barley can therefore be used as cleaning crops on soil infested with dormant seeds. The seed produced by over-wintered transplants in winter and spring cereals can be prevented from becoming incorporated into the soil by delaying the stubble cultivations for as long as possible. Once incorporated a high proportion will become dormant and serve to infest future crops.

INTRODUCTION

This investigation forms part of a larger study initiated in response to concern by growers and contracting merchants that ways and means should be found of controlling Poa trivialis in grass seed crops (unpublished survey 1966). Attwood, unpublished survey 1969) also found it to be occasionally troublesome in cereal crops in the southern half of England.

Since grass seed crops often run in rotation with cereals the behaviour of Poa trivialis in cereals may well be important in determining ways of implementing cultural and chemical control systems. The life cycle of Poa trivialis in cereals is therefore described. The behaviour and cultural control in grass seed crops has already been described by Budd (1970b, 1972).

Poa trivialis unlike Poa annua is perennial and cereal crops in infested areas are often found to contain old perennial plants growing alongside germinating seedlings. These older plants have survived from preceding crops and have now become transplanted into the new crops. The seedlings have germinated from seed which had lain dormant in the soil prior to activation by seed bed cultivations.

Work done by Cooper and Calder (1964) and Budd (1970a) has shown that Poa trivialis plants need to be vernalized by exposure to winter conditions in order to produce seed the following year. Work by Budd (1970a) has already shown that spring germinating plants are incapable of producing seed in the year of germination and consequently successive spring barley crops may be used as cleaning crops on infested land. The mature transplants however, because of their exposure to winter conditions may be able to produce seed.

This investigation studies further the behaviour of both seedlings and old transplants in cereals. Particular attention being paid to the seed producing ability of Poa trivialis and the consequent germination of that seed in the stubbles of the cereal crop.

METHOD

In 1970 and 1971 the behaviour of Poa trivialis in spring barley and winter wheat was observed throughout the growing season in trial plots sown at Cambridge.

Spring Barley This trial took the form of two cereal plots each 30 yards long by 5 feet wide sown parallel to each other using a farm drill set to drill a 7 inch spacing. Each plot represented a single replicate. In this trial only the behaviour of the over-wintered transplants was studied. Transplants of Poa trivialis were transplanted in each plot into the seed bed of the spring barley in 1971. A three year old 'matted sod' of Poa trivialis was cut into 9 by 4 inch pieces and 20 were half buried 18 inches apart in the barley immediately after sowing in March. This procedure was intended to simulate what likely happens to a spring barley seed bed where the cultivations fail to completely kill the over-wintered 'trash' from the preceding crop. The transplants were recorded for heading and seed production during the summer. The heading date was noted when each plant produced three heads.

Any plants producing seed are likely to shed their seed onto the ground before the barley is harvested. This seed is capable of germinating immediately on the surface of the ground if given moist soil conditions. In order to study their germination, freshly harvested seed was collected on the 14th of July and samples were laid down between 7 inch coulter rows of the barley crop. In order to measure the performance of Poa trivialis under lower intensities of crop competition some of the crop rows were removed by treating with paraquat to leave 14 inch spacings. Three replicates, each consisting of 400 seeds, were laid down in lines extending to three feet between the barley rows and were recorded every two weeks for germination until after harvest. The 14 inch rows were intended to compare germination under conditions of reduced crop competition. The moisture state of the soil surface was noted. The barley was harvested in the middle of August but recording was continued until early September when the stubbles were cultivated according to normal farm practice. Immediately before cultivating all ungerminated seed was swept up with some soil using a dustpan and brush. The brushing was vigorously done using a stiff hand-brush. These soil samples were then examined for ungerminated seed by sprinkling in a thin layer into germination trays containing moist peat. The peat was kept permanently moist by watering from below. All germinating seedlings were then counted. Along with these trays, controls consisting of soil samples not sown with Poa trivialis were set up in order to determine and correct for the presence of naturally occurring seedlings. The reason for sprinkling the soil samples in a thin layer on top of the peat was to enable any ungerminated seed to receive light. Chippindale (1932) showed that a proportion of Poa trivialis required light to germinate.

Winter Wheat If a grass seed crop infested with Poa trivialis is followed by a winter wheat crop it is likely that it also will come to be contaminated with seedlings and old surviving weed plants. The seed bed cultivations for the winter wheat may be insufficient to destroy the Poa trivialis plants from the old crop and these together with germinating seedlings become established in the new cereal crop.

This trial was similar in layout to the one described for spring barley. The crop was again sown with a farm drill at 7 inch spacing. 14 and 21 inch spaces were again made by treating some rows with paraquat. This was intended to resemble a poorly established crop. Pieces of cut up 'sod' were again half buried at random in each of the two replicates. For each replicate of the 7, 14 and 21 inch treatments, 12 pieces of transplants were buried immediately the crop was sown. At the same time viable Poa trivialis seed was broadcast onto the cereal plots in each replicate. This seed would germinate and grow along with the crop and transplants.

Both transplants and seedlings were recorded for heading and seed production the following summer. Seed produced by the Poa trivialis plants were again observed for germination following shedding onto the ground. The germination was recorded over a period before and after harvest, up until the stubbles were ploughed. The plot layout and procedure was the same as for the spring barley.

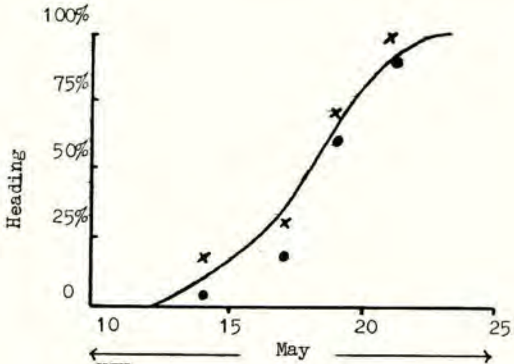
RESULTS

Figure 1 shows that the seed bed transplants of over-wintered 'trash' started to produce seed heads in spring barley on the 14th of May and heading was complete in both replicates by 24th May. All transplants in both replicates produced on average fifteen heads per plants over a period of 12 days, and when examined in July all were found to be producing ripe seeds which were beginning to be shed onto the ground.

Figure 1

Poa trivialis, heading of over-wintering

transplants in spring barley



KEY

✗ Heading of over-wintering transplants replicate 1

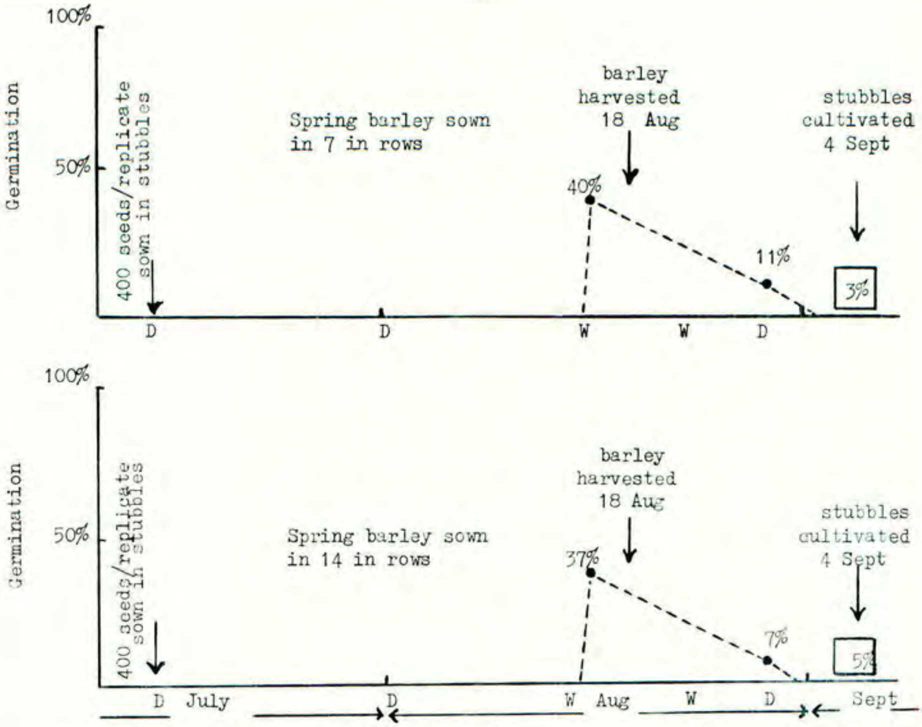
● " " " " " " replicate 2

Figure 2 shows the germination of the Poa trivialis seed in the 7 and 14 inch spacings. Also shown are the records for soil surface dampness. July 1971 was a dry month and appreciable rain did not fall until August. Sufficient rain fell during this month to ensure that the ground surface was kept moist for two to three weeks and the seed was able to germinate. A germination peak was recorded on the 15th August in both the 7 and 14 inch treatments. Three to five per cent of the seed which failed to germinate in the stubbles, succeeded in germinating in the trays.

Figure 2

Germination of shed seed of Poa trivialis

in spring barley stubbles



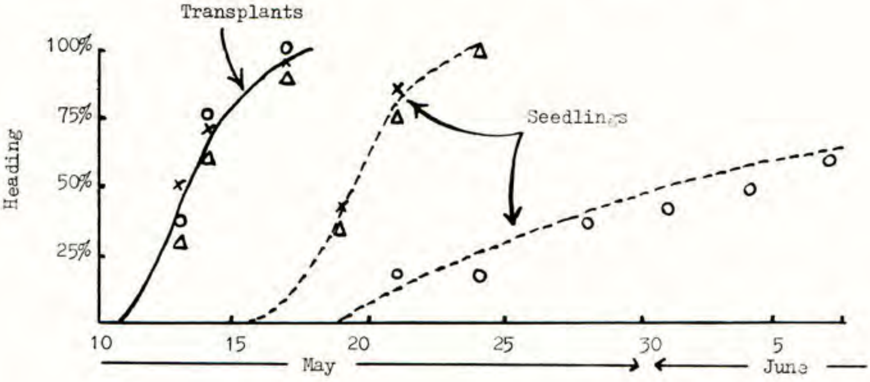
KEY

5%	Seed which failed to germinate in the stubbles and would have become incorporated into soil when the stubbles were cultivated.
	Germination potential of seed used = 95%
W =	Soil surface wet
D =	Soil surface dry

Figure 3 shows that all the transplants in the winter wheat seed bed produced seed heads in the harvest year. Heading started on the 12th May and 100% was reached on the 17th. The plants which grew from seedlings in the seed bed all produced heads in the 14 and 21 inch row spacings. In the 7 inch rows however, heading was much delayed and only 60% managed to produce seed heads.

Figure 3

Poa trivialis, heading performance in winter wheat 1971



KEY O = Poa trivialis growing in wheat sown in 7 in. rows.

Δ = " " " " " " in 14 in. rows.

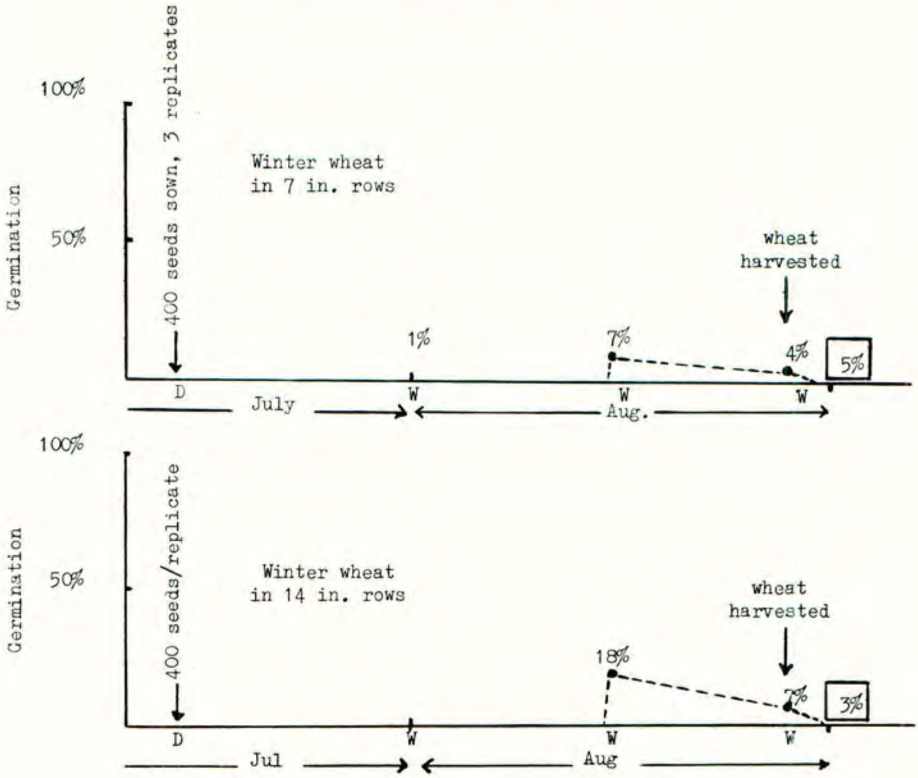
X = " " " " " " in 21 in. rows.

Results in Figure 4 show that the three replicates of Poa trivialis seed laid down in the winter wheat behave in a similar manner to those recorded in the spring barley. They are capable of germinating as soon as the soil surface becomes moist. After harvesting the crop the soil onto which the three replicates was laid was once again swept up and treated to determine the presence of ungerminated seed. The results of this examination showed that 3 to 5% of the seed which failed to germinate in the stubbles, succeeded in germinating in the trays.

Figure 4

Germination of shed seed of <u>Poa trivialis</u>

in winter wheat stubbles 1971



<u>KEY</u>

[5%] Seed which failed to germinate in the stubble and is likely to become incorporated into soil by cultivations

Germination potential of seed used = 95%

W Soil surface wet

D Soil surface dry

DISCUSSION

Figure 2 shows that in the 7 inch barley rows only 40% of the seed germinated on the ground before the barley was harvested on the 18th August. If the stubbles of the barley crop were cultivated the day after harvest then 11 + 3% of the ungerminated seed would have become incorporated into the soil. Similarly in the 14 inch barley rows 7 + 5% would have become incorporated. In the winter wheat also, see Figure 4, 3 to 5% of the seed shed into the stubble failed to germinate and these would likely have become incorporated into the soil if stubble cultivations followed immediately after harvest. Once incorporated a proportion would likely become dormant. Milton (1936) and Budd (1972) have demonstrated the ability of *Poa trivialis* to become dormant when buried in soils. It would appear therefore that spring barley and winter wheat crops infested with seed producing plants of *Poa trivialis* are likely to increase the soil 'reservoir' of dormant seed if cultivation takes place soon after harvest.

It is noticeable that the total stubble germination in the wheat and barley never reached that of the potential as measured in the laboratory. The best in the barley was only 54% compared with the laboratory test of 95%. Unpublished work by the author has shown that a possible reason could be due to critical levels of moisture available to the germinating seed. Rapid wetting and drying periods appear to be deleterious to germination. The imbibed seed and radicle may dry out and die if the soil surface dries out quickly.

In the winter wheat trials at 7 inch spacing the suppression of heading on the seedlings was probably due to the intensity of competition by the crop. In the 14 and 21 inch rows this competition was not so intense and all the seedlings were able to produce seed heads. The mature transplants however, all produced their heads 5 days earlier and the time of heading appeared to be unaffected by crop competition. This is understandable since they were transplanted as mature plants into the seed bed and were only having to compete with the germinating wheat seedlings. In the 7 inch rows the weed seedlings were having to compete with the vigorous wheat seedlings from the beginning.

Some Implications Concerning Possible Control Measures

This study has helped to confirm that spring barley can best qualify as a cleaning crop provided that there is no carry over of old vegetative plants of *Poa trivialis* from previous crops. Good ploughing the previous autumn using skim coulters to bury the 'trash' is therefore important. Cultivations of the chisel type or direct re-seeding machines without the use of paraquat is likely to assist this carry over.

In the event of this carry over and subsequent seeding of *Poa trivialis*, incorporation of viable seed into the soil can be prevented by delaying the cultivations of the stubbles after harvest for as long as possible. This enables all the seed the opportunity of germinating on the surface. If spring barley is to be sown the following year the stubbles could well be left unploughed until the autumn. The practical use of delayed stubble cultivations has already been achieved in a spring barley grass seed crop rotation, as shown by the author in (1970b) and (1972). In Field examples the infestation of *Poa trivialis* in two grass seed crops was reduced by 70% in three years. A modification of this basic technique could well prove useful in controlling other arable weeds such as wild oats *Avena fatua* in cereal crops. If this technique is adopted care would have to be taken to guard against an increase in *Agropyron repens*. This could be achieved by treating the stubbles with paraquat or glyphosate. If there has not been any carry over of seed producing *Poa trivialis* plants then the stubbles can be cultivated and ploughed immediately after harvest. This has the desirable effect of bringing further dormant seed to the surface to germinate and be killed. This operation will also greatly assist the control of *Agropyron repens*. The control of

Agropyron by this method has been fully reviewed by Cussans (1970).

It would be hazardous to consider winter wheat as a cleaning crop. Transplants are best controlled by good seed bed preparations and the seedlings by the application of one of a number of blackgrass herbicides. Delayed stubble cultivations could also be attempted. This may only be convenient however, if the following winter wheat or spring barley crop were to be direct drilled. Unfortunately however, this system of drilling could well encourage the survival of the straw borne diseases such as *Septoria* and *Ophiobolus*. Straw burning therefore would also have to be considered.

It is unfortunate that specific cultural systems often conflict with the control of other pests and diseases. It is evident therefore that combinations of cultural and chemical control systems will be necessary to afford complete protection for the crop.

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Proceedings 12th British Weed Control Conference (1974)

PROGRESS IN THE DEVELOPMENT OF THE ISOPROPYLAMINE SALT OF GLYPHOSATE FOR THE CONTROL OF AGROPYRON REPENS

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Summary The isopropylamine salt of glyphosate was applied to 49 sites in stubble situations within Great Britain from the autumn of 1971 to the spring of 1974 for the control of Agropyron repens. The rates used were 0.5 - 4.4 kg a.e./ha and 1.44 kg a.e./ha was found to give excellent control up to one year after application. In addition good control was also achieved of Agrostis spp. Good leaf emergence at the time of application was essential for good performance. No pre-emergence activity was observed in the trials, enabling winter and spring cereal crops to be drilled traditionally or direct drilled after the appearance of leaf symptoms.

Résumé De l'automne 1971 au printemps 1974, le glyphosate a été appliqué sur chaumes de céréales, sous forme de sel d'isopropylamine, en 49 points de l'Angleterre pour déterminer son action sur Agropyron repens. On a utilisé des doses de 0.5 à 4.4 kg d'équivalent acide par hectare et il s'avère que 1.44 kg/ha détruit parfaitement cette adventice pour l'année qui suit l'application. On a obtenu également une bonne destruction de l'Agrostis spp. Pour obtenir de bons résultats, il était essentiel que la végétation aérienne soit bien développée au moment du traitement. On n'a remarqué aucun effet de pré-levée dans les essais, ce qui permet de semer des céréales d'hiver ou de printemps normalement ou en semis direct dès qu'ont apparu les symptômes foliaires.

INTRODUCTION

'Couch' (Agropyron repens and Agrostis gigantea), has been a troublesome weed on British farms for many years. Agrostis stolonifera and Holcus mollis, more prevalent in the wetter western areas, are also included in the group of 'couch' weeds. Their presence is one of the major reasons for traditional autumn stubble cultivations.

When the new class of herbicides represented by N-(phosphonomethyl) glycine (glyphosate) was announced in the U.S.A. by Baird et al., 1971 their potential for 'couch' control was obvious as they offered many advantages over existing herbicides and cultural control techniques. In particular, their high degree of herbicidal activity, translocation within the plant when applied to the foliage and lack of soil activity, showed them to be promising herbicides for couch control in intensive cereal production. Baird and Begeman (1972) demonstrated that when applied to perennial species glyphosate salts were readily translocated giving good control of Agropyron repens. Early investigational work in the United Kingdom with the mono (dimethylamine) salt confirmed U.S. work and was reported by Evans (1972). Development work then began to determine the most effective way to utilise this new herbicide class under British conditions.

The isopropylamine salt of glyphosate was selected for commercialisation. This paper summarises the progress made to date in its development for couch control.

METHOD AND MATERIALS

The formulation of the isopropylamine salt of glyphosate used throughout the programme was MON-2139 (Roundup) and contained 360 grammes of acid equivalent (a.e.) per litre. The rates used varied from 0.5 - 4.4 kg a.e./ha. During the 1973/4 season 3,4,5,6 and 12 l /ha of formulated product (1.08 - 4.32 kg a.e./ha) were used to determine the commercial rate.

In the autumn, applications were generally made in stubble situations following cereals and in some cases following peas and beans. In the spring, applications were made to undisturbed stubbles and to couch regrowth following normal autumn cultivations. Previous crop residues were either baled or burnt. The majority of sites were cropped usually with winter or spring barley or wheat but a few were kept uncropped. See Table 1 which shows the sites and details. Control plots were completely untreated in the non-cropped sites. In sites which were cropped however, the control plots received paraquat and/or cultivations by the farmer as part of his normal stubble cleaning and seedbed preparation programme.

Some early small plot sites were sprayed with an Oxford Precision Sprayer. However the majority of the spraying was done with a Land Rover fitted with commercial spraying equipment manufactured by Evers and Wall Limited, to bring trial conditions as close as possible to those occurring in commercial practice. The 5.4 m boom was fitted with 12 Hardi 4110 No_2 16 fan jets. The rate of water applied was 225 l/ha at a pressure of 1.4 kg/cm^2.

Plot size in 1972/3 was $240m^2$ to enable cereal crop yields to be taken with a normal commercial farm combine. Normally $100m^2$ was cut and weighed from each plot. However for 1973/4 a plot size of $480m^2$ was used to allow adequate discard and to avoid 'couch' rhizomes being pulled into adjacent plots by cross cultivations. From 1-4 replications of the treatments were used depending on the area of 'couch' available. (Table 1).

Weed assessments were made using a 0-100 scale (100 = 100% control). Generally 3 assessments were made at each site. All sites were assessed for foliage kill at 10-21 days after treatment (DAT). Autumn sites were assessed for regrowth of 'couch' shoots in the following spring, at 150-200 DAT either before spring cultivations or in the growing crop. Spring sites were assessed for regrowth prior to seedbed preparation or in the growing crop at 30-90 DAT. All cropped sites were assessed for regrowth at 200-360 DAT after crop harvest. The lack of regrowth on treated plots being confirmed by random digging.

Crop assessments were made visually and whenever possible by plant counts shortly after emergence. Later visual assessments were made and some sites were taken to yield. Non-cropped sites were assessed at 360 DAT but some were observed over a longer period.

RESULTS

MON-2139 was applied to 'couch', usually Agropyron repens, but many sites had mixed populations of A. repens with Agrostis spp. Holcus spp, Alopecurus myosuroides, Avena spp, volunteer cereals, other seedling grasses and broadleaf

TABLE 1 - SITES AND DETAILS

AFTER HARVEST REGROWTH OF AGROPYRONS REPENS (V = Vegetative, F = Flowering)

Site	% Ground Cover	Weed Stage	Applic. Date	No. of Reps.	Following Crop
AUTUMN 1971					
Bozeat, Northants.	80	V	1/10	4	Spring Barley
AUTUMN 1972					
Wisbech, Cambs.	90	V	26/ 9	1	Spring Wheat
Flowton, Suffolk	80	V	27/ 9	1	Non crop
Burnham (1) Berks.	85	V	28/ 9	1	Non crop
Fawkham, Kent	80	V	28/ 9	1	Spring Barley
Ashford, Kent	80	V	29/ 9	1	Spring Barley
Milverton, Somerset	70	V	30/ 9	3	Grass
Mollington, Oxon	60	V	2/10	3	Spring Barley
Bozeat, Northants	40	V	3/10	2	Winter Wheat
Chicksands (1) Beds.	90	V	4/10	1	Non crop
Wormleighton, Warwicks	70	V	9/10	3	Spring Barley
Wansford, Hunts	20	V	19/10	3	Winter Wheat
Royston, Herts	50	V	20/10	3	Spring Barley
Chicksands (2) Beds.	95	V	25/10	2	Non crop
Chicksands (3) Beds.	95	V	25/10	2	Non crop
SPRING 1973					
Scarisbrick, Lancs.	99	V	13/ 2	3	Non crop
Dublin, Ireland	70	V	19/ 2	4	Non crop
Clare, Suffolk	80	V	7/ 3	3	Spring Wheat
Lutton, Northants.	80	V	7/ 3	3	Spring Wheat
Yielden, Beds.	40	V	8/ 3	2	Spring Barley
Mollington, Oxon	40	V	10/ 3	1	Spring Barley
Swineshead, Lincs.	30	V	21/ 3	4	Spring Barley
Huish, Somerset	30	V	29/ 3	4	Spring Barley
Burnham (2) Berks.	70	V	3/ 4	1	Non crop
Burnham (3) Berks.	99	V	3/ 4	3	Non crop
Burnham (4) Berks.	75	F	8/ 6	1	Non crop
Chicksands (4) Beds.	70	F	22/ 6	3	Non crop
Chicksands (5) Beds.	99	F	22/ 6	3	Non crop
Pocklington, Yorks.	90	F	5/ 7	4	Non crop
AUTUMN 1973					
Wansford (1) Hunts.	80	V	26/ 5	4	Winter Wheat
Wansford (2) Hunts.	80	F	10/ 8	4	Winter Wheat
Clare, Suffolk	75	V	4/10	4	Spring Barley
Chelmsford, Essex	90	V	5/10	4	Spring Barley
Anstey, Herts.	80	V	8/10	4	Winter Wheat
Thriplow, Cambs.	40	V	8/10	4	Sugar Beet
Royston, Herts.	80	V	9/10	4	Spring Barley
Mollington, Oxon.	80	V	11/10	4	Winter Barley
Wormleighton, Warwicks.	80	V	11/10	2	Spring Beans
Tackley, Oxon	70	V	11/10	2	Spring Barley
Bozeat, Northants.	60	V	18/10	4	Winter Wheat
Yielden, Beds.	90	V	23/10	3	Spring Barley
Flowton, Suffolk	70	V	25/10	1	Spring Barley
Wittering, Hunts.	90	V	26/10	4	Spring Wheat
Toft, Lincs.	90	V	26/10	2	Spring Barley
Lutton, Hunts.	90	V	26/10	4	Spring Barley

TABLE 1 Contd.....

Site	% Ground Cover	Weed Stage	Applic. Date	No. of Reps.	Following Crop
SPRING 1974					
Bozeat, Northants.	20	V	28/ 2	2	Spring Wheat
Lutton, Northants.	85	V	20/ 3	4	Spring Barley
Weston, Herts.	35	V	27/ 3	3	Spring Barley
Chelmsford, Essex.	50	V	29/ 3	4	Spring Barley

TABLE 2

% Control of Agropyron Repens at three periods after treatment

Ground Cover	Rate MON-2139 kga.e. / ha	AUTUMN DAT 10-21	AUTUMN DAT 150-200	AUTUMN DAT 300-360	SPRING DAT 10-21	SPRING DAT 30-90	SPRING DAT 200-300
G	0.5 - 0.9	61(3)	89(3)	69(3)	54(4)	73(3)	63(4)
P		-	-	-	71(4)	76(6)	18(6)
G	1.0 - 1.2	70(17)	91(17)	86(15)	72(7)	88(6)	90(6)
P		74(4)	82(4)	45(4)	70(5)	85(8)	30(7)
G	1.3 - 1.6	79(17)	96(17)	92(16)	78(3)	82(2)	91(3)
P		70(3)	91(3)	70(3)	61(3)	83(6)	26(6)
G	1.7 - 1.9	78(15)	96(16)	95(15)	78(6)	89(6)	92(5)
P		73(5)	82(5)	55(5)	-	-	-
G	2.0 - 2.3	86(11)	98(11)	93(10)	79(9)	93(8)	95(7)
P		85(4)	56(4)	33(4)	76(3)	95(5)	20(4)
G	2.3 - 4.4	82(21)	97(21)	95(19)	76(4)	99(3)	96(4)
P		75(5)	87(5)	71(5)	72(4)	81(5)	42(5)

Key: G = Greater than 70% ground cover of *A. repens*
P = Less than 70% ground cover of *A. repens*
DAT = Days after treatment
The figures in brackets are the number of sites

weeds were often present. The couch sites were generally in stubbles where previous crop residues had been baled or burnt. MON-2139 gave good control of all weeds present after both methods of crop residue removal but a good complete burn was essential in the latter case. The following crops were usually winter or spring cereals.

Adequate leaf area present at the time of spraying was important. The autumn of 1972 was dry and regrowth poor, giving a lower leaf area than in the autumn of 1973 which was more moist. It can be seen from Table 1 that there is a big variation between sites in the amount of ground covered by *Agropyron repens*. Generally more leaf area was present in the autumn and spring sites which were undisturbed after the previous crop harvest. It can be seen from Table 2 that the best control of *Agropyron repens* was obtained when there was a good ground cover present at the time of spraying, in both autumn and spring. In sites with heavy weed populations a good regrowth of fresh leaf was obtained after a good burn. Cultivations after harvest but prior to spraying fragmented the rhizomes, leading to a poor leaf area of Agropyron repens and poor results, this was particularly noticeable where spring applications were made after normal autumn ploughing.

Rates of MON-2139 used in the trials were from 0.5-4.4 kg a.e./ha. The early work concentrated on the higher rates but later work indicated satisfactory results above 1.0-1.2 kg a.e./ha. Table 2 indicates a probable commercial rate between 1.3 and 1.6 kg a.e./ha. During the 1973/4 season 1.44 kg a.e./ha gave consistently good results, 14 sites with good leaf area averaged 96% control one year after treatment. Lower rates gave a slower and often patchy kill of foliage which lead to sporadic regrowth of Agropyron repens, 200-360 DAT. and was considered not to be commercially acceptable. Crop safety was outstanding. No crop damage was seen in any of the sites confirming the lack of pre-emergence activity.

Autumn treatments were normally followed by winter wheat or barley. Cultivations leading up to seedbed production for winter crops commenced as soon as the weed foliage began to wilt and turn yellow, usually 10-14 days after spraying. Some sites were cultivated or ploughed 14-30 days after spraying in readiness for spring crops. Spring treatments were followed by spring wheat or barley, cultivations commencing 10-14 days after spraying.

Where cultivations or ploughing took place between 7 and 180 days after spraying, no differences in performance were recorded. Generally good performance was achieved when cultivations took place after the appearance of the first leaf symptoms 10-14 days after spraying in early autumn or spring. During the winter, leaf symptoms took longer to appear but good results were obtained. It was not found necessary to wait for complete foliage dessication. Occasionally treated rhizomes left on the soil surface after cultivations produced a few weak shoots in the spring but these were normally killed by seedbed preparation and/or crop competition.

TABLE 3

CEREAL YIELDS IN METRIC TONS/HECTARE 1972/3

MON-2139		Spring Barley			Spring Wheat		Winter Wheat
kg a.e./ha	Huish	Mollington	Royston	Swineshead	Clare	Lutton	Bozeat
0.5	2.88				0.86	1.01	
1.1	3.09		2.83	4.11	0.97	1.46	
1.6	3.25	4.21	3.01	4.15			
2.2	3.18	4.15	3.00	4.21	0.89	1.67	4.23
2.7		4.15	2.76				4.21
4.4		4.22	2.68	4.34	0.91	1.59	4.03
Control	3.30	3.73	2.79	3.87	0.87	1.03	4.16
LSD(.05)	0.49	0.32	0.63	0.60	0.34	0.79	0.86

Direct Drilling. The sites at Bozeat, Huish, Wansford, Wittering and Lutton were direct drilled. Good performance and crop safety were recorded in winter and spring crops of wheat and barley.

Non cropped sites also gave good results indicating that cultivations after spraying are not necessary for the good performance of MON-2139.

Yield data taken from the 1973 harvest is shown in Table 3. The results confirm crop safety up to the highest rate used of 4.4 kg a.e./ha. Some sites showed a trend towards increased yields over control, but a significant increase was only obtained at Mollington.

DISCUSSION

MON-2139 killed all emerged weeds present at the time of spraying such as Agropyron repens, Agrostis spp., Avena spp., Holcus spp., Alopecurus myosuroides, volunteer cereals, all other seedling grasses and broadleaf weeds. Thus the chemical may be used for stubble cleaning. The results show that good control of Agropyron repens can be obtained up to one year after application in autumn or spring, at rates of 1.3 - 1.6 kg a.e./ha and above. When no perennial weeds are present 0.75 - 1.0 kg a.e./ha would be sufficient for stubble cleaning.

The results show that MON-2139 gives good control of undisturbed Agropyron repens under British conditions, although in undisturbed stubbles up to 95% of rhizome buds may be dormant (Cussans(1970b). Traditional stubble cultivations after harvest aimed at stimulating bud growth are not necessary with MON-2139, indeed they have been seen to be detrimental in the results. Cussans (1970b) states that cultivations in dry weather delay the sprouting of buds, leading to a poor leaf emergence and fragmentation of a rhizome system built up under the previous crop. For success with autumn chemical treatments for the control of Agropyron repens some moisture is required for regrowth, and with capillary moisture bud growth is stimulated by cultivations (Chancellor (1968)). Other herbicides for the control of Agropyron repens are more effective in combination with cultivations (Cussans and Wilson (1970)), but in very wet autumns the follow up treatments of chemical or cultivations may be impossible, leading to poor performance. MON-2139 being more effective on undisturbed weeds thus has an advantage over other herbicides which require cultivations.

Caseley (1974) conducted experiments in growth chambers and has shown that glyphosate quickly translocates within the plant under ideal conditions. In the field however, it is essential to wait until leaf symptoms, a wilting and yellowing of the foliage, appear before cultivating. These symptoms indicate that the chemical will have translocated throughout the rhizome system in most weather conditions experienced in Great Britain. Rainfall within 6 hours of spraying slowed down the appearance of leaf sumptoms and seriously reduced long term control.

In both early autumn and spring, cultivations leading to seedbed production may commence 10-14 days after spraying. However in the late autumn and winter, particularly in Northern British conditions, leaf symptoms are slower to appear, taking 30-50 days. Ultimate control is not reduced as reported by Evans (1972). Good performance under cold humid conditions as shown by Caseley (1974) will be advantageous in the North of Britain where other herbicides are often not effective after a late harvest. Limited experience of good performance in Scottish conditions has been confirmed by Erskine (1974).

Evans (1972) suggested that rates in excess of 1.5 kg a.e./ha were necessary to prevent regrowth of Agropyron repens. The results here, and elsewhere, (Seddon, (1974)), indicate a commercial rate of 1.44 kg a.e./ha (4 l/ha formulated product), given a good leaf area at the time of spraying.

Variability in performance, not commercially acceptable, is seen at 1.0 kg a.e./ha and lower rates. The addition of extra surfactant at low rates in other trials has not improved performance. The erratic performance at low rates may be due to the differences in growth between clones of Agropyron repens as demonstrated by Pooswang et al., (1972).

Some pre-emergence effects of a glyphosate salt at rates in excess of 8 kg a.e. /ha in greenhouse experiments have been reported by Thomas (1974). No such effects have been observed in the reported trials or in special field trials in Britain where up to 34 kg a.e./ha was applied pre-seeding, incorporated, and post seeding to the soil surface, for wheat and barley grown on sands, clays and organic soils.

MON-2139 may be used on 'couch' infested fields which are to be direct drilled. After harvest a good burn is essential to obtain a good regrowth of 'couch'. The kill is slower than with paraquat, and so it is preferable to wait for complete foliage dessication before direct drilling to ensure a covering of soil over the seeds.

The yields taken from the 1973 harvest following application of MON-2139 confirm that couch is not always competitive at the time when the crop is making its growth in May and June. (Cussans (1970a)). The standard farmer's control of paraquat and/or cultivations was sufficient to suppress the couch so that it did not seriously affect yields, but did not give satisfactory control. Yield differences are expected from the 1974 harvest due to heavy weed infestations and a lack of crop on the untreated plots. The dry spring weather affected the crop particularly spring barley, more than the established couch which was able to grow vigourously.

MON-2139 may offer a means of couch eradication because of its efficiency. However Agrostis spp. seed heavily, and Williams and Attwood (1971) have shown that Agropyron repens can produce large numbers of viable seeds. The time taken for reinfestation will depend on the standard of husbandry particularly stubble cultivations in the post harvest period following the application of MON-2139.

Acknowledgements

The author is grateful to J.C. Seddon and other members of Monsanto Limited for their help in carrying out this work. Thanks are due also to the farmers and distributors who provided the trial sites.

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ANCYMIDOL, A NEW GROWTH REGULATOR FOR ORNAMENTAL PLANTS

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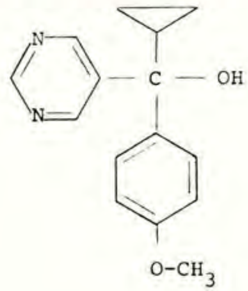
Summary Ancymidol, α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidine-methanol is a new growth regulator for ornamental plants and was previously known under the code, EL-531. Published studies on the activity of this compound are reviewed. Ancymidol shortens the internodes, and anti-gibberellin activity has been implicated as the possible mechanism of such physiological action. This conclusion is based on reversal of the effect of ancymidol by gibberellic acid application. Ancymidol can be applied as a soil drench or as a foliar spray, although soil drench applications are generally more effective than foliar sprays. Trials with cultivars of *Chrysanthemum morifolium*, *Euphorbia pulcherrima* and *Tulipa gesneriana* are described.

INTRODUCTION

Ancymidol, α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidine methanol, is a new growth regulator for ornamental pot plants.



$C_{15}H_{16}N_2O_2$ M.W. 256.28

The physical and chemical properties, and the toxicology of this growth regulator have been reported previously by Snel and Gramlich (1973).

Ancymidol reduces the elongation of internodes without affecting the number of leaves. Larson and Kimmins (1972) reported that pith cells of Chrysanthemum morifolium cv. Gay Anne sprayed with ancymidol became significantly shorter and wider than those of the untreated control. On the other hand, a soil drench application of ancymidol giving the same growth response, resulted in shorter pith cells without significant alterations in the width of these cells. Leopold (1971) suggested that ancymidol acts by virtue of being partly a gibberellin antagonist in growing plants.

Growth inhibition in the Mid-Century Hybrid lily, "Enchantment" could be reversed by an application of GA_3 (Dicks et. al. 1974). Shoub and de Hertogh (1974) demonstrated that a GA_{4+7} soil drench applied simultaneously with ancymidol to Tulipa gesneriana "Paul Richter" resulted in complete reversal of the growth inhibition caused by the growth inhibitor. These workers also reported that GA_3 was relatively ineffective in reversing the growth inhibition of ancymidol in tulips. In tulips, ancymidol appears to function through two mechanisms; it reduces the number of cell divisions in the intercalary meristem and it causes reduced cell elongation in the tulip internodes with a concommitant radial enlargement (Shoub and de Hertogh, 1974).

Ornamental plants which respond favourably to ancymidol treatments are listed by Snel and Gramlich (1973). Ancymidol can be applied either as a soil drench or as a foliar spray. The compound leaches readily in soils and is taken up effectively by plants. Growth retardation, irrespective of the species studied, appeared to be 2-5 times greater for soil drench applications than foliar sprays (Dicks, 1972; Larson and Kimmins, 1972; Moser, 1972; Snel and Gramlich, 1973). Ancymidol is considerably more active on ornamental plants than the growth regulators currently available. Dicks and Rees (1973) demonstrated that ancymidol was more than 5,000 times as effective as chlormequat chloride in controlling stem elongation of the Mid-Century Hybrid lilies "Enchantment" and "Joan Evans" when applied as soil drench. Dicks (1972) demonstrated that C. morifolium cv. Bright Golden Anne required a 200-fold higher concentration of daminozide than ancymidol to provide the same degree of growth inhibition when both compounds were applied as foliar applications. This great difference in activity was also demonstrated by Larson and Kimmins (1972).

The number of flowers in several cultivars of C. morifolium was not affected by ancymidol treatments (Larson and Kimmins, 1972) but increased concentrations of ancymidol resulted in a dose related delay in flowering (Dicks, 1972; Larson and Kimmins, 1972). Data presented by Dicks (1972) indicated, however, that the delays in anthesis of C. morifolium caused by foliar applications of either ancymidol or daminozide were not significantly different. Dicks and Rees (1973) observed a dose related delay in anthesis in Mid-Century Hybrid lilies as the result of soil drenches of ancymidol.

Pinched poinsettias (Euphorbia pulcherrima) treated with 0.25 or 0.50 mg ancymidol/10 cm. pot flowered one to two weeks earlier than the untreated control (Moser, 1972). Snel (unpublished data) noticed that "Deep Dark Tuneful" and "Regal Anne" cultivars of C. morifolium treated with only one foliar application of ancymidol, flowered 6-8 days earlier than plants grown in soil treated with chlorphonium chloride and followed by three foliar applications of daminozide. Notwithstanding this beneficial effect of ancymidol, the reduction of stem elongation was similar.

The research reported here demonstrates the effects of ancymidol on elongation growth, time of anthesis, size and number of flowers in several important European cultivars of C. morifolium, E. pulcherrima and T. gesneriana.

METHOD AND MATERIALS

Ancymidol was applied either as a soil drench or as a foliar spray to various Chrysanthemum morifolium cultivars, Euphorbia pulcherrima cv. Annette Hegg and Annette Hegg Lady, and as a soil drench to Tulipa gesneriana. Dilution series of ancymidol were prepared from the commercial formulation which is an aqueous solution containing 250 mg a.i./l. The formulated product was diluted with water and no additional spreader added. Details of application are given in the appropriate table in the results section of the paper. Commercially available reference products were used according to label recommendations. All experiments were conducted in commercial glasshouses in the Netherlands and Germany. In all instances, only one cutting or bulb was used per pot.

RESULTS AND DISCUSSION

Chrysanthemum morifolium

As shown in Table 1, the growth retardation of Chrysanthemum morifolium cv. Deep Dark Tuneful in response to similar concentrations of ancymidol was significantly greater when the compound was applied as a soil drench, rather than as a foliar spray. The differences in delay of anthesis, expressed as number of flowers in full bloom, appeared to be correlated with the application rate, although no significant differences were observed between the two application methods. It appears that the time of application and the quantity of a.i./plant are the factors determining the delay of anthesis, not the application method.

The growth retardation of this cultivar as a result of one foliar application of daminozide at 10.0 mg/plant a.i. was not commercially acceptable. In commerical practice, "Deep Dark Tuneful" is transplanted into soil treated with chlorphonium chloride and receives up to three foliar sprays of daminozide, i.e. 25.0 to 30.0 mg/plant a.i. Under those circumstances the delay in anthesis is similar to that caused by foliar applications of ancymidol at 0.5 mg/plant a.i.

In all of our experiments, irrespective of the cultivar used, ancymidol treatment did not affect the development of inflorescence colour in C. morifolium.

TABLE 1

Effect of ancymidol on elongation growth and time of anthesis of Chrysanthemum morifolium cv. Deep Dark Tuneful

Compound	Type Treatment *	Conc. Spray or Drench Solution (ppm)	Mg/Plant a.i.	% Growth Retardation	% Flowers in Full Bloom
Ancymidol	SD	2.5	0.1	37.5 ef **	46.9 bf
		5.0	0.2	53.6 h	45.2 bf
		15.0	0.6	62.5 j	16.1 gk
		25.0	1.0	76.1 l	11.9 hk
	FA	31.2	0.125	29.0 cd	52.8 bf
		62.5	0.25	32.6 de	45.2 bf
		125.0	0.50	44.5 g	25.4 fk
		250.0	1.0	59.9 ij	10.1 ik
Daminozide	FA	2500.0	10.0	9.7 b	63.5 b
Untreated Control	-	-	-	0.0 a (37.2 cm)***	100.0 a (13.8)***

* Soil drench application (SD): Drench volume 40 ml/8 cm pot. Application three weeks after initiation of photoinduction. Foliar application (FA): 4 ml spray solution/plant, 7 days after pinching when lateral shoots were 1.5 cm, 3 weeks after initiation of photoinduction.

** Figures represent the mean of 5 replications with 8 plants/replication. Means followed by the same letters are not significantly different at the 95% confidence level according to the Duncan's Multiple Range Test.

*** Figures in brackets represent the mean plant height above the rim of the pot and the mean number of flowers in full bloom, respectively. The total number of flowers was not significantly different between any of the treatments.

Euphorbia pulcherrima

In comparing the effects of ancymidol treatment on growth of Euphorbia pulcherrima, it should be borne in mind that only one application of ancymidol was used, whereas chlormequat chloride was applied four times according to normal commercial practice.

Providing the application is timed correctly (Snel and Gramlich 1973) a single application of ancymidol can provide an attractive alternative to the currently used method of inhibiting the growth of poinsettias by reducing expensive labour costs, and especially by producing aesthetically more desirable plants ready for marketing at an earlier date.

Foliar applications of ancymidol to pinched E. pulcherrima (Table 2) resulted in a significant decrease in plant height, and significant increases in both inflorescence size and flower number, when compared to untreated and commercially treated plants. No signs of leaf burning or phytotoxicity have been noted, even when the undiluted formulation of ancymidol was used as a foliar spray. Conversely, the foliage of ancymidol treated plants was usually more deeply pigmented than in untreated controls or reference treatments.

Soil drench applications resulted in the same growth retardation as foliar spray application. However, soil drench treatment resulted in a significant decrease in inflorescence size, and whilst the number of flowers were greater than in control plants, the effect was not statistically significant.

Although not listed in Table 2, ancymidol treated plants in this experiment, as well as in others, were in full flower 3-4 days earlier than untreated plants. This earlier date of full anthesis was also reported by Moser (1972).

Tulipa gesneriana

A large interest has been generated in the effect of ancymidol on pot-grown Tulipa gesneriana, both in the United States and in Europe (Shoub and de Hertogh, 1974).

Results from preliminary experiments conducted in Europe confirm those of U.S. workers (Table 3). In this particular experiment, applications were made on the day plants were moved from outside rooting beds into the glasshouse and a significant dosage related growth inhibition curve was obtained. In all of our experiments, when application was withheld until a later stage, a considerably higher dosage of ancymidol was required for equal growth inhibition.

Shoub and de Hertogh (1974) concluded that the internodes of tulip display a different sensitivity to ancymidol. The first internode is the most sensitive and the fourth the least responsive. Our findings (unpublished data) agree in that growth of the various internodes was not equally inhibited by ancymidol.

TABLE 2

Effect of ancymidol applications on elongation growth, size of inflorescence and number of flowers of pinched Euphorbia pulcherrima "Annette Hegg"

Compound	Application technique *	Mg/plant a.i.	Plant Height % of Control	Inflorescence Size % of Control **	Number of Flowers % of Control **
Ancymidol	FA	0.5	72.8 d	115.6 ab	121.4 a
	SD	0.5	66.6 d	91.4 e	114.2 ab
	FA	0.75	70.9 d	118.8 ab	121.4 a
	SD	0.75	67.4 d	95.2 de	114.2 ab
Chlormequat	FA	X-rate	89.1 c	103.0 cd	89.2 c
Untreated control	-	-	100.0 b	100.0 de	100.0 bc

* One application 4 weeks after pinching. Foliar application (FA), spray volume 10 ml/plant; Soil drench application (SD), drench volume: 50 ml/12 cm. pot.

**Mean of 6 replications with 10 plants/replication. Means followed by same letter are not significantly different at the 95% confidence level according to Duncan's Multiple Range Test.

TABLE 3

The effect of soil drench applications of ancymidol on the growth of Tulipa gesneriana cv. Brilliant Star

Mg/plant a.i.*	Plant Height % of control **
0.075	100.7 a
0.10	97.0 ab
0.125	92.7 b
0.25	63.5 c
0.3125	49.6 d
0	100.0 a (34.25)

* Application made on the same day the plants were moved from the outside rooting beds. Shoot length 2-4 cm. Shoots were yellow-brown.

** Means of 4 replications with 36 plants/replication. Means followed by the same letter are not significantly different at the 95% confidence level according to Duncan's Multiple Range Test. Figure in brackets represents the height of the untreated control in cm.

Although more research is required to determine the response of various Tulip cultivars to ancymidol treatments under European conditions, it is felt that soil drench treatments with ancymidol offers interesting possibilities for expanding the use of tulips as indoor potted plants.

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PP528 - A NEW PHENYL TETRAZOLE PLANT GROWTH REGULATOR

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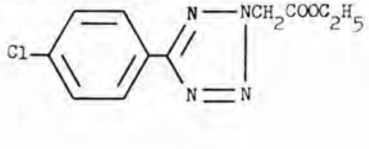
Summary PP528, ethyl 5-(4-chlorophenyl)-2H-tetrazol-2-ylacetate, is a new experimental growth retardant from Plant Protection Ltd. Foliar application of this systemic compound selectively inhibited the terminal growth of many woody and non-woody species. Vegetative shoot growth of apple, plum and cherry was effectively reduced at rates of 50-500 ppm, depending on species. Results on apple and plum were comparable to daminozide used at rates of 1500-2500 ppm. Internode length was reduced with apple and cherry but not plum. Phytotoxicity was usually restricted to minor chlorosis and leaf curl; no fruit damage was observed. A first trial on grape in 1973 showed increases in berry size and sugar content following a reduction in shoot extension. Six trials are showing a similar effect on shoot growth this year at 40-80 ppm. PP528 has shown some promise for checking top growth of peanuts and as a chemical pinching agent for Azaleas.

Resumé PP528, ethyl 5-(4-chlorophenyl)-2H-tetrazol-2-ylacetate, est un nouveau produit experimental retardeur de croissance de Plant Protection Ltd. L'application sur les feuilles de ce composé systémique retardait de façon selective, la croissance terminale de nombreuses espèces ligneuses ou non-ligneuses. La croissance végétative des racines de pommiers, pruniers et cerisiers était réduite, de façon efficace, aux doses de 50-500 ppm, selon les espèces. Les resultats obtenus sur pommiers et pruniers étaient comparables à ceux du daminozide, utilisé aux doses de 1500-2500 ppm. La longueur des entrenœuds était réduite sur les pommiers et cerisiers, mais non sur les pruniers. La phytotoxicité se limitait habituellement à une faible chlorose et à l'enroulement des feuilles. Un essai préliminaire sur la vigne, en 1973, entraina une augmentation de la taille des grains et de la teneur en sucre, aprés réduction de la croissance des racines. Six autres experiences, effectuées cette année, montrent un resultat identique sur la croissance des racines, aux doses de 40-80 ppm. PP528 donne des resultats encourageants pour réduire la croissance des feuilles de cacahuètes et entraine un pincement chimique des Azalées.

INTRODUCTION

PP528 is a new systemic growth retardant with the chemical name ethyl 5-(4-chlorophenyl)-2H-tetrazol-2-ylacetate and the structural formula:-



PP528 has been found to retard or inhibit the vegetative growth of plants when sprayed on to the foliage. It appears to be readily translocated from leaves to the apical meristem the growth of which is arrested or interrupted. The intensity of the effect and its duration depend on the species treated and the rate of chemical applied. Suppression of apical growth can lead to shorter stems and by the reduction or elimination of apical dominance to the stimulation of lateral buds and increased branching in some species.

During the last 2-3 years trials designed to show the spectrum of activity of the compound have been initiated in a range of agricultural situations. Activities under examination include the control of vegetative growth, flower induction and yield enhancement of fruit trees, growth suppression and yield enhancement in grape vines and peanuts, simple growth control in hedgerow species and attempts to improve habit in ornamentals.

METHODS AND MATERIALS

Formulation and application

As PP528 is insoluble in water a water-dispersible granular formulation, JF3912, containing 50% w/w active ingredient was used. To ensure adequate cover of the foliage a surfactant was necessary and Cirrasol ALN-WF (an ethoxylated mixture of cetyl and stearyl alcohols) was incorporated at 0.1% w/v in the spray solution.

Large mature trees were sprayed using a Land-Rover mounted motorised sprayer fitted with an Allman No. 10 fan nozzle, smaller trees with a CO_2 pressurised hand sprayer fitted with a Delavan cone nozzle and the grapes with a tractor mounted 6-nozzle inverted U-boom. The volume of application in all cases was to the point of run-off or approximately 1200 l/ha. An Oxford Precision Sprayer was used to treat vegetable crops at 400 l/ha. Four to six replicate trees, vines or plots were used in these trials, mostly in randomised block designs.

Assessments of growth and flowering

Shoot growth measurements on mature trees were taken at intervals throughout the season on 10 random or 10 marked shoots per tree. A smaller but fixed number of shoots per tree were measured in trials on younger trees. Grape shoots were measured, at intervals, from a tag on the fifth internode to the apex. Wherever possible all flowers or clusters of flowers were counted on each tree but if over-all size precluded this, counts were made on four large well-separated branches per tree.

RESULTS

Fruit trees

Growth retardation. An appreciable and consistent reduction in growth has been obtained with a range of fruit tree species. Table 1 shows that shoot growth of Cox's Orange Pippin (COP) and Bramley varieties was reduced 10-20% and 20-35% respectively with PP528, at rates up to 150 ppm, applied 2-4 weeks after full bloom.

There was a distinct graded varietal response with Cox's Orange Pippin being less affected than Bramley. Worcester Pearmain was the most susceptible and the young maiden trees tested showed a 75% reduction in shoot extension at 100 ppm. Similarly with young Cox's Orange Pippin trees, trial 3, the chemical produced a more pronounced effect when compared with results from mature trees. Daminozide (as 'Alar') produced similar growth reduction when applied at 1500-2000 ppm.

Table 1

Apple - Effect of PP528 on shoot length and flowering

Shoot growth (cm) 1973

Treatment	ppm	Trial no.	1	2	3	4	5	6
		Variety	COP	COP	COP	Bramley	Bramley	Worcester
		Time from spraying (weeks)	12	12	7	8	8	7
PP528	50		*34.7	37.7		**34.3	**35.9	
PP528	100		**33.1	36.1	*10.5	**28.2	**34.4	**5.1
PP528	150		**28.1	40.1		**27.3	**29.4	
PP528	200				12.4			**4.2
PP528	300				**9.8			**2.4
Daminozide	1500					**27.0	**32.6	
Daminozide	2000		**30.2	31.3				
Untreated			38.6	37.7	15.9	42.0	43.9	17.0
				Number of flower clusters				
PP528	50		121	13.2		*27.4	29.7	
PP528	100		97	13.8	34	**32.5	32.5	26
PP528	150		106	14.4		19.5	29.1	
PP528	200				25			25
PP528	300				42			*10
Daminozide	1500					**30.5	33.5	
Daminozide	2000		106	**15.4		24.8A	31.5A	
Untreated			92	13.1	51	23.2	29.2	29

In all tables * and ** indicate those results significantly different from untreated plants at the 5% and 1% levels respectively. A = Autumn application.

Flower clusters are expressed per branch for trials 1, 4 and 5, per 50cm of branch for trial 2 and per tree for trials 3 and 6.

Measurements of shoot length and leaf number taken after completion of the season's growth showed that internodal distances were reduced consistently and significantly whereas the number of leaves per shoot remained constant.

Four year Marjorie's Seedling (MS) plums were sprayed over-all at two growth stages; early, 70% petal fall, 1 cm shoot length and 4-6 leaves and late, four weeks after full bloom, 10cm shoot length and 10-12 leaves. Data in Table 2 show that early treatment with rates up to 250 ppm was ineffective whereas late treatment led to significant stunting of 30-40% at 200 ppm. Higher rates than this did not give a greater effect.

Table 2

Marjorie's Seedling Plum - Effect on PP528 on shoot length and flowering

Treatment	ppm	Date of treatment	Shoot growth (cm) 1973 May 9	Shoot growth (cm) 1973 May 24	Flowers/tree 1974 May 9	Flowers/tree 1974 May 24
		Time from spraying (weeks)	8	10		
PP528	50		68.8		749	
PP528	100		72.9	63.4	948	790
PP528	200			**42.5		693
PP528	250		59.8		1092	
PP528	500			**38.1		886
Daminozide	2500		65.7	66.4	1115	705
Untreated			67.5	68.9	493	493

In contrast to apple the number of leaves per shoot was reduced whilst internodal distance was not greatly affected (Table 3).

Table 3

Marjorie's Seedling plum - Effect of PP528 on leaf number, internode length and no. of lateral branches

Treatment	ppm	Leaves/ branch	Stem length (cm)	Internode length (mm)	Lateral shoots/ branch
PP528	100	34.7	72.7	21	**8.2
PP528	200	**26.4	**47.7	*19	**9.1
PP528	500	**24.3	**50.4	22	*10.6
Daminozide	2500	38.4	82.7	22	1.6
Untreated		35.1	77.0	22	1.5

Trees were treated May 24th and assessed August 30th.

Daminozide produced a short duration effect which had disappeared by 4-6 weeks.

A second trial on Victoria produced similar results but as a bacterial canker disease necessitated complete destruction of the trees before flowering the data have not been included.

Merton Glory and Merton Bigarreau cherry varieties, sprayed in June when growth of 26-28 cm had already occurred, were considerably checked (Table 4). The former were retarded by 40-80% at 200-500 ppm.

Table 4

Cherry - Effect of PP528 on shoot length and flowering

Treatment	ppm	Variety	Shoot growth (cm) 1973 Merton Glory	Shoot growth (cm) 1973 Merton Bigarreau	Flowers/tree 1974 Merton Glory	Flowers/tree 1974 Merton Bigarreau
		Time from spraying (weeks)	7	7		
PP528	200		*28.6	36.0	340	336
PP528	500		**9.7	25.1	74	110
Untreated			51.5	54.1	268	518

Only two replicate trees were available for each treatment and with only one untreated Merton Bigarreau tree the data were not significant ($P = 0.05$) for this variety, although growth reduction was appreciable. As with apple the internodal length was shortened but there was no effect on the number of leaves per shoot.

Phytotoxicity. This was not generally a serious problem and the effects in most instances were temporary. With Cox's Orange Pippin and Bramley slight marginal necrosis was observed on the younger leaves 1-2 weeks after treatment with the highest rates of PP528. The Worcester Pearmain maiden trees showed up to 20% leaf scorch and 13% apical abscission at 100 ppm. These effects were not observed on mature trees. The loss of apical dominance induced several axillary buds on each shoot to commence growth.

Marjorie's Seedling plum showed some slight chlorosis and leaf curl but no leaf scorch even at 500 ppm. Reduction of apical dominance again led to axillary bud development (Table 3). In this instance the trees had acquired a distinctly bushy compact habit by the year end.

Marginal leaf browning occurred with cherry at 200 ppm and some splitting of the leaf margins was apparent at 500 ppm. Additionally leaves adopted a more vertical hanging position. By early summer 1974 there was no residual growth effect from the previous years spraying on apple but there was an indication that both cherry varieties and Marjorie's Seedling plum were somewhat slower growing. There was no damage to fruit in any trial.

Yield. In the year of treatment there was no significant reduction in total yield, fruit number or fruit size of apples. The amount of fruit produced in cherry and plum trials was insignificant but no obviously adverse effect was observed.

Effect on flowering in the year after treatment. Only in one case, trial 4, on Bramley, was there a statistically significant increase in flowering that could be related to chemical treatment (Table 1). Daminozide produced a positive effect in this trial and in trial 2 on Cox's Orange Pippin.

Data from the plum trial (Table 2) indicate an appreciable and consistent flowering response particularly with the early application (where no growth effect was noted) but disappointingly this was not significant at the 5% level, presumably because the over-all tree variability was too great.

There was an indication of a reduction in flower number with cherry at 500 ppm.

Grapes

A first trial on Thompson Seedless variety in Cyprus in 1973 showed about 50% reduction in shoot extension, 11% increase in berry size and 8% increase in sugar content when 50-200 ppm PP528 was applied at the post shatter stage when berries were 5-6 mm in diameter.

Preliminary data available from 5 of 6 trials now under way in California (Table 5) show reliable control of shoot growth at rates as low as 40-80 ppm. There has been no effect on rachis extension and phytotoxicity has been confined to slight chlorosis and necrosis of the younger leaves with some accompanying leaf curl.

Table 5

Grapes, Thompson Seedless - Effect of PP528 on shoot length

Shoot length (cm) 1974

Treatment	ppm			1	2	3	4	5
		Trial number		1	2	3	4	5
		Growth stage treated	(% Cap loss	50		90		
			(Berry diameter (mm)		2-3		3-4	4-5
		Time from spraying (days)		22	20	28	15	20
PP528	20			31.6	28.2	21.8	21.7	26.8
PP528	40			18.7	18.5	20.7	15.2	25.8
PP528	80			16.9	13.3	19.3	14.0	19.8
Untreated				26.5	29.0	33.4	19.4	31.3

Statistical analysis not yet available.

Other woody species

Unnamed cultivars of the ornamental genera Forsythia, Deautzia and Weigelia were only slightly retarded at 400 ppm and subsequent growth was uneven.

PP528 is showing some promise in replacing the hand-pinching normally practised for the production of short, busy Azalea plants.

Peanuts

In USA vine growth was retarded 19.5, 9.8 and 9.0% at rates of 2.0, 1.0 and 0.5 kg/ha. Daminozide (as Kylar 85) gave only 4% reduction at 1.0 kg/ha. Neither chemical gave any yield improvement in this first trial. Slight interveinal chlorosis at 2 and 1 kg/ha was the only damage observed.

Vegetables

French bean (Phaseolus spp). With Haricot vert type bean, variety 'Cascade' increases of 7-20% in total fresh weight, 22-35% in commercially acceptable fresh weight and 24-37% in the number of commercially acceptable beans were obtained with 100-200 g/ha. The variability of the trial was such that the data were not significant at 5% and their confirmation is therefore necessary.

Pea (Var. Early Onward). There was no significant response with rates up to 200 g/ha.

Brussels sprouts. The apical growth of three varieties of Brussels sprouts; Peer Gynt, Frigostar and Topscore, has been stopped by sprays of 0.25-2.0 kg/ha PP528 applied in 400 l/ha.

DISCUSSION

In recent years there has been a growing interest in the general use of plant growth regulators for the control of growth and flowering in fruit trees, vines and other crops. In addition their use may facilitate normal cultural practices where dense growth often hinders cultivation, spraying and harvesting.

Flower induction in young vigorous fruit trees often follows a temporary check in growth. Daminozide has been shown to reduce apical dominance and effect flower induction in young vigorous apple trees, (Williams, 1972), increase flowering and fruit set of Marjorie's Seedling plum (Modlibowska, 1973), reduce tree size, hasten flowering and ripening in cherry (Modlibowska, 1973), Chaplin and Kenworthy, 1970), reduce elongation of young grape vine shoots (Weaver and Pool, 1971) and increase fruit set (Weaver, 1972).

In comparison, PP528 has been very successful in reducing vegetative growth of apple, plum, cherry and grape.

Applications to apple made within the few weeks after bloom, normally accepted as the critical period for any flower bud stimulation, gave only a slight indication of a positive effect on flowering. Luckwill (1969) has shown that the optimum concentration of daminozide for flower production was considerably less than that required for maximum growth suppression. Interestingly, in this connection the apparent increase in flowering obtained with Marjorie's Seedling plum was greater with rates of PP528 which did not produce any growth suppression, although it is also possible that the earlier application may have been at least partly responsible.

Only with cherry, at the high rate of 500 ppm, was there any evidence of flower suppression and here it was associated with a rather massive degree of shoot retardation. The reduction in whole tree size of Marjorie's Seedling plum at high rates of PP528 and the denser canopy resulting from the lateral shoot proliferation, would certainly produce an undesirable diminution in light penetration.

The first grape trial showed that increased berry size and sugar content followed PP528 induced growth reduction. Further trials presently under way in California have shown already a parallel effect on shoot extension and yield data will be available later this year.

With some encouraging results, continuing research on peas, beans, soya and cotton is based on the idea of reducing excessive vegetative growth and possibly diverting assimilates and nutrients from the growing tips with the consequent improvement of yield. Possible benefits could be in the form of earlier harvest (beans and cotton), improved pod and boll set (beans, soya and cotton), easier cultivation and harvesting and denser planting (peanuts).

In general it is evident from the results that there are big differences in dose response between species and even between different varieties. Hopefully formulation studies will effect changes in foliar penetration and allow some improvement in this respect.

Flowering responses are the result of a highly complex series of hormone interactions within plants and further work will be necessary to determine fully any practical commercial uses of PP528.

Acknowledgements

I am especially grateful to my colleagues in ICI United States, particularly Dr S. R. Colby and Mr E. E. King at Goldsboro, N.C. and Mr L. Whitendale at Visalia, Ca. for their considerable part in the U.S.A. Programmes.

I wish also to acknowledge the help and co-operation afforded by Messrs. D. Chandler, D. Mount, A. B. Scripps and A. Jackson who willingly allowed the use of their orchards.

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USE OF A PLANT GROWTH REGULATOR MIXTURE FOR PARTHENOCARPIC FRUIT SETTING IN APPLE

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Summary The need for regularised cropping in the British fruit industry is examined. It is pointed out that much of the fluctuation is due to frost damage or pollination failure of blossom. Reference is made to experiments conducted with plant growth regulator sprays which have enabled unpollinated Cox's Orange Pippin fruit to develop to maturity in each of the past seven years, and which have shown that the optimum timing for application appears to depend on the prevailing weather conditions during flowering. In 1974, application at 50% petal fall was more effective than at five or ten days later.

Experiments investigating possible disadvantages of spraying with plant growth regulators are also described. No reductions in flower bud numbers were found in the year following spray application. Parthenocarpic Cox fruit was found to be indistinguishable from unsprayed seeded fruit in taste, shape and storage ability, though it was significantly smaller. Possible commercial uses of such sprays are discussed.

Resume Le besoin de régularité des cultures fruitières en Grande-Bretagne est examiné. On montre que la fluctuation actuelle est en grande partie imputable aux dégâts causés par la gelée et à la non-pollinisation des fleurs. On se reporte à des experiences effectuées avec traitement aux hormones par pulvérisation, grâce auxquelles le fruit non pollinisé de la Cox's Orange Pippin a pu parvenir à maturité durant chacune des sept années passées. Ces expériences on montré que le moment le plus propice de l'application dépend des conditions atmosphériques pendant la fleuraison. En 1974, une application fut plus efficace alors que 50% des pétales étaient tombés que cinq ou dix jours plus tard.

On a aussi décrit des expériences effectuées dans le but d'étudier les désavantages éventuels du traitement aux hormones par pulvérisation. Aucune réduction du nombre des boutons floraux n'a été trouvée dans l'année suivant le traitement par pulvérisation. Le fruit parthénocarpique de la Cox s'est révélé nullement différent de celui à pépins non traité en ce qui concerne le goût, la forme et le comportement en locaux de conservation, bien qu'il ait été sensiblement plus petit. Les éventuels emplois commerciaux du traitement aux hormone par pulvérisation sont l'objet d'une discussion.

INTRODUCTION

The promotion of fruit setting has recently become a significant use of plant growth regulating substances. Over the last twenty years, apple fruit output per unit area in Britain has increased considerably; for example, a comparison between two average years, 1953 and 1970, shows that the national average dessert apple production in this country rose from 6·5 to 11·0 t/ha. This increase has largely been due to advances in cultural techniques, including the use of new chemicals to control pests, diseases and weeds. If British fruit growing is to continue to survive and increase in efficiency, it is imperative that a regular crop of high quality fruit is produced with greater reliability. At present, cropping can vary considerably from year to year. In 1971, dessert apple production was 12·43 t/ha yet, in the following year, the figure was 8·44 t/ha. Some of this may be due to low numbers of flower buds formed in the previous season, but a good deal of this variability is caused by the prevailing weather conditions at flowering time, e.g. frost damage of blossom or bad pollination conditions.

Though the regulation of flower numbers by plant growth regulator application is, at present, still rather speculative, the use of growth regulators to improve fruit set itself appears promising, and increasing the generally low percentage of flowers maturing to marketable fruit can make a substantial difference to yield. The development of normal apple fruit is dependent on successful pollination and, as Luckwill (1953) has shown, such development is the result of hormone production by the developing seed. Seedless fruit production is very rare. Gorter and Visser (1958) studied the ability of 21 different varieties to set parthenocarpically (i.e. without seeds) and found that only 4 were capable of yielding any mature seedless fruit at all and, even then, not in every year. Some cultivars have been found to set fruit after frost has destroyed the ovules or styles (Swarbrick, 1945; Abbott and Luckwill, 1962). However, until recently, seedless fruit of our most widely grown commercial variety of dessert apples, Cox's Orange Pippin, had not been recorded.

In 1971, Kotob and Schwabe reported that a single aqueous spray containing 600 mg/l gibberellic acid (GA_3), 300 mg/l 6-(benzylamino)-9-(tetrahydro-2-pyranyl)-9H-purine (SD8339, a synthetic cytokinin), and 40 mg/l naphthoxyacetic acid (NOXA) was effective in setting Cox flowers which had not been pollinated. The timing of the spray application appeared to be fairly critical, and two weeks after 50% petal fall seemed to be the optimum. The results of the experiments presented below are to a considerable extent concerned with the assessment of possible disadvantages of spraying Cox trees commercially.

MATERIALS AND METHODS

To prevent any natural pollination, flowers were decapitated at the 'pink bud'/'balloon' stage by cutting away petals, anthers and stigmas with a razor blade. In plant growth regulator trials, the clusters were thinned to ten on each length of branch studied and all but two flowers removed from each cluster including the 'King' flower. The 1974 experiment on the optimum time of spray application serves as a good example of the technique. In this experiment, seven Cox trees were selected, each being 'split up' into four branch areas. In each area, the clusters were thinned to 50, making a total of 100 flowers for each treatment on the tree. The four treatments were randomly allocated within each tree. In the first treatment, a plant growth regulator mixture (300 mg/l GA_3, 300 mg/l NN'-diphenylurea, 40 mg/l NOXA) was applied to the decapitated flowers at the time of 50% petal fall as an aqueous spray. Five days later, the same mixture was applied to another 100 flowers, and, after a further five days, to another 100. The fourth group of flowers was used as unsprayed controls.

Data from a comparative experiment carried out in 1973 are presented in Table 1, in which it was also possible to include observations on any after-effects on the treated trees. In this experiment six small Cox trees on M9 rootstock were 'divided' into two approximately equal parts. All flowers were thinned to two per cluster and, on one randomly selected half-tree, the remaining flowers were decapitated and sprayed with a plant growth regulator mixture after approximately seven days. After three to four weeks, the number of fruitlets on each half-tree were made equal by removing the excess from the seeded part. This process was again performed later in the season after 'June drop'. In this manner, the two parts of a tree were bearing the same number of fruit throughout the season. The fruit was collected at harvest and the data on size, weight and seed number recorded.

In spring,1974, measurements were made on these six trees of both the number of flower clusters and the length of fruiting wood. The data were collected when the buds had burst and the unopened flowers were visible.

In the storage trial, equal numbers of parthenocarpic and seeded fruit were kept in a cold store for 4 months and then compared for incidence of infections.

RESULTS

In every year since 1968 parthenocarpic Cox fruit was obtained with plant growth regulator sprays. Flowers were prevented from receiving pollen either by decapitation or by being covered with muslin to prevent flying pollinating insects from reaching them. In 1972, a set of 6% was achieved without pollination.

As found by Kotob and Schwabe (1971), the timing of the spray application appears to be fairly critical, particularly when the flowers have been cut. Drying winds and prolonged sunshine accelerate senescence of the unpollinated flower. Once an abscission layer has formed it seems unlikely that a plant growth regulator application could prevent abscission. During the 1971-1973 period, weather conditions at Wye were characterised by long periods of bright sunshine during the blossom time. It was observed that the hormone applications were more effective when applied at or soon after petal fall. In 1974, an experiment was carried out to compare the effectiveness of a plant growth regulator spray applied to decapitated flowers at various stages of development. It was found that spray applied at 50% petal fall resulted in a 4·0% set, whereas spray applied five days later or ten days later only gave 0·3 and 0·4% sets respectively, not significantly different from the unsprayed control (0·9%).

Foliar application of GA_3 had sometimes been observed to stimulate shoot development and inhibit flower bud formation in pear trees.

Table 1

The number, shape and weight of apple fruits harvested in 1973, and the subsequent flower bud production in 1974; a comparison between hormone-sprayed and control tree-half-units

		Fruit picked in 1973					Measurements made in Spring 1974		
Tree	1973 Trtmnt	Number of Apples P	A	S	Mean Wt(g)	Mean L/D	Flower Buds	Branch Length (cm)	Buds/cm
A	hormone	2	0	0	122·9	0·817	284	1433	0·198
	control	0	0	0	-	-	549	2949	0·186
B	hormone	16	0	11	131·7	0·834	429	2042	0·210
	control	0	1	14	179·0	0·826	343	2045	0·168
C	hormone	5	0	0	176·5	0·817	191	1816	0·105
	control	0	0	5	221·5	0·829	325	2037	0·160
D	hormone	17	0	4	113·7	0·831	239	1483	0·161
	control	0	7	18	158·1	0·819	264	1361	0·194
E	hormone	31	2	2	122·0	0·809	318	1387	0·229
	control	0	1	40	162·1	0·804	422	2083	0·203
F	hormone	45	2	0	95·4	0·817	354	2111	0·168
	control	0	14	46	139·0	0·812	370	2685	0·138
Total	hormone	116	4	17	115·5*	0·820	303	1712	0·179
	control	0	23	123	155·7*	0·813	379	2193	0·175

*Mean weights significantly different at P = 0·001.

P, A, and S refer to the number of parthenocarpic fruit, the number of fruit having only aborted seeds, and the number of fruit having at least one plump seed, respectively.

L/D refers to the quotient, length of apple/diameter of apple.

Branch length refers to the total length of fruiting spurs and flowering maiden wood.

Experiments have been performed to determine whether the plant growth regulator mixtures used might reduce flower bud numbers in the year after spray application in our work with apples. Table 1 summarises the results obtained from an experiment carried out in 1973/4. It can be seen that the number of flower buds/cm on half-trees which had been sprayed with a plant growth regulator mixture and borne predominantly parthenocarpic fruit was very close to the count on half-trees which had received no spray and borne a similar number of seeded fruit. Statistically, no significant differences could be demonstrated.

It has often been noticed that fruit sprayed with GA_3 is more elongated than unsprayed fruit (cf. parthenocarpic pears). This elongation can occur with Cox, but only if high concentrations of GA_3 are used. It can be seen from Table 1 that the length/diameter ratios for the sprayed and unsprayed fruit are very similar, again no statistical difference being found.

Parthenocarpic fruit tend to be slightly smaller than seeded fruit and this is shown in Table 1 where the reduction in size is statistically significant.

The storage ability of parthenocarpic apples was compared with that of seeded fruit in 1972, and no differences were observed. In both 1971 and 1972, tasting panels, when given unnamed pieces of both parthenocarpic and seeded apple flesh, gave purely random preferences.

Several experiments have been undertaken to test the effectiveness of plant growth regulator mixtures in setting seedless fruit in other apple varieties. The cooking apple cultivar, 'Grenadier', was found to be the most responsive to plant growth regulator applications and gave 10·5 and 15·0% parthenocarpic sets in 1972 and 1973.

DISCUSSION

It now appears possible to set Cox fruit without pollination occurring. For seven successive seasons at Wye, plant growth regulator sprays have enabled unpollinated flowers to develop to mature fruit of marketable size. For hormone spraying to be used commercially, several questions must be satisfactorily answered:-

i. Does the value of the increased crop and the improved regularity of cropping exceed the cost of the spray and application?
ii. Do the parthenocarpic fruit have any characteristics which render them unsaleable?
iii. Do the sprays have any undesirable effects on the trees?

During the last three years we have endeavoured to answer these questions. In general, the answer is very promising as far as questions i. and ii. are concerned. Experiments have shown that, in taste, shape and storage ability, plant growth regulator-stimulated parthenocarpic fruit are indistinguishable from seeded fruit.

As regards question iii. qualitative observations of tree growth have failed to show <u>any</u> adverse spray effects on the growth of Cox trees, and in two quantitative experiments, designed to detect such effects, no significant differences in flower bud counts were found in the following year.

The most likely situation in which plant growth regulator sprays would be used commercially would be when the fruit tree is capable of bearing a good crop but fails due to lack of pollination or late frosts. Cox orchards are usually inter-planted with pollinator trees such as Worcester, Lord Lambourne or most recently *Malus* species (Church, Goodall and Williams, 1974). Often the value of the crop taken from the pollinator trees is lower than that from the Cox trees. It would be advantageous to plant Cox as a monoculture both for easier picking and increased crop value. It might be envisaged that, in this situation, cropping could be raised to an acceptable and regular level by the use of plant growth regulator sprays.

Areas or particular fields in this country which would be suitable for apple growing but cannot at present be used for this purpose because of a high frost risk, could be brought into production with the use of hormone sprays.

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Proc. 12th Br. Weed Cont. Conf. (1974)

THE EFFECTS OF COMBINED APPLICATION OF CHLORMEQUAT CHLORIDE AND A HERBICIDE MIXTURE TO WHEAT

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Summary A greenhouse experiment is described in which spring wheat, cv. Pompe, was treated with the growth retardant, chlormequat chloride and a herbicide mixture, alone or in combination. The herbicide mixture contained dichlorprop, MCPA, ioxynil and bromoxynil (Oxitril 4). Chlormequat chloride and the herbicide mixture both reduced stem length considerably and the shortening effect was significantly increased by the combined application. Grain yield was reduced 15 % by chlormequat chloride and 49 % by the herbicide. There was no significant difference in the influence on grain yield by the herbicide alone or in combination with chlormequat chloride. The reduction in grain yield caused by the retardant was attributed to a lower thousand grain weight, whereas the herbicide decreased the number of ears per plant, the number of grains per ear as well as the thousand grain weight. The effect of the herbicide on the yield is contradictory to results obtained in Swedish official field trials on winter wheat. It therefore appears that winter wheat and spring wheat are influenced differently by the herbicide.

INTRODUCTION

The use of the growth retardant chlormequat chloride is not generally recommended for wheat production in Sweden. The reason for this is that lodging in wheat normally seems to be a less important problem in Sweden than in many other countries. Secondly there is a considerable risk of yield decreases and the chances of profitable yield increase are very small when the retardant is applied in cases where untreated wheat would not have lodged (Wünsche, 1970a, Bengtsson, 1971). However, the weather situation during the last three years has caused more lodging in wheat crops than usual and for that reason the farmers' interest in chlormequat chloride treatment has increased. Also the possibility of applying the growth retardant in combination with herbicides has contributed to this interest.

Much experimental work has been carried out with combined application of chlormequat chloride and various herbicides (see Sturm, 1965, Jung et al., 1966, Niemöller, 1968, Sandford & Stowell, 1968, Smit, 1968 and Siebert et al., 1972). According to Frohner (1965) neither the shortening of wheat by chlormequat chloride nor the weed killing properties of the herbicides were changed.

If the herbicide scorched the crop the scorching was sometimes increased by application of the retardant, but the effect was not serious or permanent. Crop yields were not adversely affected by chlormequat chloride or herbicides, alone or in combination (Caldicott & Nutthall, 1968).

Some herbicides also reduce stem length. Engström (1965) reported an increased stem shortening effect of chlormequat chloride in combination with MCPA + dicamba and 10 % yield losses in comparison with MCPA + dicamba alone.

Recently the Swedish retailer of chlormequat chloride (formulated as "Cycocel"), in advertisments reported 12 % yield increases of winter wheat treated with "Cycocel" in combination with the herbicide "Oxitril 4", containing dichlorprop (350 g/l), MCPA (130 g/l), ioxynil (58 g/l) and bromoxynil (38 g/l). One of the purposes of this communication is to show that those results should be viewed with care. It is also true that in official field trials with combined application of chlormequat chloride and "Oxitril 4" to winter wheat, yield increases have been obtained (Weeds and Weed Control, 1974). However, in these trials there were no treatments with the retardant alone and therefore it is not possible to draw any certain conclusions from the results whether there was an interaction between the retardant and the herbicide.

This paper describes a greenhouse experiment with spring wheat treated with chlormequat chloride and "Oxitril 4", alone or in combination.

MATERIAL AND METHODS

The experiment was conducted with spring wheat, cv. Pompe, and started on April 8, 1974. The plants were grown in a glasshouse in 3 litre plastic pots containing an organogenic soil. Three weeks after sowing the plants were thinned, six plants of a uniform size being left in each pot. The soil was fertilized once every week by adding 250 ml per pot of a nutrient solution containing 2 g/l of a mixed fertilizer. The fertilizer contained 17.5 % N, 4.6 % P and 9.2 % K.

Treatments were given four weeks after sowing (in early tillering stage). Spray applications (eight 6-plant replicates) were as follows:

untreated (control); "Cycocel" (10 ml/l), equivalent to 4 g chlormequat chloride/l); "Oxitril 4" (20 ml/l); "Cycocel" + "Oxitril 4" (the same amounts as in their separate application).

The spraying was carried out with special equipment. The pots were placed on a conveyor belt with a constant speed of 15 m/min. On this belt the plants passed under a spraying nozzle giving 0.8 l/min at a pressure of 3 kg/cm^2.

Due to intense sunshine it was often impossible to control the greenhouse temperature which varied between 18° and 27° C during the day and between 12° and 20° C during the night. The relative humidity varied between 40 and 90 %. Supplementary light was given by means of fluorescent tubes so that the day length throughout the experimental period was never less than 18 hours.

As chlormequat chloride has a strong influence on transpiration (Wünsche, 1970b and 1971) the water content of the soil was checked daily by weighing the pots. Water was added to each pot to bring it back to a predetermined weight. In order to compensate for environmental differences the pots were circulated around the greenhouse bench.

The plants were harvested when they were well ripened, 110 days after sowing.

RESULTS

As can be seen from Table 1 the herbicide "Oxitril 4" as well as the retardant, reduced stem length and the length of ears considerably and the shortening effect was increased by the combined application of the growth retardant and the herbicide. Analysis of variance showed a strong interaction between chlormequat chloride and "Oxitril 4" in this respect. The reduced stem length also resulted in a decreased straw yield. The decrease was strongest for the application of the herbicide but there was no interaction between the retardant and "Oxitril 4".

Table 1

Influence of chlormequat chloride and the herbicide "Oxitril 4" on plant length, yield components and yield of spring wheat, cv. Pompe, means and the S.E. of mean

	Untreated	Chlormequat chloride	"Oxitril 4"	Chlormequat chloride + "Oxitril 4"
Plant length, cm	100.4 ± 1.0	78.3 ± 1.4***	83.9 ± 1.5***	69.3 ± 0.8***
Number of tillers per plant	5.0 ± 0.2	5.3 ± 0.5	3.2 ± 0.1***	3.9 ± 0.1***
Number of heads per plant	4.2 ± 0.2	3.6 ± 0.2	2.0 ± 0.1***	2.6 ± 0.1***
Length of heads, mm	102.6 ± 1.7	93.2 ± 1.6**	93.4 ± 1.2***	88.9 ± 1.4***
Number of kernels per head	45.7 ± 1.2	44.6 ± 1.6	40.3 ± 1.6**	39.7 ± 1.2**
Thousand kernel weight, g	39.5 ± 0.6	31.9 ± 0.9*	32.9 ± 1.1*	31.7 ± 0.9**
Grain yield per pot, g	34.6 ± 1.6	29.6 ± 1.5*	17.7 ± 1.01***	18.9 ± 2.6***
Grain yield per pot, rel.	100	85.5	51.2	54.6
Straw yield per pot, g	42.4 ± 1.7	37.5 ± 1.8	20.7 ± 0.9	22.7 ± 0.6
Straw yield per pot, rel.	100	88.4	48.8	53.5

*, **, ***: Significantly difference from control, $P < 0.05$, $P < 0.01$ and $P < 0.001$, respectively

Tillering was not significantly influenced by chlormequat chloride alone, but "Oxitril 4" alone or in combination with the retardant significantly reduced the number of tillers as well as the number of ears per plants. Also the number of grains per ear was reduced by the herbicide.

Thousand grain weight was reduced significantly by the growth retardant as well as by the herbicide but no interaction was shown in this respect. Grain yield was reduced with 15 % by chlormequat chloride and 49 % by the herbicide. There was no significant difference in the influence on grain yield by the herbicide alone or in combination with the retardant.

DISCUSSION

The effect of chlormequat chloride on the grain yield is in agreement with the results of earlier experiments by the author (Wünsche 1970a, b and 1971). The decreased grain yield was mainly attributed to a lower thousand grain weight. It is interesting to note that in similar experiments, application of chlormequat chloride to barley or rye never has caused any yield decreases. On the contrary, the growth retardant sometimes increased grain yield in these two species (Wünsche, 1970b and 1971).

It may seem surprising that the herbicide "Oxitril 4" reduced the grain yield so strongly. One explanation might be that the amount applied has been too high. In a greenhouse, the environmental conditions often are rather different from those in the open field and thus the plants will not develop in the same way as field grown plants. For example the waxes in the cuticular layers may be changed so that the herbicide will penetrate more easily and damage a greenhouse plant more than a field-grown plant. In addition, in this experiment, due to the absence of weeds, injuries on the wheat plants caused by the herbicide could not be balanced by reduced weed competition. This assumption is supported by work done by Munro et al. (1973) on studying the effects of four herbicides on relatively weed clean crops of winter wheat. In these experiments yield depressions were obtained from all chemicals in the range 0.1-0.3 t/ha.

The reduction in grain yield caused by "Oxitril 4" was attributed to a decreased number of ears per plant, a decreased number of grains per ear as well as to a lower thousand grain weight.

The author is well aware of the limited value of this kind of greenhouse experiment if the results are to be applied to field conditions. Nevertheless, such experiments may provide valuable information on which plant characters could be influenced by a growth regulator or a herbicide also in the field. Of course, the results should be viewed with care as the effects usually will be less pronounced under field conditions.

As regards grain yield, the effect of combined application of chlormequat chloride and "Oxitril 4" to spring wheat is opposite to the results obtained in official field trials with winter wheat (Weeds and Weed Control, 1974). It seems unlikely that this difference can be explained solely in terms of differences between the environmental conditions in the greenhouse and in the field. It is tentatively concluded that winter wheat and spring wheat are influenced differently by the herbicide. However, more experimental work is needed to clarify this problem. One field trial with winter wheat has already been carried out this summer by the Department of Plant Husbandry at the Agricultural College in Uppsala. In this experiment, winter wheat was treated with different amounts of "Oxitril 4", alone or in combination with chlormequat. However, due to the weather conditions the harvest was delayed and it has not been possible to present the results in this report.

Experiments are also needed in which the effects of the individual herbicides are studied, alone or in combination with chlormequat chloride. As "Oxitril 4" contains four different herbicides this, however, means very large experiments with many different combinations of treatments.

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NOTES

BROMOFENOXIM + TERBUTHYLAZINE - A NEW CONTACT HERBICIDE COMBINATION FOR BROAD-LEAVED WEED CONTROL IN SPRING CEREALS

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Summary A combination of bromofenoxim and terbuthylazine was evaluated as a broad-spectrum herbicide for spring cereals in replicated small-plot and unreplicated farm scale trials over a four year period (1971-1974). A dose of 0.33 + 0.2 kg ai/ha gave effective control of the major broad-leaved weeds of spring cereals when applied before the crop tillered. *Chrysanthemum segetum* and other weeds were well controlled by 0.5 + 0.3 kg ai/ha. These dosage rates were highly selective, and safe on all spring barley, spring wheat, and spring oat varieties tested.

INTRODUCTION

Despite the wide range of spring cereal herbicides available to the farmer it is obvious that spraying is still limited by the suitability of the weather and in an average year only six days may be entirely satisfactory for spraying hormone type herbicides. Evans (1969) collected information illustrating this problem and highlighted the frequency with which hormone weedkillers were applied outside the safe crop stages, usually later rather than earlier. Evans (1966) also produced evidence that post-emergence herbicides used in spring cereals did not give the yield increases that were common some sixteen years earlier - Blackman and Roberts (1950), although of course there are other important benefits to be expected from herbicide use e.g. easier harvesting. It is probable therefore that mistimed application of hormone herbicides is common and, in view of the damage that can occur in these circumstances, may restrict or reduce the potential yield benefit to be derived from removal of weeds. Such an effect will be more pronounced at low levels of infestation, and when hormone tolerant species are present.

This situation led us to examine non-hormone development products based on bromofenoxim (3,5-dibromo-4-hydroxybenzaldehyde 2,4-dinitrophenyloxime) and chlorotriazines, herbicides which were known to be selective or marginally selective in cereals, the constraints to the separate use being high cost and/or marginal selectivity, and inadequate weed spectrum.

Since 1971 combinations of bromofenoxim and several chlorotriazines have been screened and intensively studied in glasshouse and field experiments. Bromofenoxim and terbuthylazine (2-t-butylamino-4-chloro-6-ethylamino-s-triazine) was selected for further development. In glasshouse studies this combination appeared to act almost entirely through the foliage and there was evidence of synergistic activity, an important discovery since it enabled the proportion of the less selective triazine to be reduced. This paper outlines the UK field development work on this product, which was introduced commercially in 1974.

MATERIALS AND METHODS

The combination used contained bromofenoxim and terbuthylazine in the proportions 1.65:1.0 and formulated as a wettable powder with a total a.i. content of 50%. Early trials were conducted using a tank-mix of the two ai's formulated separately as wettable powders, but from 1973 a "complete" WP formulation was used. In all trials comparisons were made with commercially available herbicides; these were dicamba + mecoprop or bromoxynil + ioxynil in the small plot trials, according to the weed problem at individual sites . Doses of the treatments used are given in kg ai/ha.

Small plot logarithmic trials had 3 replicates and the 2 x 20 m plots were treated using a modified Chesterford Mini-log sprayer. Plot size in the finite yield trials was 30 or 40 m^2 and treatments, which were applied using a precision plot sprayer, were normally replicated four times. All the small plot experiments were sprayed using a water volume of 190 litres/ha at 2.1 kg cm^2. In farm scale trials, applications were supervised by CIBA-GEIGY personnel who recorded application conditions and crop and weed growth stages. Sites were located over the whole country, from Somerset across to Kent and East Anglia and up into Scotland. The spring cereal variety screens were unreplicated and each treatment was sprayed as one swathe (2.5 metres) across six rows of each variety.

Treatment timing was specified by crop growth stage and ranged from the 1 leaf up to the late tillering stage with preference being given to applications when the crop had 3 to 4 leaves. Weed growth stages varied considerably but plants generally had no more than 6 leaves when treated at the preferred crop-stage in small plot trials. Farm-scale trials were often sprayed rather later than this.

The proposed EWRC 1 to 9 scale was used to assess weed control and crop vigour at all sites 2-5 weeks after treatments and again in late June/July. Weed counts were also carried out on the finite sites using a minimum of 4 x 0.125 m^2 quadrats/ plot. In logarithmic trials records were kept of the minimum effective dose for acceptable weed control and the maximum doses tolerated by the crop. Harvesting of small-plot finite trials was by combine harvester and plot yields were corrected to 16% moisture content.

RESULTS

Weed control

Acceptable weed control was achieved at five logarithmic trials in 1971 with an average minimum effective dose of 0.165 + 0.1 kg ai/ha and at one site with a *Chrysanthemum segetum* infestation, this weed was controlled by 0.44 + 0.26 kg ai/ha. For 1972 finite trials a dose of 0.33 + 0.2 kg ai/ha was chosen with a 50% increase where *C. segetum* was a problem.

Results over the three year period (1972-1974) from the 31 small plot replicated trials reported here (and from a further 20 trials not reported) showed bromofenoxim and terbuthylazine to be a wide-spectrum herbicide combination giving virtually complete control of the major annual broad leaved weeds of spring cereals. In the 1973 farm-scale pre-market evaluation, 75 farmers used the combination and the weed control results were comparable with those from small plot trials. The weed control information from small-plot and farm scale trials is summarised in table 2 at the end of this report.

Mayweeds, *Polygonum* spp., *Stellaria media*, *Sinapis arvensis* and other species were well controlled when treated at the 3-4 leaf stage using 0.33 + 0.2 kg ai/ha, although control of *Polygonum aviculare* was best when plants had no more than 2-3 leaves. At this dose rate results were almost always better than the dicamba + mecoprop standard used in small-plot trials and in the farm scale trials bromofenoxim + terbuthylazine was superior to the standard herbicide at 35 sites. The higher dose of 0.5 + 0.3 kg ai/ha was necessary to control some weeds, notably Chrysanthemum segetum, Galeopsis tetrahit and Lycopsis arvensis.

In small-plot experiments the increased dose of bromofenoxim + terbuthylazine gave results almost equal to those achieved using the bromoxynil + ioxynil standard. No comparison was possible in farm scale trials since inappropriate standards were used at nearly every site.

Tripleurospermum maritimum ssp. inodorum was the commonest mayweed but Matricaria recutita was equally susceptible at the few sites where it occurred. Field observations also suggested that Raphanus raphanistrum was, like Sinapis arvensis, very susceptible when treated with 0.33 + 0.2 kg ai/ha.

Only low populations of Galium aparine were encountered in a few trials and were not controlled by bromofenoxim + terbuthylazine. There was also little effect on Poa annua and no lasting control of perennial species whether monocotyledenous or dicotyledenous.

Application timing

Since a major objective of the development was to overcome the damage potential associated with inaccurate application timing of "hormone" type herbicides, the effect of inaccurate application timings on the activity and safety of bromofenoxim + terbuthylazine was closely examined. Early application is of little use with any contact herbicide if the weeds are not yet emerged and in three seasons' trials, with the exception of C. segetum and Galeopsis spp. with their extended period of germination, there have been no failures with the bromofenoxim and terbuthylazine combination resulting from late weed flushes. In both replicated and farm scale trials weed control was poorer where application was delayed until the crop was well tillered. This was particularly so where weeds which generally proved more difficult to control were present e.g. C. segetum.

Early and late herbicide applications (1 leaf to late tillering) were as well tolerated as application at the preferred crop stage (3 to 4 leaves).

Crop vigour

In early logarithmic trials during 1971 bromofenoxim and terbuthylazine exhibited a high level of selectivity and was consistently well tolerated without damage at 1.0 + 0.5 kg ai/ha. A higher rate of 1.32 + 0.8 kg ai/ha (the highest used in logarithmic experiments) caused no more than very slight crop depression at a few sites and from which the crop recovered by late season.

Crop vigour scores from finite treatments in small-plot trials are given in rating categories in table 1. At only 3 sites in 3 years was crop health rated as unacceptable (greater than EWRC score 4) and this was only after treatment with overdose rates. No damage was seen at any sites sprayed on a farm scale. At five sites for which results are not included, bromofenoxim + terbuthylazine caused severe damage but at all these sites (which were on light soils) there were trace element deficiencies, or anhydrous ammonia fertilizer had been injected too deeply. Correct diagnosis and prompt treatment of the deficiencies permitted recovery of the crops to give near average yields.

In 1972 and 1973, 41 spring cereal varieties were tested (most of them in both years) when no adverse varietal reactions were seen.

Table 1

Distribution of mean crop vigour score for spring cereals treated with bromofenoxim and terbuthylazine: 1972 to 1974. (assessed 2 to 4 weeks after application at the crop 3 to 4 leaf stage)

Herbicide	Dose (kg a.i./ha)	Number of trials in each rating category using the EWRC 1 to 9 scale 1.0-1.9	2.0-2.9	3.0-3.9	4.0-4.9
dicamba + mecoprop	5.6 l product	24	6	4	1
bromoxynil + ioxynil	2.1 l product	16	3		
bromofenoxim + terbuthylazine	0.33 + 0.2	38		1	
bromofenoxim + terbuthylazine	0.66 + 0.4	35	1	1	2
bromofenoxim + terbuthylazine	0.5 + 0.3	15	1	1	
bromofenoxim + terbuthylazine	1.0 + 0.6	12	3	1	1

Crop yields (replicated small-plot trials)

Spring cereal yields from seven small plot trials are presented in table 3. The first group of five trials were treated with the basic dose rate (0.33 + 0.2 kg ai/ha) and double this rate. The standard treatment was dicamba + mecoprop. None of the treatments, including the standard, had any effect on crop yields which were similar to untreated plots. *Chrysanthemum segetum* was present at the last two sites (T 1857, T 1858) and a higher dose was therefore used (0.5 + 0.3 kg ai/ha), with bromoxynil + ioxynil as the standard treatment. At T 1857 crop depressions were apparent earlier in the season and the overdose rate of 1.0 + 0.6 kg ai/ha did cause a statistically significant yield depression. In 1974 bromofenoxim + terbuthylazine was again well tolerated by spring barley and spring wheat crops at seven sites (table 4) and gave results equal to the standard treatments. Yield was reduced significantly at one site on a sandy loam soil by the highest overdose rate (1.0 + 0.6 kg ai/ha). At this site crop growth was impaired by lack of soil moisture in May/June.

DISCUSSION

On the basis of these results, bromofenoxim and terbuthylazine was shown to be a safe and effective broad-spectrum herbicide for spring cereals when used at a dose of 0.33 + 0.2 kg ai/ha. Where more resistant weeds such as *C. segetum*, *Lycopsis arvensis* and *Viola* spp. were present, a 50% higher dose was necessary (0.5 + 0.3 kg ai/ha). Susceptible weeds were controlled if treated when they had no more than 3 to 4 true leaves, though it was found that *P. aviculare* should have no more than 3 true leaves. Galium aparine , Avena fatua, other annual grasses and perennial weeds were resistant.

The correct timing of the application posed certain problems, since as a contact herbicide combination, application too early was to be avoided but late application meant that other factors also had to be considered. Weeds are that much larger and more tolerant if treatment is delayed, but perhaps of even greater importance is the degree of cover cast by the crop canopy and its effect upon the spray reaching weeds beneath this. Subjective assessments of ground cover in spring cereal crops showed that up to the very early tillering stage this was generally less than 10% of the total ground area but beyond this stage the appearance of secondary tillers rapidly increased ground cover to more than 50% when the crop first met across the rows.

The two weeds C. segetum and Galeopsis tetrahit proved slightly more difficult to control in these trials because of their extended germination period in contrast to most other common broad-leaved weeds of spring cereals. Consequently further weeds could emerge when the bromofenoxim and terbuthylazine combination was applied at the otherwise "optimum" time. Both species also grew rapidly and could recover from considerable damage, especially if sprayed when the plants had more than 4 leaves. Thus there may be difficulty in deciding whether to spray early and depend on crop competition to smother later emerging weeds, or to wait until more weeds have emerged in the hope that the oldest weeds can still be controlled. In spite of this difficulty (which also applies to other comparable herbicides), bromofenoxim + terbuthylazine usually gave very acceptable control of these species, especially where the crop provided adequate competition.

Overall the product was safely applied earlier and over a longer period than hormone herbicides. It thus offers the farmer a substantial advantage by more than doubling the number of days on which he can treat spring cereals at a time of peak workload. This allows him to treat a greater proportion of his acreage (where necessary) and, equally important, to spray only when weather conditions are suitable.

Acknowledgements

Thanks are due to those farmers who co-operated in providing trial sites, and to all members of the company's field trial teams who were engaged in the development of this material.

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Table 2

Mean percentage weed control achieved with bromofenoxim and terbuthtlazine in small plot and farm scale trials over a three year period (1972-1974).

Weed Species	0.33 + 0.2 kg a.i./ha	0.5 + 0.3 kg a.i./ha
Aethusa cynapium	80 (6)	
Anagallis arvensis	100 (4)	
Aphanes arvensis	100 (1)	
Atriplex patula	79 (1)	
Capsella bursa-pastoris	91 (3)	100 (2)
Chenopodium album	99 (13)	100 (1)
Chrysanthemum segetum	73 (6)	91 (10)
Fumaria officinalis	100 (1)	100 (1)
Galeopsis tetrahit	68 (7)	100 (2)
Lamium purpureum	90 (4)	100 (1)
Lycopsis arvensis		100 (2)
Mayweeds (mainly Tripleurospermum maritimum)	91 (15)	95 (3)
Myosotis arvensis	98 (4)	99 (1)
Papaver spp.	99 (4)	100 (1)
Polygonum aviculare	84 (31)	97 (8)
P. convolvulus	97 (26)	99 (9)
P. lapathifolium/P. persicaria	92 (12)	100 (3)
Senecio vulgaris	73 (1)	
Sinapis arvensis	100 (5)	100 (3)
Solanum nigrum	100 (1)	
Spergula arvensis	100 (2)	100 (3)
Stellaria media	90 (32)	94 (4)
Urtica urens	94 (4)	95 (1)
Veronica spp. (mainly persica)	85 (19)	100 (1)
Viola spp.	65 (12)	91 (10)

(Figures in brackets indicate the number of sites at which each weed occurred.)

Table 3

Spring cereal yields in 1973 after treatment with bromofenoxim + terbuthylazine at the crop 3 to 4 leaf stage (Yields as % of untreated)

Herbicide	Dose (kg ai/ha)	T 1850	T 1851	T 1852	T 1859	T 1874	T 1857	T 1858	Mean
dicamba + mecoprop	5.6 l product	100	100	99	98	100			99
bromofenoxim + terbuthylazine	0.33 + 0.2	97	102	99	99	97			99
bromofenoxim + terbuthylazine	0.66 + 0.4	96	106	96	97	96			98
bromoxynil + ioxynil	2.1 l product						101	106	103
bromofenoxim + terbuthylazine	0.5 + 0.3						102	114	108
bromofenoxim + terbuthylazine	1.0 + 0.6						91*	103	97
untreated yield (tonnes/ha)		5.04	4.95	4.46	3.02	2.94	3.59	3.35	
standard error of individual means (tonnes/ha)		± 0.12	0.10	0.07	0.07	0.05	0.08	0.09	

* indicates that result is significantly less than untreated at 5% level

Table 4

Spring cereal yields in 1974 after treatment with bromofenoxim + terbuthylazine at the crop 3 to 4 leaf stage (Yields as % of untreated)

Herbicide	Dose (kg ai/ha)	570	572	574	575	576	579	640	Mean
dicamba + mecoprop	5.6 l product	-	93	104	89	93	97	97	95
bromofenoxim + terbuthylazine	0.33 + 0.2	105	104	105	101	94	98	95	100
bromofenoxim + terbuthylazine	0.66 + 0.4	100	101	99	98	98	99	95	99
bromoxynil + ioxynil	2.1 l product	-	99	103	98	99	102	97	100
bromofenoxim + terbuthylazine	0.5 + 0.3	100	105	102	97	101	99	97	100
bromofenoxim + terbuthylazine	1.0 + 0.6	102	92	91*	93	92	100	95	95
untreated yield (tonnes/ha)		3.25	5.06	3.43	4.04	3.45	5.53	4.68	
standard error of individual means (tonnes/ha)		±0.30	0.25	0.12	0.11	0.12	0.09	0.11	

* indicates that result is significantly less than untreated yield at the 5% level

Proceedings 12th British Weed Control Conference (1974)

NEW RESULTS WITH BENTAZON* AND BENTAZON COMBINATIONS IN RICE

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Summary The use of bentazon on rice was evaluated in a total of about 200 trials in the years 1970 and 1974 throughout the rice growing areas of the world. Foliage treatments, normally 2 kg/ha at the 3-5 leaf stage, were evaluated on sown rice in Europe, America and Africa. These were applied both by ground equipment and air. Under adverse conditions higher rates of active ingredient were necessary when application was by fixed wing aircraft.

In Asia granular formulations were evaluated in standing irrigation water.

Bentazon controlled a wide range of weed species including those normally resistant to phenoxy herbicides.

Bentazon did not control graminaceous weeds, and where these were present other herbicides had to be used as a pre-treatment for bentazon spray in sown rice, or formulated with bentazon in the granules used on transplanted rice.

INTRODUCTION

In the past 4 to 5 years the range of effectiveness, mode of action, and crop compatibility of bentazon have been reported on in numerous (approx. 70) publications. Bentazon is taken up via the leaf and the shoot into the plant system and develops its herbicidal action in the metabolism of the treated plant. The fact that bentazon, in general, is completely tolerated by plants belonging to the gramineae and leguminosae families, while on the other hand a whole range of broadleaved weeds and cyperaceae are susceptible to bentazon, is explained by the different courses in metabolizing the active ingredient. That is, bentazon is quickly broken down in a tolerant crop plant or at least is converted into a non-phytotoxic form; whereas sensitive weed plants die before the active ingredient can be metabolized into a harmless form.

Bentazon's main application as a rice herbicide will be where

1) the rice herbicides normally used do not sufficiently control certain weeds (e.g., Butomus umbellatus in nothern Italy, Commelina spp. in Texas, Cyperus serotinus, Scirpus hotarui and Sagittaria spp. in many parts of Japan),

2) phenoxy-herbicides cannot be applied at a certain time due to reasons of selectivity, or

* Common name for: 3-Isopropyl-1H-2,1,3-benzothiadiazine-4(3H)-one-2,2-dioxide Active ingredient ot the commercial product Basagran R

3) phenoxy-herbicides cannot be applied because of the danger of drift to sensitive neighbouring crops.

Bentazon serves the above purposes well since it has a very broad range of effectiveness as a rice herbicide, is selective in all development stages of rice, and does not present the danger of drift, which is so common among the phenoxy-herbicides.

The following paper reports on further results from trials and treatments in practical usage with bentazon in rice.

METHOD AND MATERIALS

Bentazon was used for weed control in rice either as a spray (for foliage treatment) or a granular formulation (for soil treatment).

Sown rice

Foliage application in small plot replicated trials was carried out with knapsack sprayers. In large-scale trials and in practical usage the material was applied by ground equipment, fixed-wing planes, or helicopters. In all cases before foliage application, which took place during the 3-5 leaf stage of the weeds, the water was drained from the rice fields.

In the regions of Europe, the Americas, and Africa where sown rice is grown the normal practice was to precede the bentazon foliage treatment with a preliminary treatment ot the rice field with a herbicide effective against grasses, such as Echinochloa. The application rates for bentazon when used for foliage treatment consisted of 1.5, 2.0, and in special cases 3.0 kg of the active ingredient per hectare.

Transplanted rice

In Asia - especially in Japan and Taiwan - bentazon was combined with other herbicides, which for the most part are effective against grasses, and developed into a granular formulation. For these rice herbicide combinations developed into a granular formulation, bentazon was applied at rates of 2-3 kg of the active ingredient per hectare. Examples of the herbicide combinations used are:

a) bentazon (10 %) + CG 102 = C 288 (5.5 %) in 30-40 kg granules/ha

b) bentazon (7 %) + benthiocarb (7 %) + simetryn (1.5 %) in 30-40 kg granules/ha

c) bentazon (10 %) + benthiocarb (10 %) in 30-40 kg granules/ha

d) bentazon (10 %) + MCPA (1.5 %) or 2,4-D (1.5 %) in 20-30 kg granules/ha

The granular formulations a - c were applied 10-15 days after the rice was transplanted; application of granular formulation d took place 30 days after transplanting. This was done mainly to control the perennial weeds which have become a problem in Japan. Application was carried out in the irrigation water.

RESULTS

Sown rice

a) Small scale trials

From a total of 111 small plot replicated trials on sown rice in Europe, America and Africa, the herbicidal effect of bentazon, applied at the 3 to 5 leaf stage of the weeds, is summarized in two tables. These two tables contain the most important weeds found in the trials carried out. From these tables it can be seen that bentazon actually controlled most of the rice weeds, including the cyperaceae, very well. As is known, bentazon has no herbicidal effect on gramineae.

b) Large scale trials and practical usage

In 1973 and 1974 bentazon at 2 kg/ha (4 l./ha of Basagran) in 300-400 l. of water was applied for weed control on more than 50.000 hectares of rice in Italy, Romania, and Spain. Ground equipment was used for most of the treatments. These applications in practical usage confirmed the results obtained in the previous trials. Applications made by helicopter and fixed-wing planes at a volume rate of 50-150 l./ha of water were also satisfactory and in many cases were equal to the treatments with ground equipment.

In 1974 however there were initially some unsatisfactory results following the application of bentazon by air. This appeared due to a combination of cold weather conditions and an advanced stage of weed growth, especially where weed infestations were dense. Experience showed that under these adverse conditions weed control by aircraft application was satisfactory provided that the rate of active ingredient was increased up to 3 kg/ha and that an adequate volume of spray mixture was used; not less than 100 l./ha, and preferably 150 l./ha

Transplanted rice

The mixed bentazon herbicides having a granular basis, which were tested mainly in Japan, gave very good control not only of the easy to control weeds but also of <u>Scirpus hotarui</u>, <u>Cyperus serotinus</u>, <u>Eleocharis kuroguwai</u>, <u>Sagittaria pygmaea</u>, and <u>Sagittaria trifolia</u>. In the past these weeds were for the most part not susceptible to the herbicides used. The effect of bentazon, however, decreases if the granules are applied too early - that is, before emergence of the weeds - and substantial leaching of 2 cm or more per day results in heavy leaching losses before the weeds to be controlled have been able to take up enough of the active ingredient.

DISCUSSION

Rice herbicides must control gramineae, cyperaceae, and broadleaved rice weeds. In areas with intensive growing a single application very seldom is adequate. Growers have, therefore, changed to the practice of using several herbicides in sown and transplanted rice. Where the available herbicide combinations do not offer satisfactory control of certain weeds, or where certain herbicides for reasons of selectivity or drift danger cannot be applied, then the use of bentazon offers many advantages.

The use of bentazon demands particular attention to application techniques. If heavy leaching in the rice field leads to rapid of loss of the active ingredient, then the granular treatment must be adapted very exactly to the early post-emergence stage of the weeds. The depth of water in the field should not exceed 3-5 cm.

Table 1

Percentage control of Dicotyledonous weeds in sown rice using bentazon at the 3-5 leaf stage of the weeds (number of trials in brackets)

	Bentazon kg/ha 1.5	2.0
Ageratum conyzoides	92 (2)	98 (3)
Alternanthera sessilis	78 (3)	91 (5)
Ammania spp.	99 (8)	99 (13)
Bacopa spp.	99 (1)	99 (1)
Bergia aquatica	98 (3)	99 (3)
Eclipta alba	-	94 (2)
Jussiaea abyssinica	98 (3)	99 (3)
Sesbania exaltata	-	98 (6)

Table 2

Percentage control of Monocotyledonous weeds in sown rice using bentazon at the 3-5 leaf stage of the weeds (number of trials in brackets)

	Bentazon kg/ha 1.5	2.0
Alisma spp.	98 (17)	97 (37)
Butomus umbellatus	94 (6)	92 (16)
Commelina spp.	100 (2)	99 (15)
Cyperus difformis	95 (9)	94 (13)
Cyperus esculentus	-	100 (1)
Cyperus flambristilis	-	100 (1)
Cyperus iria	-	100 (1)
Cyperus rotundus	95 (1)	95 (1)
Cyperus spp.	100 (1)	96 (5)
Fimbristylis dichotoma	99 (2)	99 (3)
Heteranthera limosa	100 (1)	100 (1)
Mariscus longibracteatus	97 (2)	98 (3)
Sagittaria spp.	95 (3)	98 (2)
Scirpus maritimus	97 (23)	95 (50)
Scirpus mucronatus	95 (13)	95 (26)
Typha spp.	-	98 (5)
Echinochloa spp.	no efficacy	

If a fixed-wing plane is used for a bentazon foliage treatment in sown rice, special care must be taken that the spray mixture is distributed well. This can be accomplished with high water rates (e.g., 150 l./ha) and by a double flight over the area, each time changing the flight course by 50 %. Experience in 1974 suggests that if the weeds have passed the optimal 3-5 leaf stage, then the rate of bentazon must be increased up to 2.5 or 3.0 kg/ha for fixed-wing application.

Application by means of ground equipment does not require this higher dose since ground equipment works with pressure above atmospheric pressure and guarantees better penetration of the rice crop by the spray mixture.

According to the previous results, a helicopter - due to the wind generated by the rotor - brings about better penetration of the spray mixture in the crop; and, thus, better or more certain results can be obtained than with a fixed-wing plane. Further experience and the resultant data must still be collected.

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SOME RESULTS WITH BENTAZONE IN MIXTURES WITH PHENOXYALKANOIC HERBICIDES FOR USE IN CEREALS UNDERSOWN WITH CLOVER

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Summary Bentazone was tested in mixtures with MCPB, 24DB and MCPA, for use in cereal crops undersown with clover. All mixtures were shown to be selective, although a mixture of bentazone and MCPA caused some damage on red clover. Information on weed control from these trials is limited, but previous work has shown that a mixture of bentazone + MCPB has a broad spectrum of activity when used in peas. Further tests will be carried out with this mixture in 1975.

Résume Le bentazone a été essayé en divers mélanges avec le MCPB, le 24DB et le MCPA pour le désherbage de céréales sousensemencées de trèfle. Tous les mélanges essayés se sont montrés sélectifs, à l'exception d'une formulation de bentazone et de MCPA qui a causé quelques dégâts sur trèfle rouge. Les informations concernant l'efficacité herbicide, résultant de ces essais, sont encore limitées mais des travaux antérieurs ont prouvé qu'un mélange de bentazone et de MCPB possède un large spectre d'activité herbicide pour le désherbage des pois. Des essais complémentaires seront effectués avec ce mélange en 1975.

INTRODUCTION

Bentazone (BAS 351H) is a thiodiazinone derivative, Fisher (1968), which controls a wide range of broadleaved weeds, and is selective in a range of graminaceous and leguminous crops, Richardson and Dean (1973).

In order to give a broader spectrum of weed control a mixture of bentazone and 24DP was developed for use in cereals, Jung and May (1970), and a mixture of bentazone and MCPB was developed for use in peas, Taylor and May (1972). In Sweden a mixture of bentazone and MCPA (BAS 4330H) has been developed for use in red clover undersown in cereals, Aamisepp (1974).

Initial trials in the United Kingdom, with bentazone alone and in mixture with 24DB, showed a high degree of crop tolerance against clover undersown in cereals. Further trials were carried out in 1973 and 1974, comparing mixtures of bentazone with 24DB, MCPB and MCPA.

METHOD AND MATERIALS

Seven trials were laid down during the period 1973-1974, in crops of spring cereals undersown with red or white clover.

In all trials a randomised block design was used, replicated four times. Plot size was 2.0 x 12.5 metres or 2.4 x 12.5 metres. All treatments were applied with a

Van der Weij knapsack sprayer fitted with cone nozzles, at a volume of 250 l./ha pressure.

Weed control and crop tolerance were scored visually 2-4 weeks after application. In trials A and B, the assessments were made according to the EWRC scale. In the remaining trials, assessment was made on a direct percentage basis.

Formulations used:

BAS 4330H - an a.c. containing 25% w/v bentazone + 12.5% MCPA

BAS 3517H - an a.c. containing 48% w/v bentazone

24DB - an a.c. containing 30% a.e.

MCPB - an a.c. containing 40% a.e.

MCPA - an a.c. containing 40% a.e.

BAS 3517H + MCPB (formulated mixture) - an a.c. containing 20% w/v bentazone + 20% MCPB a.e.

Two standard proprietary mixtures were used for comparison:-

MCPB + MCPA containing a.i. as in New Legumex

24DB + MCPA + benazolin containing a.i. as in Legumex Extra

Table 1

Site Details

Trial	Year	Site	Clover cultivar	No. of trifoliate leaves at time of application
A	1973	Gloucs.	Red, Essex Broad	$1\frac{1}{2}$
B	1973	Oxon.	White, New Zealand	1
C	1974	Gloucs.	Red, Hungerapolytetraploid	1-2
D	1974	Suffolk	White, New Zealand	0-3
E	1974	Northants.	Red, Essex Broad	1-2
F	1974	Northants.	Red, Essex Broad	1-2
G	1974	Northants.	Red, Essex Broad	1

Table 2

Crop Vigour and Weed Control Assessments 8 days after application (1973 trials) using EWRC scoring method

Treatment	kg/ha	clover vigour		Polygonum aviculare		Stellaria media		Papaver rhoeas	Galium aparine	Sinapis arvensis	Tripleurospermum maritimum
	Trial	A	B	A	B	A	B	A	A	A	B
BAS 3517H	3.0	2	1	8	9	1	1	4	1	1	1
•BAS 3517H + MCPB	7.5	3	1	2	1	1	1	1	1	1	1
•BAS 3517H + MCPB	5.0	2	1	4	1	1	1	1	1	1	1
BAS 3517H + 24DB	3.0 + 3.5	3	1	3	1	1	1	1	1	1	1
BAS 4330H	5.0	6	4	2	1	1	1	1	1	1	1
BAS 4330H	3.0	3	1	6	3	1	3	1	1	1	1
MCPB + MCPA	7.0	3	1	7	1	8	7	5	1	2	9
24DB	7.0	2	1	6	1	3	9	2	3	2	9
Weeds	No. of leaves at application			2-6		2-6		cotyledon	4-6	4	4

• as formulated mixture

Table 3

% Crop Vigour Reduction & % Weed Control Assessments relative to untreated

(1974 trials)

Treatment	rate 1./ha	TRIAL C: Crop vigour	TRIAL C: S. media	TRIAL D: Crop vigour	TRIAL D: Raphanus raphanistrum	TRIAL D: Silene alba	TRIAL D: Chenopodium album	TRIAL D: Polygonum convolvulus	TRIAL E: Crop vigour	TRIAL E: Polygonum aviculare	TRIAL E: S. media	TRIAL E: Veronica spp.	TRIAL F: Crop vigour	TRIAL G: Crop vigour	TRIAL G: Polygonum convolvulus	TRIAL G: Polygonum aviculare	TRIAL G: T. maritimum	TRIAL G: Veronica spp.
BAS 3517H + MCPB + MCPA	2.0 + 3.75 + 1.6	20	100	15	100	86	100	10	3	95	95	96	0	5	85	97.5	96	87
BAS 3517H MCPB + MCPA	3.0 + 3.75 + 0.8	20	100	7	100	93	100	20	3	96	97.5	97	0	5	89	99	98	93
BAS 3517H + MCPB + MCPA	2.0 + 2.5 + 1.6	15	100	7	100	100	100	10	3	90	97.5	93	0	5	88	98	88	85
BAS 3517H + 24DB	2.0 + 3.5	10	100	0	66	50	100	10	0	82.5	82.5	75	0	10	80.5	95	65	82.5
BAS 3517H + MCPB	2.0 + 2.5	5	97.5	7	83	86	100	10	0	89	90	89	0	3	80.5	91.5	86	91.5
BAS 3517H + MCPB	2.0 + 3.75	0	100	10	86	83	100	10	0	88	86	85	0	0	70	89	85	88
BAS 4330H	2.0	20	100	0	100	96	100	10	3	85	88	93	0	3	75	93	88	90
MCPB + MCPA	7.0	25	95	0	70	76	100	10	0	93	89	97.5	0	5	80.5	97	24	86
Weed size at application			4 in.		5-6	2-4 leaves	4-6	2-4		6 in.	8 in.	4-5 in.			8 in.	6 in.	12 in.	6 in.

In trial C 24DB + MCPA + benazolin was used.

DISCUSSION

1973 Trials

Mixtures of BAS 3517H plus MCPB, 24DB or MCPA gave very good control of the weed species present, except the lower rate (3 l./ha) of BAS 4330H (bentazone + MCPA). BAS 3517H, 24DB, and the mixture of MCPB + MCPA gave inferior weed control.

Red clover proved to be the more sensitive crop and slight vigour reduction was noted with all treatments, but BAS 4330H at 5 l./ha was the only treatment to cause serious damage. This treatment was also the only one to cause some phytotoxicity to the white clover.

1974 Trials

Mixtures of BAS 3517H plus MCPB, 24DB or MCPA were further tested, including different rates and ratios in the mixtures. Further mixtures were tested of BAS 3517H + MCPB, adding small amounts of MCPA, to obtain a still safe, but more effective treatment. Unfortunately, the full range and effectiveness could not be ascertained with these mixtures as germination of weed numbers and species was restricted. However, the range and herbicidal activity of the BAS 3517H + MCPB mixture has been previously reported from trial work carried out on peas, Taylor and May (1972).

The results obtained show that BAS 3517H in mixtures with MCPB plus MCPA appears to be marginally the most efficient treatment of any combination tested, giving good control of all weed species present, except black bindweed (Polygonum convolvulus) in trial D. Black bindweed, however, was well controlled in trial G.

The mixtures of BAS 3517H + MCPB were slightly less effective than in the mixture where MCPA was added, but still gave very satisfactory and similar control to that obtained with MCPB + MCPA. The latter however, gave poor control of Tripleurospermum maritimum in trial G. BAS 3517H + 24DB would appear to be the least effective treatment tested in this trial.

Crop vigour reduction on red or white clover tended to be greater with treatments containing MCPA, but no treatment gave any serious vigour reduction in any of these trials.

In view of the results obtained in 1973 and 1974, it is hoped to test the BAS 3517H + MCPB mixture on a large scale in 1975 on clover grown for seed as well as on cereals undersown with clover, as this mixture exhibited good crop tolerance combined with a wide range of effectiveness.

Acknowledgements

The authors wish to thank Mr. P.M. Woodcock for his help in carrying out the trials programme. Thanks are also due to the farmers who co-operated with us in these trials.

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A NEW APPROACH TO WEED CONTROL IN WINTER CEREALS WITH AUTUMN APPLICATIONS USING METHABENZTHIAZURON

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Summary Autumn treatment with methabenzthiazuron at 1.4 lb a.i. per acre to wheat, barley, and oats has given season long control of most of the autumn germinating problem broad leaved weeds including Aphanes arvensis, Lamium purpureum, Papaver rhoeas, Stellaria media, Tripleurospermum maritimum ssp. inodorum, and Veronica spp. as well as the meadow grasses Poa annua and Poa trivialis. Galium aparine is not controlled by methabenzthiazuron and if present in a weed population a follow-up treatment of mecoprop is necessary in the spring. Spring germinating weeds such as Polygonum aviculare did not cause a problem in competitive crops.

INTRODUCTION

The prime objectives of weed control in winter cereals are:

1. The reduction or elimination of competition
2. Reduction in harvest contamination
3. Ease of harvesting and drying

Weed control in many crops is based on the principal of removing competition as early as possible, where appropriate by the use of pre-emergence herbicides. In the United Kingdom broad leaved weed control in winter cereals has been, for nearly 30 years, largely based on the use of post-emergence herbicides 5-7 months after sowing, some two-thirds of the way through the life of the crop. While this usually achieves objectives 2. and 3. the first, and probably major objective, cannot be fully achieved since some of the competition from weeds has already taken place. This factor, together with the critical aspect of timing in relation to weed stage, crop stage, other husbandry operations and favourable weather conditions for both the spraying operation and the uptake and translocation of growth regulator herbicides, has combined to produce a situation where little average yield benefit has been established from spring herbicide applications (Evans 1966 and 1969). Included in this average are trials where the use of herbicides resulted in substantial yield increases, but there were many where yield depressions were recorded.

It would not be unreasonable to suggest that the latter situation arises as a result of late removal of weeds, plus the effects of wrongly timed spring applications (Munro 1972; MAFF S.E. Region 1970, 1972, and 1973; MAFF E. Region 1971; MAFF E. Midland Region 1971; and British Farmer & Stockbreeder 1972) the latter occuring because of the limited time available for spring spraying (Phillipson 1972), and the difficulty in establishing the correct growth stage of some varieties (Makepeace 1973). As an alternative to improving spring applications a better approach would be to eliminate or reduce the need for such treatment.

Work by Hack (1969), Kolbe (1970) and Budd (1970) demonstrated that methabenzthiazuron as an autumn treatment at a rate of 1.4 lb/acre could give a season's control of a wide range of dicotyledonous weeds and Poa species in autumn sown cereals and grass. Additionally, Kolbe (1970) showed that control in the autumn produced a consistent positive yield response, whereas spring treatment with phenoxypropionic acids, although providing satisfactory weed control, produced little or no benefit when compared with untreated winter wheat crops.

Methabenzthiazuron has been used commercially for several years on winter cereals in European countries, including the United Kingdom, for control of Alopecurus myosuroides at 2.8 lb/acre and has proved safe to crops (MAFF 1974, Bagnall & Jung 1968).

This paper describes work undertaken since 1968 in the United Kingdom to determine the effectiveness of methabenzthiazuron as an autumn treatment in winter cereals at a rate of 1.4 lb/acre, with particular emphasis on the control of Matricaria spp., Stellaria media, Papaver rhoeas, Veronica spp., Poa annua and Poa trivialis.

METHOD AND MATERIALS

Methabenzthiazuron was used throughout as the commercial formulation (Tribunil), a 70% wettable powder. The properties of methabenzthiazuron are described by Hack (1969).

The trials reported here were carried out between 1968 and 1974 in the cereal growing areas of Eastern and Southern England.

Small plot trials were carried out using randomised block layout with two or three replicates; applications being made by a pressurised knapsack sprayer at 25-50 gal/ac.

Grower trials comprised unreplicated 1-5 acre plots sprayed with farm sprayers using 20-25 gal/ac. Comparisons were made with untreated areas and/or farmer applied spring growth regulator herbicides.

Soil types covered during the investigation ranged from loamy coarse sands to clay loams.

Weed control assessments were made in the spring and summer by taking quadrat counts or by a visual scoring based on the BBA (Biologische Bundesanstalt - Federal German Biological Institute) scale 1-9 where:-

1 = Complete control
2 = 97.5% "
3 = 95% "
4 = 90% "
5 = 85% "
6 = 75% "
7 = 65% "
8 = 32.5% "
9 = No control

The latter type of assessment was made in conjunction with an estimate of weed ground cover on the untreated plots.

Yields were measured in the small plot trials using a mini-combine harvester.

Yield was calculated in the grower trial by measuring the distance travelled by the combine to harvest a standard volume of grain.

RESULTS

The results of four replicated and four grower trials carried out between 1968 and 1973 are summarised below in Tables 1 & 2.

Table 1

Summary of weed control trials with 1.4 lb/ac methabenzthiazuron 1968-1973

Weed Species	No. of Trials	Median % Control	Mean no. of weeds per sq m on untreated	Range of % Control
Aphanes arvensis	6	100	15.3	98-100
Matricaria spp.	5	100	79.0	99-100
Poa spp.	6	93	21.1	52-99
Polygonum aviculare	5	46	104.5	0-76*
Ranunculus arvensis	2	85	13.5	78-100
Stellaria media	4	100	6.5	100
Veronica spp.	5	100	15.4	20-100
Viola arvensis	2	97	28.0	87-100

*Polygonum aviculare all germinated in the spring

Three trials were taken to yield during 1972 and 1973 and the results are given in Table 2.

Table 2

Yield of winter wheat treated with methabenzthiazuron at 1.4 lb/ac in the autumn

Year	Replicates	Cultivar	Yield as % of untreated
1972/3	2	West Desprez	107
1972/3	2	West Desprez	119
1971/2	Grower*	Maris Nimrod	111

*1.05 lb/ac

During the season 1973/4 24 grower trials were carried out with methabenzthiazuron applied in the autumn at 1.4 lb/ac to winter cereals, and the results of weed control are summarised in Table 3.

Table 3

A summary of 24 weed susceptibility trials with autumn applied methabenzthiazuron at 1.4 lb/ac during 1973/4

Weed Species	No. of Sites	Median % Control	Range	Susceptibility* Rating
Anagallis arvensis	1	100	-	S
Aphanes arvensis	10	100	-	S
Apera spica-venti	1	100	-	S
Capsella bursa-pastoris	5	100	-	S
Cerastium vulgatum	1	100	-	S
Galium aparine	1	0	-	R
Lamium amplexicaule	3	100	-	S
Lamium Purpureum	6	100	-	S
Legousia hybrida	3	88	67 - 100	MS
Myosotis arvensis	3	100	-	S
Papaver rhoeas	9	100	90 - 100	S
Poa annua	21	95	78 - 100	S
Poa trivialis	1	98	-	S
Senecio vulgaris	6	100	-	S
Stellaria media	18	100	91 - 100	S
Tripleurospermum maritimum ssp. inodorum	18	100	83 - 100	S
Veronica persica	16	100	75 - 100	S
Viola arvensis	15	50	0 - 100	MS

*Susceptibility Rating (Weed Control Handbook 1972)

S = Susceptible	Complete or nearly complete kill
MS = Moderately Susceptible	Partial kill or variable results
R = Resistant	No useful effect

Table 4

No. of sites at which particular weed species germinated in the spring following an autumn application of methabenzthiazuron

Weed Species	No. of Sites
Chenopodium album	4
Poa annua	5
Poa trivialis	1
Polygonum aviculare	16
Polygonum convolvulus	6
Polygonum persicaria	2
Stellaria media	4
Tripleurospermum maritimum ssp. inodorum	3

DISCUSSION

The trials conducted between 1968 and 1974 with methabenzthiazuron at 1.4 lb/ac showed that it was feasible to control the most important autumn germinating weeds in winter cereals, which included Matricaria spp., Stellaria media, Aphanes arvensis, Veronica spp., and Papaver rhoeas, and also the meadow grasses Poa annua and Poa trivialis.

Meadow grasses appear to become an increasing problem in cereal growing, and, being alternative hosts may perhaps account for the increase in Opomyza shoot fly infestations in some areas.

Methabenzthiazuron applied in the autumn deals effectively with many broad leaved weeds such as Matricaria spp., Papaver rhoeas and Stellaria media, which can be difficult to control in the spring because of problems with correct timing. This technique and novel approach also removes weed competition from an early stage in the life of the crop which gives it a distinct advantage over traditional spring applications.

In some of the 24 trials a number of weed species germinated in the spring, as shown in Table 4, but it was found that in a vigorously growing crop these did not present a problem, presumably because of the competitive effect of the crop and/or any remaining methabenzthiazuron residues. In only one case, where the crop was thin and provided little competition was it judged that a spring treatment was needed because Chenopodium album had germinated in the spring and not been suppressed.

Perennial broad leaved weeds such as Cirsium arvense can be difficult to control with growth regulator treatments in the spring because applications against annual broad leaved weeds need to take place earlier than application against Cirsium arvense. However, if methabenzthiazuron is used in the autumn, a late application of phenoxyacetic acids e.g. MCPA or 2,4-D, can be used for more effective perennial broad leaved weed control.

Galium aparine is not controlled by methabenzthiazuron, but after spraying with methabenzthiazuron in the autumn only mecoprop will be needed in the spring since Matricaria spp., Aphanes arvensis, Papaver rhoeas etc. will already have been controlled.

The trials were conducted on soils ranging from loamy coarse sand to clay loam, and soil type did not appear to affect herbicidal activity, confirming that methabenzthiazuron can be used on all mineral soil types; it is not, however, suitable for use on organic soils.

Methabenzthiazuron at 1.4 lb per acre is now recommended, and approved under the Agricultural Chemicals Approval Scheme, for application pre-emergence to winter barley and winter oats, and pre- and post-emergence to winter wheat up to 6 weeks after drilling for annual broad leaved weed and meadow grass control.

Acknowledgements

The authors wish to thank the farmers who co-operated in developing this new technique, and also for the help received from other members of Bayer U K Limited.

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NOTES

WEATHER LIMITATIONS ON CEREAL SPRAYING IN THE SPRING

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Summary An attempt was made to determine how weather conditions restrict the time available for spraying cereals in the spring. Objective criteria by which to define spraying days were established by comparing subjective observations with weather records at the Weed Research Organization in Oxfordshire. Spraying conditions over five seasons in three localities were contrasted. Spraying can be restricted to as few as one day in four or even fewer where drift is a hazard. Better accuracy of spray timing might be achieved by improvements in the organization on the farm spraying operation or the development of new herbicides that could be safely used over a wider range of crop and weed growth stages.

INTRODUCTION

The correct time to apply most post-emergence cereal herbicides is restricted to certain growth stages of crop and weeds. Most of the commonly used broad-leaved weed herbicides can be applied safely only between the fully tillered to jointing stages of winter cereals and the three, or five,-leaf to jointing stages of spring cereals (Weed Control Handbook, 1972). Sprayed too early, the phenoxyacetic acid herbicides cause leaf or ear deformities. Sprayed too late, the benzoic acid herbicides in particular, can prevent grain swelling with consequent severe yield losses. Limitations to the timing of the hydroxybenzonitrile herbicides, on the other hand, are imposed by the increased resistance of the weeds with advancing age. Wild-oats, too, are susceptible to herbicides such as barban and chlorphenprop-methyl only at certain critical growth stages.

Bad weather further reduces the time available for spraying. An attempt to qualify this limitation, and its variation in different localities and seasons, was made as part of a continuing study of cereal tolerance to herbicides at the Weed Research Organization. In view of the difficulty in defining the influence of weather conditions on the efficiency of herbicide application an empirical approach was adopted.

METHOD AND MATERIALS

Initially a spraying day was defined as such from a consensus of the independently recorded opinions of several experienced members of W.R.O. staff, all concerned with spraying operations in the field. Half-day periods during April and May in 1973 and 1974, but excluding weekends, were categorised as good, possible or bad. In 1973 four observers contributed to the assessment of spraying days and in 1974 the number was doubled to give a wider spread of experience and to reduce personal bias.

Over the same period weather records were collected at W.R.O. Logical criteria involving rainfall and windspeed were suggested and then manipulated to give correlation with the assessments of spraying conditions recorded by the observers.

Objective weather criteria, established in this way, were then applied to rainfall and windspeed data recorded at three widely separated meteorological stations over the past five years. The stations chosen for the exercise were Abingdon in Berkshire, Cranwell in Lincolnshire and Honington in Suffolk, each in, or close to, important cereal growing areas.

During the time that this exercise has been under way at W.R.O., attempts have been made to relate the spraying conditions to the growth stages of farm crops. This culminated, in 1974, in regularly walking all of the cereal crops on two local farms and noting growth stages of crops and weeds.

RESULTS

The weather criteria derived as a result of the 1973 and 1974 'spraying days' exercises are laid out in table 1, and the correlation between the numbers of spraying days, determined by using the weather criteria and those subjectively recorded by the observers is shown in table 2. Further alterations to the criteria did not improve the level of agreement because of obvious inconsistencies between the observations when set alongside the weather data.

Using the weather criteria, the number and distribution of spraying days, at the three widely separated meteorological stations over the past five seasons, were calculated and are presented in figure 1. The spraying periods presented in the histograms are accumulated over ten day intervals through April and May.

In general spraying conditions were better at Abingdon than at the other two sites and better in 1971 than in other years. 1972 and 1973 at all sites showed fewest spraying days over the two month period. The number of possible spraying days in each of the ten day periods varied from 0 to 8 with an average of just over 4. The factors preventing spraying are expressed in table 3. From this it appears that the fewer spraying days at Cranwell and Honington were due to more windy days than at Abingdon.

Finally, the development of the cereal crops on the two Oxfordshire farms is illustrated in figure 2. The graph is derived from field assessments at approximately 10 day intervals and represents only a broad picture of the spraying priorites on these farms. Few weeds germinated in the spring barleys until the crop reached the five-leaf stage. The main spraying periods were the last three weeks in April for winter wheat and the last two weeks in May for spring barley.

Table 1

Weather criteria used to define spraying periods

Spraying periods am 0600 - 1200 hrs GMT
pm 1200 - 1800 hrs GMT

Windspeed - average of 6 hourly integrated windspeeds

Rain - summed from continuous trace recording

GOOD - wind: average of 8 mile/h or less

rain: less than 0.5 mm in period
for am. no rain in previous 12 hrs
for pm. no rain in previous 6 hrs, or less than 1 mm in previous 18 hrs

POSSIBLE - wind: average 9 - 12 mile/h

rain: less than 0.5 mm in period
for am. less than 1 mm in previous 12 hrs
for pm. less than 1 mm in previous 6 hrs, or less than 2 mm in previous 18 hrs

BAD - wind: average of 13 mile/h or above

rain: more than 0.5 mm in period
for am. more than 1 mm in previous 12 hrs
for pm. more than 1 mm in previous 6 hrs or more than 2 mm in previous 18 hrs

Wind and rain classed independently and spraying period follows category of the limiting factor.

Table 2

Comparison of spraying days assessed by observation and weather records (WRO Oxford)

	No. of spraying days (excludes week-ends)			
	Good	Possible	Bad	Overall agreement
1973 Consensus of 4 observers	$8\frac{1}{2}$	$11\frac{1}{2}$	21	84%
From weather records (see table 1)	11	$9\frac{1}{2}$	$20\frac{1}{2}$	
1974 Consensus of 8 observers	14	$16\frac{1}{2}$	12	81%
From weather records (see table 1)	17	$10\frac{1}{2}$	15	

Fig. 1

Spraying days

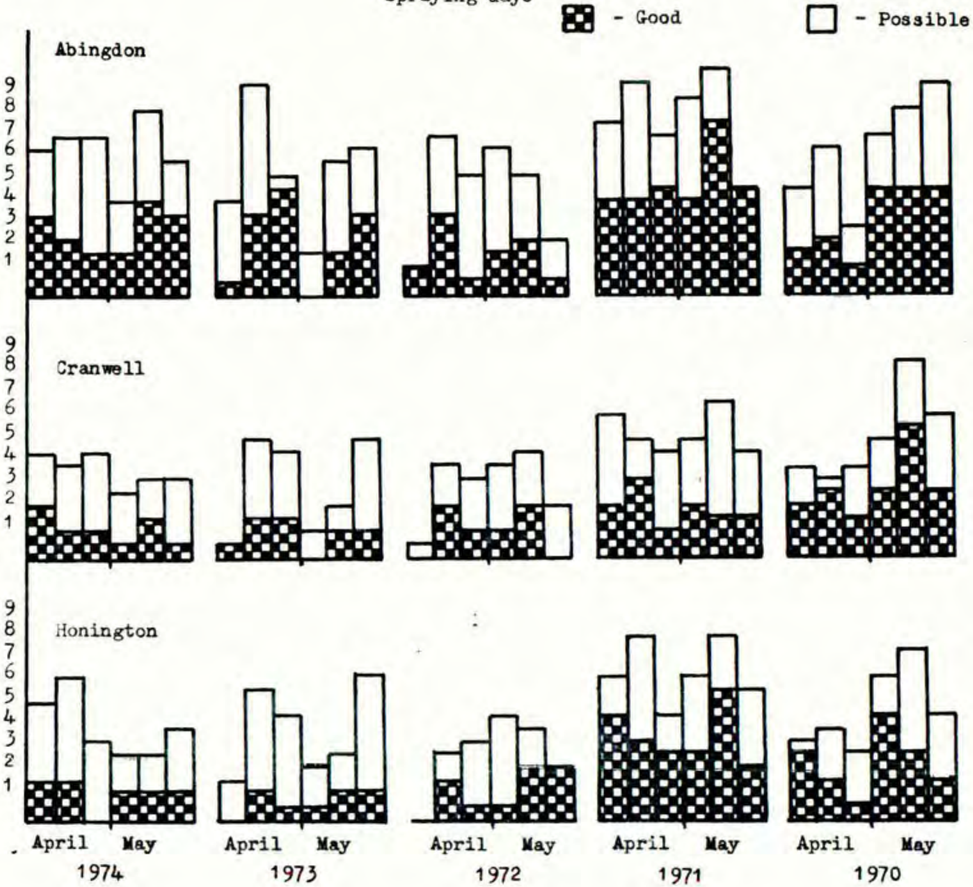

Fig. 2

Cereal crop development in relation to herbicide spraying

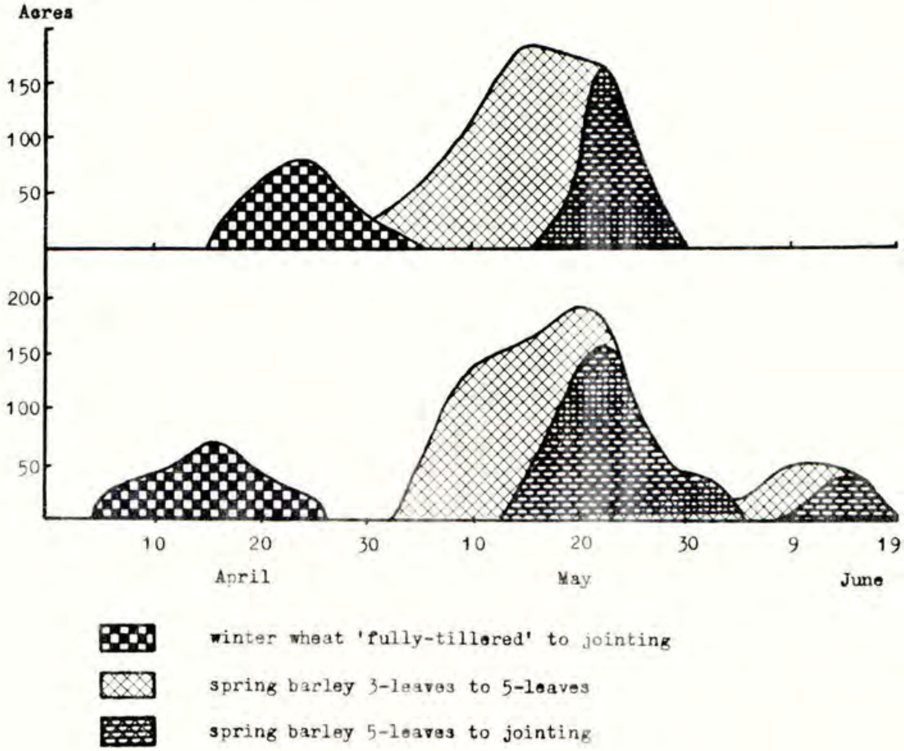

Table 3

Factors limiting spraying days (includes week-ends)

Site:	Abingdon		Cranwell		Honington	
Year:	1973	1974	1973	1974	1973	1974
No. of days (out of 61) on which spraying prevented:	32½	27	44	40½	39½	39½
by rain:	21	11½	19	6	20	5½
by wind:	20	21	38	39	32½	36½

DISCUSSION

The derivation of the weather criteria was made on an empiric basis from subjective assessments, due to the lack of detailed knowledge about the influence of weather conditions on the efficiency of herbicide activity. It is clear, too, that different types and formulations of herbicides may be affected in different ways.

While it is possible to outline the sort of conditions under which a growth-regulator herbicide should be most efficient, it is practically impossible to define the point at which conditions deteriorate to give an unacceptable result. The dose of herbicide recommended by the manufacturer should be sufficient to give a satisfactory result even under marginal conditions and hence we have concerned ourselves only with two factors, wind and rain, which will prevent the spray landing evenly and remaining on the target area long enough to enter the foliage.

The weather criteria, presented in table 1, are the result of an investigation over two seasons but would need correction and expansion over several further seasons before serving as a practical guide to spraying conditions. They are, however, of some value in comparing spraying conditions between sites and seasons on an objective basis.

The growth stages of crop and weeds determine the period during which spraying should take place. There is some difficulty in defining precisely the growth stages during which a cereal crop will show maximum tolerance to the growth-regulator herbicides. This is especially so in winter wheat in which the period of optimum safety is often only a week and may be less. In spring barley, herbicides, such as ioxynil and mecoprop, that can be used from the three leaf stage through to jointing, should make the problem of correct spray timing easier.

It seems reasonable to assume that, over most of mid and southern England, the main spraying periods will be from about the 10th to 30th April for winter cereals and from the 10th to 30th May for spring sown crops. It is evident from figure 1 that in each of these 20 day periods the number of possible spraying days can be as few as $5\frac{1}{2}$. In situations where spray drift over adjacent crops or gardens must be avoided the available days would be even fewer.

While it is not possible to generalise on the problems faced by any one farmer, it must be clear that in many cases improvements in the organization of the farm spray operation could lead to better spray timing and reduce the dangers of herbicide damage to crops.

A complementary approach to the problem is provided by the introduction of new broad leaved weed herbicides that can be safely used over a wider span of crop growth stages.

Acknowledgements

Our thanks are due to our colleagues who recorded their assessments of the spraying conditions, to R. Simmons who supervised the automatic recording of weather data at W.R.O. and to the Meteorological Office for supplying data from their various weather stations.

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STUDIES WITH SOLUBILIZED HERBICIDE FORMULATIONS

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Summary. Certain water soluble herbicides have been formulated in mixed liquids namely oil and water by using suitable surfactants as cosolvents. This process, termed solubilization, confers properties which are normally associated with oil solutions, including an ability to pass easily through bark or leaf cuticle. Solubilized paraquat, aminotriazole and glyphosate are thereby made active when applied to poplar bark. Solubilization does not greatly affect the activity of leaf-applied paraquat or aminotriazole, but considerably enhances the effects of leaf-applied glyphosate. The possible practical applications of the technique are discussed.

INTRODUCTION

The activity of a herbicide which is sprayed on to the aerial parts of a weed is limited by many factors. Of these, the rate of entry into the plant and the speed of movement in the vascular system are often of primary importance. Water solutions of herbicides generally penetrate bark or leaves slowly but, once within the plant, translocate freely. On the other hand some herbicides which dissolve in oil enter the plant rapidly but are then relatively immobile. Lipophilic attributes of herbicide formulations which assist entry are rarely found in combination with the hydrophilic properties which favour translocation. Most herbicides or derivatives thereof which are used for leaf sprays are soluble in oil or water but not in both these solvents.

With herbicides which are themselves acids, ester or oil soluble amine derivatives can often be made. Both the latter dissolve in oil and so pass readily through bark or cuticle. Within the plant they break down to release the parent acid, which is often slightly soluble in water. Thus, esters and oil soluble amines exhibit in some degree the desired combination of lipophilic and hydrophilic properties. However when esters are injected into plants they often have less activity than equivalent doses of ordinary amine salt formulations (Turner, 1973). Injected oil-soluble amine salts have also been found to be slightly less phytotoxic than simpler metal or amine salts. These results suggest that the slow hydrolysis of esters and the low water solubilities of some herbicidal acids and oil-soluble amine salts may be factors which limit their systemic activity. Many herbicides are not acids capable of forming suitable oil-soluble amine or ester derivatives. A widely applicable method of formulating such herbicides which confers properties typical of both oil and water solutions could have advantages.

One possible way of achieving this aim is to use a cosolvent to make a mixed solution containing an oil, water and a herbicide. Several materials have been examined in this context, including acetone and isopropanol. Some of the mixed solutions made with these cosolvents are more phytotoxic than equivalent water solutions. However most organic cosolvents of low molecular weight appear to have practical disadvantages. Usually a very large proportion of highly volatile material is needed to make mixed solutions containing only a little herbicide.

While most cosolvents have little potential, promising results have been obtained with certain surfactants. These compounds, widely used as wetting or emulsifying agents have molecules which include both lipophilic and hydrophilic groups. Some are soluble in both oil and water and can be used as cosolvents to prepare clear single phase mixed solutions. This process has been termed "solubilization" (McBain, 1942). It is discussed in detail by Winsor (1954). Solubilization is of practical importance in several fields, usually for bringing oil-soluble compounds into mixed solutions with a larger proportion of water. This report discusses work at WRO with herbicides in solutions consisting mainly of oil.

MATERIALS AND METHODS

Bark applications. Cuttings of a poplar hybrid x Populus gelrica Lit. were used for all experiments on bark uptake of herbicides. The cuttings were selected from 1 year old stems which had been collected from stool beds in winter and kept for several months at 0°-5°C in a cold room. Cuttings 0.3 m long, with a diameter of 15-25 mm were prepared immediately before the start of experiments. All wood with visibly damaged buds or bark was discarded. The material was graded so as to provide cuttings of approximately even thickness for the blocks of replicated experiments. From 10 to 25 replicates were used. Solutions were applied by sprayer to a 0.1 m long segment at the centre of each cutting. During spraying the cuttings were placed horizontally on wire racks, with the ends shielded by a frame made of hardboard. A volume rate of 400 l/ha was used. After spraying, the cuttings were left undisturbed for 24 h and then planted vertically in large pots containing moist peat-sand compost. During planting and when watering, care was taken to avoid transferring herbicide from the sprayed part of the cuttings to their ends. The planted cuttings were kept in a glasshouse and the effects of treatments were assessed by weighing shoot growth, at between 19 and 40 days from spraying.

Except where otherwise stated, commercially formulated herbicides containing wetting agent were used. Additionally, 0.25% v/v of a proprietary non-ionic surfactant Agral 90* was included in all water based spray solutions. An aminotriazole formulation containing ammonium thiocyanate activator was employed. Before solubilization, aqueous solutions containing up to 10% of the herbicide were made. MCPA potassium salt was solubilized with xylene by means of a surfactant - phosphate ester, LoD*; the spray solution contained 10% v/v of LoD, the appropriate weight of MCPA salt in 10% v/v of water and 80% v/v of xylene (Table 1). In the experiment summarised in Table 2 paraquat, aminotriazole and glyphosate were solubilized by means of sodium dioctyl sulphosuccinate*; spray solutions contained 10% w/v of this surfactant and 10% v/v of a water solution of the herbicide in a paraffinic oil, Shellsol T*. In a further experiment (Table 3) a glyphosate formulation* without wetting agent was brought into mixed solutions with Shellsol T by means of a mixture containing 67% v/v of Agral 90 and 33% v/v of glycerol mono-oleate. A relatively concentrated solubilized preparation was mady by mixing together 33.3% of this

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* "Agral 90". 90% alkyl phenol ethylene oxide condensate, supplied by Plant Protection Ltd.
* "LoD". Supplied by Albright and Wilson Ltd., Oldbury Division.
* Sodium dioctyl sulphosuccinate. Supplied as "Manoxol OT" by Hardman and Holden, Manchester.
* "Shellsol T". Supplied by Shell Chemicals (UK) Ltd.
* Glyphosate without wetting agent. Formulation MON 0139.

solubilizer, 33.3% v/v of an aqueous solution containing 95 g/l of glyphosate, and 33.3% v/v of Shellsol T. This preparation formed a very fine, stable emulsion when shaken with a larger volume of water. A comparison was made of the effects of bark applications of glyphosate in this type of emulsion, glyphosate as a solution in water, and solubilized solutions of the herbicide in Shellsol T (Table 3).

Foliage applications. Foliage treatments were applied to pot-grown plants of 6 woody species, beech (Fagus sylvatica), privet (Ligustrum ovalifolium), hawthorn (Crataegus monogyna), willow (Salix fragilis), poplar, (x Populus gelrica) and Rhododendron ponticum. Beech, privet, hawthorn and Rhododendron were planted in 25 cm pots during the winter. Willow and poplar were grown from cuttings planted directly into pots of similar size. The plants used for the experiments summarised in Tables 4 and 6 were grown in a glasshouse; all other work was conducted outdoors. Randomised block designs with from 6 to 8 replications were used. Sprays were applied to outdoor-grown material in June or July when the leaves were fully expanded but had not started to become senescent. At this time the plants were from 0.5 m to 1 m tall. In all experiments examining foliage replications, herbicide solutions in water were solubilized with a mixture of 67% v/v of Agral 90 and 33% v/v of glycerol mono-oleate. One ml of this mixture was capable of solubilizing an equal volume of solution containing up to 100 g/l of paraquat, aminotriazole or glyphosate. Herbicide formulations containing wetters were used for a preliminary experiment with greenhouse grown poplars (Table 4). In this experiment sprays were applied at a volume rate of 400 l/ha. In all other experiments examining foliage applications, a glyphosate formulation without wetter was used and the volume rate was 148 l/ha. Soil surfaces were covered during spraying to prevent root uptake of herbicides. In all cases treated plants were subjected to heavy watering with overhead irrigation equipment at 24 h after spraying. This treatment was intended to simulate heavy rainfall.

Experiments with hawthorn and greenhouse grown poplar examined the effects of adding either 10% v/v of an emulsifiable oil (Sun 6*) or 10% v/v of a surfactant (Agral 90) to aqueous glyphosate sprays (Tables 6 and 7). To reduce viscosity it was necessary to add 10% v/v of acetone to the surfactant solution.

Leaf injury was assessed by estimating areas of living leaf as a percentage of the area present on untreated control plants. Regrowth was removed and weighed at the conclusion of experiments. With outdoor-grown plants the final assessment was at 10-12 months from treatment.

For simplicity, statistical analysis of all experimental data has been carried out using the original untransformed values.

RESULTS

Bark applications. Aqueous MCPA - K salt was much less active than an ester-in-oil when sprayed onto cuttings (Table 1). When the salt was solubilized with oil, phytotoxicity was enhanced to about the level of the ester-in-oil solution. Xylene and a blank solubilizer solution were inactive.

Most solubilized solutions of paraquat, aminotriazole and glyphosate were much more phytotoxic than equivalent water based sprays (Table 2). None of the latter significantly affected shoot growth. As in the previous experiment, the blank solubilizer in oil was without effect.

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* "Sun 6": a paraffinic solvent supplied by B.P. Ltd.

The experiment with glyphosate which is summarised in Table 3 was conducted in a cool glasshouse in winter, when shoot growth was slow. 5000 ppm of glyphosate solubilized with Shellsol T was significantly more phytotoxic than an equivalent aqueous solution. However the solubilized preparation was inactive when applied to cuttings as an emulsion in water.

Foliage applications. Sodium dioctyl sulphosuccinate was found to be very phytotoxic to foliage. Some solvent oils also caused severe contact injury which may rule out any possibilities of herbicide translocation. Many surfactants other than sodium dioctyl sulphosuccinate were phytotoxic. However after prolonged trials some surfactants, including certain blends of Agral 90 and glycerol mono-oleate, were found to be almost non-phytotoxic and suitable for solubilizing water soluble herbicides into a phytobland oil, Shellsol T. Table 4 shows some results of a preliminary experiment with solubilized paraquat, aminotriazole and glyphosate. Solubilization slightly enhanced the contact activity of paraquat and the chlorotic effects of aminotriazole, but had little effect on their longer term phytotoxicity. However solubilized glyphosate had much more systemic activity than the ordinary water based spray. Thus, 0.4 kg/ha of glyphosate in aqueous solution was almost ineffective, but 0.1 kg /ha as a solubilized formulation completely suppressed regrowth and partially defoliated the test plants. A blank solubilizer-in-oil solution was inactive. Similar effects were observed in a larger experiment with five woody species (Table 5). At rates up to 1 kg/ha solubilized or aqueous glyphosate sate did not kill privet, but reduced the size of shoots and leaves. At the lower application rates weights of regrowth were significantly reduced by solubilization. At 0.75-1 kg/ha activity was not enhanced. Beech was more susceptible; at the end of the experiment all plants sprayed with 0.4 kg/ha of aqueous or solubilized glyphosate were dead or moribund. At 0.1-0.2 kg/ha solubilization greatly enhanced phytotoxicity. Similar results were obtained with applications of 0.05 kg/ha or 0.1 kg/ha to poplar foliage. In willow and Rhododendron, low doses of glyphosate markedly increased the production of new growth in the season following treatment. This increased growth resulted from the development of large numbers of axillary shoots, the herbicide apparently affecting apical dominance. Very marked differences between solubilized and ordinary solutions of glyphosate were observed with Rhododendron. All the plants sprayed with 4 kg/ha of aqueous glyphosate regrew strongly but 9 of the 8 plants treated at this rate with solubilized formulations were dead when the experiment ended.

In experiments with poplar and hawthorn, solubilized glyphosate had much more effect than aqueous solutions containing oil or a large amount of surfactant (Tables 6-7).

DISCUSSION

When aqueous solutions of herbicides are solubilized into an oil they sometimes behave as if they had acquired true oil solubility. For example, they resemble oil solutions in that they become capable of movement through bark. Solubilization sometimes also increases foliar activity, as with glyphosate, presumably by increasing the rate at which herbicides penetrate through cuticle. However this effect has not been observed with paraquat and aminotriazole. It is likely that the activity of these herbicides is not limited by their rate of entry into leaves, but by some other factor. At present only a few herbicides have been examined and it is difficult to foresee the likely practical importance of solubilization. However this new type of formulation appears to offer interesting possibilities with several water-soluble herbicides and growth regulator compounds. The technique is of course most likely to be useful with materials which cannot otherwise be brought into oil solutions. Of the herbicides which have been examined, glyphosate appears to be of particular interest. The information which is now available suggests that solubilization sometimes increases the activity of foliage applied glyphosate by a factor of about 4. By contrast the addition of emulsified oil or a large amount of surfactant to aqueous sprays has relatively little effect.

While the technique offers interesting possibilities, there are obvious drawbacks. The costs of formulation are probably most important. In the experiments which have been described solubilized herbicides were applied in volumes of oil of from 148 l/ha to 400 l/ha. In some circumstances it might be economic to use medium volume oil based sprays, particularly sprays based on kerosene or diesel oil. However the cost of large amounts of oil will often be prohibitive. It may be possible to reduce the use of oil by applying relatively concentrated solubilized preparations at very low volume rates. Alternatively, a concentrated formulation might be emulsified with a larger volume of water and applied at medium or high volume rates with a conventional sprayer.

Low volume applications. The surfactant mixture now employed for solubilizing glyphosate can be used to make a formulation containing 3%-4% of the herbicide. This solution has been successfully applied at 20 l/ha to herbaceous species with spinning disc equipment of the type described by Byass and Charlton (1968). Preliminary results suggest that solubilized glyphosate applied with this equipment is much more phytotoxic than aqueous solutions applied conventionally. Full results will be published elsewhere. Other work by colleagues at WRO suggests that these effects of solubilized herbicide formulations may extend to herbaceous weeds.

Oil-in-water emulsions. When sprayed onto bark, an emulsion containing glyphosate was much less active than an oil solution (Table 3). Similar results have been been obtained in preliminary experiments with foliage applied emulsions of the solubilized solutions. The reasons for this low activity are not fully understood, but may be a result of the herbicide being firmly held in the oil phase of the emulsion. If a similar formulation is made which contains a water soluble dye, Tartrazine, in place of the herbicide, the dye does not move readily from the oil droplets of the emulsion into the continuous water phase.

While it may be possible to reduce the volume of oil used for applying solubilized herbicides, large amounts of surfactant are also needed. The amounts which are required appear to be largely independent of the volume rate. With the mixture now used 1 kg of surfactant, costing perhaps £1, is needed to formulate 0.1 kg of glyphosate. With a herbicide of high cost this may be reasonable. However with many cheaper herbicides, the cost of the materials now used is likely to be prohibitive. Attempts are being made to find cheaper, more efficient solubilizers.

In the experiments with willow and *Rhododendron* low doses of glyphosate significantly increased regrowth weights, apparently through an effect on dormant lateral buds. A somewhat similar response of grasses to low doses of the herbicide has been observed by Coupland and Caseley (1974).

Acknowledgements

The authors wish to thank Dr. K. Holly and other colleagues for advice in conducting the experiments and in the preparation of this report. The assistance of many chemical firms in providing samples of herbicides, surfactants, etc. is also acknowledged.

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Table 1

Effect of MCPA applied to the bark of poplar cuttings, after 19 days

	No. of living cuttings (out of 10)	Mean fresh wt of shoots (g)
Untreated control	10	3.30
Xylene sprayed control	10	3.33
Xylene/L6D sprayed control	10	3.40
25,000 ppm MCPA as iso-octyl ester in xylene	2	0.01
as K-salt in water	10	1.42
as K-salt solubilized	2	0.03
Standard error		± 0.120

Table 2

Effect of herbicides applied to the bark of poplar cuttings. Mean fresh wt of shoots per cutting (g) after 30 days

	Aqueous spray	Solubilized spray
Control (means of 30)	7.3	7.4
5000 ppm paraquat	6.9	2.3
20,000 ppm paraquat	6.5	2.3
5000 ppm aminotriazole	8.1	7.3
20,000 ppm aminotriazole	6.6	2.1
5000 ppm glyphosate	6.8	1.7
20,000 ppm glyphosate	6.2	1.5
Standard error		± 0.58

Table 3

Effects of glyphosate applied to the bark of poplar cuttings: fresh weights of shoots after 46 days (g)

Spray formulation	Glyphosate concentration, ppm 0	1000	5000
Aqueous solution	1.85	1.99	1.32
Solubilized solution, in oil	1.89	2.19	0.69
Solubilized solution, emulsified in water	2.20	2.14	1.64
Standard error		± 0.19	

Table 4

Effects of foliage applied glyphosate, paraquat and aminotriazole: fresh weights of poplar leaves (g) after 48 days

Herbicide treatment	Aqueous spray	Solubilized (oil-based) spray
Control	24	23
0.1 kg/ha paraquat	24	21
0.4 kg/ha paraquat	8	6
0.1 kg/ha glyphosate	21	7
0.4 kg/ha glyphosate	23	1
0.2 kg/ha aminotriazole	24	24
0.8 kg/ha aminotriazole	18	15
Standard error (all comparisons)	± 1.1	

Table 5

Effects of foliage applied glyphosate: weights of new growth after 10-12 months (control = 100)

	Glyphosate, kg/ha					
(1) Privet	0	0.25	0.5	0.75	1.0	
Aqueous spray	100	91	85	47	34	S.E.
Solubilized formulation	97	64	37	40	45	± 8.1
(2) Beech	0	0.05	0.1	0.2	0.4	
Aqueous spray	100	98	106	78	7	S.E.
Solubilized formulation	100	71	51	33	10	± 13.2
(3) Poplar	0	0.05	0.1	0.2	0.4	
Aqueous spray	100	71	74	11	1	S.E.
Solubilized formulation	98	24	2	0	0	± 5.4
(4) Willow	0	0.05	0.1	0.2	0.4	
Aqueous spray	100	181	151	43	17	S.E.
Solubilized formulation	119	188	37	11	4	± 10.5
(5) Rhododendron	0	0.5	1	2	4	
Aqueous spray	100	158	155	69	43	S.E.
Solubilized formulation	106	81	49	15	3	± 16.1

Table 6

Effects of foliage applied glyphosate: dry weights of poplar regrowth after 30 days (g)

Spray formulation	Glyphosate, kg/ha 0	0.1	0.4	
Aqueous, with 0.25% Agral 90 ,	2.3	2.1	0.4	
Aqueous, with 10% emulsified oil	2.2	2.1	0.3	S.E.
Aqueous, with 10% Agral 90	1.9	1.6	0.1	± 0.14
Solubilized, in oil	1.9	0.0	0.0	

Table 7

Effects of foliage applied glyphosate: fresh weights of new growth at 10 months (hawthorn) (g)

Spray formulation	Glyphosate, kg/ha 0	0.125	0.5	
Aqueous, with 0.25% Agral 90	24.2	17.4	15.1	
Aqueous, with 10% emulsified oil	25.2	17.7	10.7	S.E.
Aqueous, with 10% Agral 90	20.9	14.3	13.1	± 2.72
Solubilized, in oil	22.3	15.6	5.5	

Proceedings 12th British Weed Control Conference (1974)

THE ENHANCEMENT OF POTENCY AND SELECTIVITY OF ASULAM IN LINSEED FLAX

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Summary Greenhouse and field studies have shown that selective control of wild oats (*Avena fatua* L.) in flax (*Linum usitatissimum* L.) with asulam is influenced by formulation, spray volume and the growth stages of the weed and crop.

The sodium salt of asulam has been shown to have better selectivity than the acid. Wetter addition (0.125%) resulted in a considerable increase in the activity against wild oat with only small or insignificant effects on the flax. A volume of 56 l/ha gave better wild oat control than higher spray volumes. Although flax retardation was more evident at the low spray volume the selectivity margin was still adequate.

A study of the complex interaction of crop and weed growth habits shows that asulam should not be applied to very young seedling flax and that application should be delayed until the majority of the wild oats have between three to six leaves.

Résumé: Des études en serre et en plein champ ont démontré que le désherbage sélectif de la folle avoine (*Avena fatua* L.) dans le lin, à l'aide de l'asulam, est influencé par la formulation, le volume de bouillie et le stade de croissance des mauvaises herbes et des cultures.

Il a été démontré que le sel de sodium de l'asulam donne une meilleure sélectivité que celle de l'acide. L'addition d'un mouillant a résulté en un accroissement notable de l'activité contre la folle avoine tandis que sur le lin les effets ont été mineurs ou insignifiants. Un volume de 56 l/h se revela plus efficace contre la folle avoine que de plus grands volumes. Bien que le retardement de la pousse du lin se revela plus prononcé à 56 l/h, la marge de sélectivité restait suffisante.

Une étude sur la interaction complexe des habitudes de croissance des cultures et des mauvaises herbes démontré que l'asulam ne doit pas être utilisé sur très jeunes pousses de lin et que l'application doit être retardée jusqu'à ce que la majorité des folles avoines présente de trois à six feuilles.

INTRODUCTION

The need for an efficient herbicide for wild oat control in flax has been frequently stated. Competition studies (Bell and Nalewaja 1969) have shown that 80 wild oat per yd^2 reduced yields by 57-71% and 160 per yd^2 by over 80%. This confirmed earlier studies by Selleck (1961) and Carder (1955). The latter found that while barley, wheat and oats offered strong competition to wild oat, flax suffered badly.

Initial greenhouse studies (unpublished) by May & Baker indicated that flax was resistant to doses of asulam which gave good control of wild oats and suppression of some important annual broad-leaved weeds. This was confirmed in field tests in Canada in 1963 (Cook, P.D., 1963, 1963a and Molberg, E.S., 1963). Further field tests in 1964, which included the use of a wetter, gave some disappointing results, with occasional reports of unacceptable chlorosis (Clarke and Cook, 1964) and decreased crop yields (Molberg 1964). When all the information was collated it became obvious that several factors were implicated but it was still believed that asulam was potentially suitable for the control of wild oats in flax.

A study was made to investigate some of the variables, especially those related to plant morphology, path of uptake and formulation which might affect the activity of a herbicide on these two species (Hibbitt,1969). This paper describes greenhouse studies which have been confirmed both in field experiments and commercial usage.

MATERIALS & METHODS

Chemical

Unless stated, asulam was applied as 'Asulox' (40% w/v sodium salt formulation). In the preliminary formulation experiment (Table 1) the following were compared with the sodium salt; an aqueous solution of the ammonium salt, a 25% w/v wettable powder prepared from asulam acid and three emulsifiable concentrates containing the acid (A-20% w/v in isophorone, B-30% in methyl ethyl ketone and C-40% in cyclohexanone). Spray solutions for the pH experiment (Table 2) were prepared by adjusting the pH of solutions of asulam acid using normal NaOH solution up to pH 7 and decinormal solution for pH values between 7 and 11.

The wetter added in these experiments was an alkyl phenol polyoxyethylene condensate.

Experimental

Spraying for all pot experiments was carried out with an overhead laboratory sprayer and the field experiment was sprayed with a Colwood fixed dosage sprayer.

In most of the pot experiments wild oat and flax were grown 3 per 9 cm whalehide pot and these experiments were of factorial or randomised block design with 3 or 4 replicates of 2 pots/treatment. When doses were topically applied (Table 5) there was one plant per pot with 5 replicate plants per treatment,and mixed populations of flax and wild oat (Table 9) were sown in polythene containers approximately 35 x 25 x 17.5 cm deep, 2 replicates per treatment. In the field experiment (Table 7) flax was sown at 60 lb/ac and two replicate 2.0 x 6.1 m plots were sprayed per treatment. In a pre-spray count there were an average of 30 x 2-4 leaf wild oat per area of plot sampled (1.2 x 5.5 m).

Assessments of activity were generally made one month post-application. Fresh weights of surviving wild oat were determined and the percentage fresh weight reduction calculated, based on unsprayed plants. Flax damage was assessed on the basis of reduction in plant fresh weight or height: any visual abnormalities were also recorded. In the field experiment, a pre-spray count of wild oat was made and at harvest the number of seeding wild oat was recorded and expressed as a percentage of the original number per plot. Flax height at three fixed points in each plot was also recorded.

In these experiments asulam has been applied at doses from 0.5 lb/ac (0.56 kg/ha) to 8 lb/ac (8.96 kg/ha) at spray volumes from 5 gal/ac (56 l/ha) to 50 gal/ac (560 l/ha).

RESULTS

Table 1

The effect of formulation on the activity of asulam

Formulation	ED_{90} (lb/ac) wild oat	Maximum tolerated dose (lb/ac) flax
Sodium salt	2	>8
Sodium salt + 0.8% wetter	1	2
Ammonium salt	4	>8
Wettable powder (acid)	2	>8
Emulsifiable concentrate (A) (acid)	8	2
Emulsifiable concentrate (B) (acid)	2	2
Emulsifiable concentrate (C) (acid)	2	4

Sprayed at 50 gal/ac - outside pot experiment - wild oat 2-3 leaf, flax 12 leaves.

Table 2

Effect of pH on the potency of asulam

pH of spray solution	ED_{90} (lb/ac) wild oat
3.4	2.75
5.0	2.30
6.0	1.60
7.0	1.40
8.0	1.50
9.0	1.45
10.0	1.40
11.0	1.35

Sprayed at 20 gal/ac - greenhouse - wild oat $2\frac{1}{2}$-$4\frac{1}{2}$ leaf. (Asulam solutions all contained 0.1% wetter). pH adjusted with NaOH.

Table 3

Effect of soil shielding on the activity of asulam on seedling wild oat

Asulam (lb/ac)	% wetter	% reduction (fresh wt) spray applied to	
		plant and soil	plant only
2	0	48	4
3	0	84	0
1	0.1	55	12
1.5	0.1	76	29

Sprayed at 20 gal/ac - greenhouse - wild oat 1-1½ leaf.

Table 4

Effect of plant or soil shielding on the activity of asulam on established wild oat

Asulam (lb/ac)	% wetter	% reduction (fresh wt) treatment applied to		
		plant and soil*	plant only*	soil only*
1	0.1	100	100	12
1.5	0.1	100	100	21
1	0.2	100	100	0
1.5	0.2	100	100	0

plant and soil* - normal spray application
plant only* - as above, but soil covered with cotton wool which was later removed
soil only* - asulam dose applied to soil by pipette.

Sprayed at 20 gal/ac - greenhouse - wild oat 4-5 leaf tillering.

Table 5

The effect of the position of application on the activity of asulam on wild oat

Position of asulam droplet	% fresh weight reduction % asulam in droplet	
	0.5	1.0
Tip of 1st leaf	36	49 a
Base of 1st leaf	50	98 b
Tiller from 1st leaf	24	76 ab
Tip of 2nd leaf	65	54 a
Tip of 3rd leaf	69	89 b
Axil of emerging leaf	70	100 b

Treatments followed by the <u>same</u> suffix are not significantly different ($p = 0.05$), Duncans Range Test. Droplets applied by microsyringe - greenhouse - wild oat 3-4 leaf.

Table 6

The effect of growth stage, wetter concentration and spray volume on the activity of asulam on wild oat (greenhouse)

Spray volume (gal/ac)	% wetter	% reduction (fresh wt of living plants) growth stage at spraying: $1\frac{1}{2}$ leaf, lb/ac asulam 1	$1\frac{1}{2}$ leaf, 2	4 leaf + tillering, 1	4 leaf + tillering, 2	5 leaf + tillering, 1	5 leaf + tillering, 2
5	0	0	64	45	81	51	81
	0.125	100	100	100	100	100	100
	0.25	100	100	100	100	100	98
	0.5	98	100	100	100	100	100
10	0	23	22	30	54	35	71
	0.125	85	100	95	100	95	100
	0.25	98	100	97	100	96	100
	0.5	100	100	94	100	100	100
20	0	14	50	12	41	47	68
	0.125	94	100	90	100	85	100
	0.25	97	100	89	100	99	100
	0.5	95	100	100	100	100	100

Table 7

The effect of wetter addition on the activity of asulam on wild oat and flax in the field

lb/ac asulam	% wetter	Spray vol. (gal/ac)	% control of wild oat seeding	% reduction in flax height
0.5	0	5	0	0
"	0.25	"	88	3
"	0.5	"	61	15
1.0	0	"	54	4
"	0.25	"	100	3
"	0.5	"	84	15
2.0	0	"	87	0
"	0.25	"	100	7
"	0.5	"	98	5
0.5	0	10	4	4
"	0.125	"	63	4
"	0.25	"	72	7
1.0	0	"	59	1
"	0.125	"	94	7
"	0.25	"	97	5
2.0	0	"	84	0
"	0.125	"	100	38
"	0.25	"	99	11

Sprayed at 5 & 10 gal/ac - field experiment - wild oat 2-4 leaf, flax (cv Redwing) 20-40 cm high - approximately 40 leaves.

Table 8

Effect of asulam rate, wetter concentration and spray volume on flax

		Mean plant wt (g)	L.S.D.
Asulam (lb/ac)	0	17.2	1.27 (p<0.001)
	0.75	17.8	
	1	16.3	
	1.5	15.8	
	2	14.5	
% wetter	0.05	16.1	ns
	0.075	16.6	
	0.1	16.5	
	0.15	16.2	
	0.2	16.3	
Spray volume (gal/ac)	5	15.7	0.8 (p<0.001)
	10	17.0	

No interactions were statistically significant

Sprayed at 5 and 10 gal/ac - greenhouse - flax (cv Noralta) 16-20 leaf (no side shoots).

Table 9

Selectivity of asulam for wild oat control in flax

Asulam (lb/ac)	% wetter	Flax Fr.wt. (g)	Flax Ht. (cm)	Wild Oat Fr.wt. (g)	Wild Oat Seed no.
0	0	144	58	163	506
1	0.1	141	53	0	0
1	0.2	174	43	0	0
1.5	0.1	204	53	1	0

Sprayed at 10 gal/ac - outside pot experiment (mixed population) wild oat 3-5 leaf tillering. Flax, Noralta, 22-26 leaf.

DISCUSSION

A. Formulation

The experiment with different formulations of asulam demonstrates two important points (Table 1). First, that the sodium salt of asulam is more selective between wild oat and flax than is the parent acid. Second, that the addition of wetter has a marked effect on the activity of the sodium salt.

The first of these points prompted an investigation into the effect of solution pH on the activity of asulam. Preliminary experiments showed that asulam has a pK_a value of 4.9. Thus in solution at pH 5, asulam is approximately 50% dissociated whilst almost complete (>90%) dissociation occurs at pH 6. As can be seen from Table 2 there is a marked increase in the activity of asulam solutions against wild oat between pH 5 and 6 thus demonstrating the greater activity of the compound in the ionised form. In practice this state is most conveniently achieved by preparing spray solutions from concentrated aqueous (40% w/v) solutions of asulam sodium salt. It is worth noting that throughout the world most water used for preparing agricultural spray solutions has a pH of between 6 and 9 (Ashworth and Crozier, 1972) which would ensure at least 90% dissociation of asulam.

The concentration (0.8%) of wetter added to the sodium salt solutions of asulam used in the initial formulation experiments was subsequently found to be unnecessarily high. The results given in Tables 6 and 7 show quite clearly that the addition of as little as 0.125% wetter resulted in a considerable increase in the activity of asulam sprays against wild oat in both greenhouse and field experiments. Similar sprays applied to flax resulted in small or insignificant reductions in plant growth.

B. Growth stage at spraying

Asulam can be absorbed both through the leaves and through the roots, but root uptake is only important in the case of seedling plants (Tables 3 and 4). As wild oat grows the leaf area exposed to overhead sprays increases enormously, leading to increased spray retention per unit weight of plant (Hibbitt, 1969) and a parallel increase in the efficacy of asulam sprays (Table 6). On the other hand, the cotyledons of flax are easily wetted, but as the plant grows they become shielded by the true leaves, and soon senesce. The amount of spray retained by flax does not, therefore, greatly increase as the plant grows.

As a consequence of this important difference in the growth habits of flax and wild oat, it is possible to obtain maximum potency against the weed and maximum selectivity towards the crop, by delaying treatment until the majority of the wild oats have between three and six leaves. This is also convenient in practice, because (i) earlier spraying is inefficient, due to subsequent germination of other wild oat plants, and (ii) spraying later than the six leaf stage allows the wild oat to suppress the crop before treatment.

C. Spray volume

Both the field and greenhouse experiments have shown that a volume of 5 gal/ac gives better wild oat control than higher spray volumes (Tables 6 and 7). From table 8 it can be seen that flax retardation is also more evident at the low spray volume, but the selectivity margin is still adequate.

Thus it has been shown that asulam can effectively control wild oat in flax providing the several requisites outlined in this report are all implemented (Table 9). Field trials in Canada (Hardisty, 1971) confirm this: 12 and 16 oz/ac asulam, without wetter, increased crop yields by 30 and 50%, with moderate wild oat control, while with 0.1% wetter added both doses increased yields by 70% with over 90% wild oat control.

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Proceedings 12th British Weed Control Conference (1974)

THE USE OF ESTER AND ETHER DERIVATIVES TO MODIFY THE SOIL BEHAVIOUR OF AN ACIDIC HERBICIDE

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Summary As a pre-emergence herbicide, haloxydine, (3,5-dichloro-2,6-difluoro-4 hydroxy-pyridine) gives a variable performance in the field. Part of this variability can be ascribed to excessive soil mobility and numerous ester and ether derivatives have been prepared in an attempt to overcome this difficulty. In general, esters either hydrolysed rapidly in soil or were herbicidally inactive. Several ethers were found which were relatively stable in soil and also showed useful activity; residue studies suggest such compounds release haloxydine after uptake by plants. Ethers were less persistent than the K^+ salt formulation of haloxydine, mainly through losses by volatilisation.
In glasshouse experiments, the reduced soil mobility of ethers can be exploited to give enhanced selectivity between crop and weed species.

Quand l'haloxydine (3,5-dichloro-2,6-difluoro-4 hydroxy-pyridine) est appliquée avant la levée les résultats obtenus sont variés.

Cette variation peut s'expliquer en partie par un mouvement excessif du produit chimique dans le sol; de nombreux esters et éthers dérivés sont mis au point pour essayer d'eliminer ce problemè.

De façon générale, les esters etaient rapidement hydrolysés dans le sol ou bien étaient inactifs. Certains éthers se montrérent relativement stables dans le sol et étaient en même temps actifs. L'examen des résidus indique que l'haloxydine est relâchée quand le composé est utilisé par la plante. Les éthers étaient moins persistants que l'haloxydine (sous forme de sel de potassium), ceci dû principalement à une plus forte volatilisation.

Dans les experiences en serres, la réduction du mouvement des éthers dans le sol peut être mise à profit pour améliorer l'action selective du produit entre les cultures et les mauvaises herbes.

INTRODUCTION

The performance of some soil-applied herbicides can be improved by appropriate formulations: for example, granules are successful in preventing rapid loss of volatile herbicides such as tri-allate and dichlobenil (Hance et al 1973, Verloop 1972). The formulation approach is, however, generally less successful with anionic compounds of pKa4 or less. Such compounds are readily leached through soil and activity may vary according to rainfall after application. Similarly, selectivity between crop and weed species may be variable when plant response is dependent on the position of the herbicide in the soil.

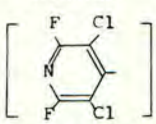
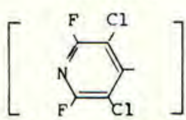
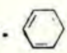
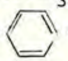
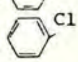
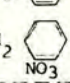
Attempts have been made to modify the soil behaviour of anionic herbicides by means of derivatives such as esters and ethers. For example, the soil mobility of amiben methyl ester is much less than that of amiben itself (Talbert et al 1970): in this case, however, the ester rapidly hydrolyses to the parent compound in soil.

Haloxydine is a highly active anionic herbicide (pKa 2·3) which has shown some promise for pre-emergence weed control in rice, cotton, and cruciferous crops, for control of wild oats in Spring barley and as a total herbicide. However, both the level of activity and selectivity have been variable under field conditions and glasshouse studies suggest that at least part of this variability can be attributed to the high mobility of haloxydine in soil (see below). To overcome this variability we looked for derivatives of haloxydine having:-

1) Low hydrolysis (to haloxydine) in soil
2) Low soil mobility
3) High herbicidal activity

Over 30 compounds have been studied. This paper discusses the properties of some of these derivatives (see Table 1 for structures) and presents some biological data to show how reduced soil mobility may change the pattern of herbicidal activity.

Table 1 Structures of compounds discussed in text

Code	Structure 	Code	Structure 
A (haloxydine)	OH	G	$O(CH_2)_2OCH_3$
B	OOC. 	H	$OCH_2COO.CH_2CH_3$
C	$OOC.C(CH_3)_3$	I	$OCH_2C{\equiv}CH$
D	OOC  OCH_3	J	OCH_2 
E	$OOC.N(CH_3)_2$	K	OCH_2 
F	OCH_3	L	OCH_2 

1. HYDROLYSIS AND HERBICIDAL ACTIVITY OF DERIVATIVES

Rates of hydrolysis were determined in soil and in nutrient solution culture; herbicidal activity was estimated from solution culture only.

Methods and Materials

For soil studies, 40µg of each derivative was incubated under aerobic conditions with 50g of sandy clay loam soil (pH 6.5, organic matter 4%, water 26%). At set time intervals samples were taken and extracted with 0.01M $CaCl_2$; the extract was made alkaline by addition of NaOH and partitioned with diethylether. Haloxydine remained in the aqueous phase; this phase was then acidified (HCl), partitioned again with diethyl ether and the ether phase (containing haloxydine) was dried over Na_2SO_4. The extract was methylated using diazomethane, and methylated haloxydine estimated by GLC using a ^{63}Ni electron capture detector.

For nutrient solution culture experiments, seeds of wheat (Kolibri) and radish (Scarlet Globe) were pre-germinated and sown on 1 mm nylon gauze fixed at the top of 150 ml polystyrene beakers containing Hoaglands solution. Haloxydine derivatives were added at 0, 1.0, 5.0 and 20.0 ppm w/v from acetone solution (final concentration of acetone in the medium did not exceed 0.1%). Plants were grown under glasshouse conditions and visually assessed for damage after 14 days. Haloxydine, at 0.2, 0.5 and 1.0 ppm was included as a standard.

Following assessment of phytoxicity, nutrient solutions, containing both the haloxydine derivative and haloxydine released by hydrolysis, were extracted by partitioning with diethylether under acidic conditions. Haloxydine and its derivatives were then separated by further partitioning the diethylether extract with distilled water under alkaline conditions; haloxydine separated into the aqueous phase and was bioassayed with wheat using the nutrient solution technique described above.

Tests with freshly prepared standard solutions of haloxydine derivatives showed that the extraction proceedures did not themselves hydrolyse the chemicals.

Results and Disussion

Examples of hydrolysis rates in soil are given in Table 2: data from nutrient solution culture are shown in Table 3. Once it was found that the solution culture method gave results in good agreement with both laboratory and field soil data (section 2), the solution method was used exclusively for initial testing of novel derivatives.

Table 2 Hydrolysis of esters and ethers in soil: % (of theoretical maximum) haloxydine released

Chemical	Incubation time (days)									
	1	2	3	6	10	17	24	31	69	100
haloxydine	-	-	-	-	104	-	83	-	-	65
B	94	94	94	94	94	77	-	-	-	-
C	32	46	63	71	79	73	79	71	-	-
D	58	83	90	92	94	83	-	-	-	-
E	7	7	7	7	7	3	3	5	3	3
F	0	0	1	1	5	12	12	14	14	14
G	0	0	0	0	0	0	0	0	2	0

Table 3 Hydrolysis of ethers in solution culture

Chemical	% hydrolysis after 14 days	Approximate herbicidal activity, relative to haloxydine
A (haloxydine	-	1
G	1-2	0.1
H	50	0.8
I	0	0.2
J	5-15	0.6
K	1	0.4
L	40-75	0.8

The ester derivatives either hydrolysed rapidly to haloxydine, e.g. compound B Table 2. or were herbicidally inactive, e.g. compound E. Field trials at two locations confirmed that B hydrolysed to haloxydine within 3 days. Rapid hydrolysis was also found with some haloxydine ethers; such compounds were of no further interest. However, high herbicidal activity was found without rapid hydrolysis in some cases, e.g. compounds: G, I, J, K.

Of the compounds studies, J combined the highest level of herbicidal activity observed with relatively low rates of hydrolysis. From field studies (section 2) it appears that the initial herbicidal activity is due to uptake of J itself, but that haloxydine released several weeks after application may contribute to longer term activity.

Analysis of foliage of wheat (Kolibri), oilseed rape (Victor) and wild oats (Avena fatua, L) grown in soil treated with compound J showed that the plants contained lethal concentrations of haloxydine, but very little of the ether derivative. Similar results have been obtained with G (R.T. Hemingway, personal communication). Hence it appears that these compounds, and probably other active ethers also, are rapidly hydrolysed within plant tissue.

2. MOBILITY AND PERSISTENCE OF HALOXYDINE ETHERS IN SOIL

Mobility of compounds G, I, J, were studied in both laboratory and field experiments; persistence was studied in the field only.

Methods and Materials

In the laboratory, soil mobility was studied by a thick layer descending chromatographic technique (Gerber et al 1970). Briefly, a 5mm thick layer of a pH 5.9 sandy clay loam soil, containing 5% organic matter, was spread on a 5x30 cm plate. The plate was supported at an angle of 5° to the horizontal, and a cloth wick dipping into 80ml 0.01M $CaCl_2$ was attached to the upper end. A 1 cm band of soil, 2-3 cm from the upper end of the plate, was removed and replaced by herbicide treated soil; after elution the soil was split into 5 cm bands and bioassayed against wheat using the nutrient solution method described above.

For field studies, haloxydine, compounds J, G, I were applied at rates of 1, 2, 4 and 4 kg/ha respectively at each of three spring barley sites in S.E. England in April 1972. using a 4 replicate, randomised block design, and a plot size of 5x 2m. Haloxydine was applied as a surface spray only; G and I were applied before drilling and lightly incorporated by the seed drill. Compound J was applied by both methods.

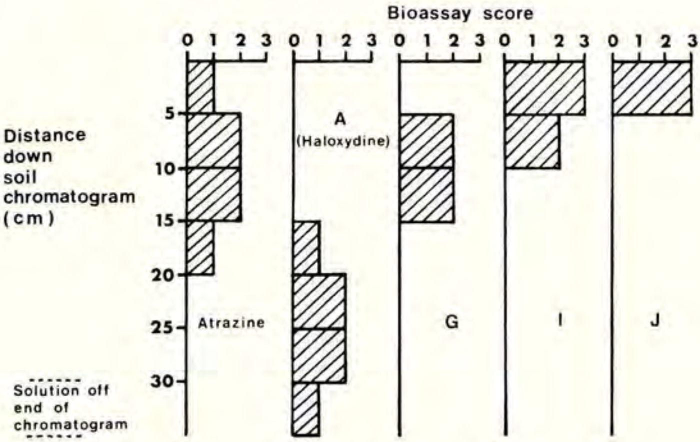
Two sampling methods were used. Soil cores, 7·3 cm diameter by 5 cm deep, were collected with a metal cylinder; this method gave results which could be expressed directly in terms of kg/ha for the herbicide residues. Small corers were also used to study distribution of residues down the soil profile; samples were split into 0-2·5, 2·5-5, 5-10 and 10-15 cm horizons. In this case, the area sampled is not known accurately and residues were calculated using an assumed bulk density for the soil of 1·2 g/cm^3.

For both methods, 10 samples were collected per plot at four time intervals after treatment, up to a maximum of 10 weeks. Ethers were extracted with acetone and analysed by GLC as described earlier for methylated haloxydine. Samples were also analysed for haloxydine itself. A further field experiment was carried out on the highly volatile ether, compound I. Two 2m x 6 m plots on a bare, dry, sandy loam soil were sprayed at 1 kg/ha; 7·4 cm Petri dishes were placed at random on each plot before spraying and samples collected to estimate the quantity of ether which actually hit the ground. After spraying, one plot was lightly incorporated using a hand rake. Two sets of 5 metal cylinder samples were taken from each plot at set time intervals and analysed as above.

Results and Discussion

Laboratory data on mobility are given in Fig. 1; as expected, the ethers were much less mobile than haloxydine. Their relative mobilities were in the same order as their water solubilities, J, 0·7 µg/ml, I, 110µg/ml; G 440µg/ml. Confirmation of reduced mobility was obtained from the field experiments, where at least 90% of the residues were generally located within the top 5 cm of soil throughout the 10 week sampling period.

Fig. 1. Leaching of herbicides on soil chromatograms; wheat bioassay of soil sections; 0 = no damage, 3 = dead.



Data on persistence are shown in Tables 4 & 5. The ethers are volatile compounds vapour pressures - J, 7×10^{-5} torr; I, $2 \cdot 4 \times 10^{-2}$ torr; G, $7 \cdot 3 \times 10^{-3}$ torr - and there was a rapid loss during the first few days. For I, losses were too great for this compound to have any practical use as a soil applied herbicide. Following incorporation, however, the half life of the remaining residues was comparable to haloxydine.

Table 4

Soil residues at first sampling and half lives of their residues. Numbers in brackets are hours between application and incorporation (above) and application and sampling (below). Haloxydine, J, G and I were applied at 1, 2, 4 & 4 kg/ha respectively.

Site	Haloxydine (surface)	J (surface)	J (incorporated)	G (incorporated)	I (incorporated)
1	0.41 (-) (72)	0.86 (-) (72)	1.51 (2) (24)	2.29 (2) (24)	0.63 (2) (24)
2	0.52 (-) (24)	1.77 (-) (24)	1.12 (4) (4)	1.01 (4) (4)	0.21 (4) (4)
3	0.92 (-) (24)	0.89 (-) (24)	0.50 (15) (24)	0.39 (15) (24)	0.04 (15) (24)
Mean half-life and 95% confidence interval (days)	30 (21-39)*	20 (15-24) 21 (17-24)*	42 (33-51) 39 (31-47)*	27 (23-31)	46 (38-53)

* Calculated from residues in 15 cm cores; other values are calculated from residues in the 7.3 cm diameter, 5 cm deep cores. The half life of haloxydine was only calculated for 15 cm core data because of its high mobility in soil.

Table 5

Effect of incorporation on persistence of compound I. 1kg/ha applied to bare soil

		Time after application (hours)					
		0	0.5	6	30	150	484
Soil Residues kg/ha	not incorporated	0.76	0.46	0.42	0.20	0.09	0.06
	incorporated	0.80	0.53	0.58	0.34	0.27	0.25

The maximum quantities of haloxydine detected after applications of 4 kg/ha G, 4 kg/ha I and 2kg/ha J were 0.03, 0.08 and 0.25 kg/ha. These figures, giving, for example, a total of about 18% hydrolysis for J, are in good agreement with data obtained from laboratory soil and solution culture work, (see above).

Although releasing some haloxydine into the soil, J has the most favourable combination of properties of the ethers so far studied, i.e., very low soil mobility, high herbicidal activity and by comparison with other ethers, relatively low volatility.

3. BIOLOGICAL DATA

Methods and Materials

Glasshouse experiments were carried out on Spring Barley (var. Zephyr) and wild oats. Plants were grown in 13 or 16 cm plastic pots, using a specially formulated compost consisting of 50% sandy clay loam, 25% vermiculite and 25% grit, plus added fertilizer. Pre-emergence spray applications were applied using a travelling-boom laboratory sprayer. For soil incorporated treatments, herbicide was added in distilled water carrier, at a rate of 100 ml/kg oven dry compost, and mixed in a small Gardener ribbon blender before application. The pots were top watered with a hand-held metal spray lance. In the data presented, W1 indicates a watering rate of 50 ml/pot/day, W2 indicates a rate of 100 ml/pot/day.

Results and Discussion

Glasshouse studies on selectivity between cereals and wild oats illustrate some of the potential benefits to be derived from the reduced soil mobility of haloxydine derivatives. When applied as fully incorporated pre-emergence treatments, neither haloxydine nor its derivatives show marked selectivity (Table 6). Nevertheless, barley wheat and wild oats differ in their response to controlled placement of these compounds within the soil profile; the two crop species appear to respond primarily via root uptake whereas wild oats can respond to herbicide placed around shoot regions above seed level. Similar differential response to controlled placement has also been found with thiocarbamate wild oat herbicides (Parker, 1963).

This type of effect is illustrated in Table 7. Here, the haloxydine ether compound G was incorporated into the top 2.5 cm of compost, and seeds of barley and wild oats sown at depths of 1.3 cm (within the treated layer) 3.8 and 5.1 cm (below the treated zone). Barley showed significant response only when sown within the chemical band whereas wild oats showed definite phytotoxicity from deeper sowing.

Table 6

Activity against wheat, barley and wild oats. Pre-emergence treatments fully incorporated into soil. % damage, visual assessment.

Chemical	A		I			J		
Dose, ppm	0.25	0.5	1.0	2.0	5.0	0.5	1.0	2.0
Barley	38	65	30	47	77	10	35	58
Wheat	47	65	45	72	90	50	62	72
Wild oats	52	65	50	77	88	40	67	77

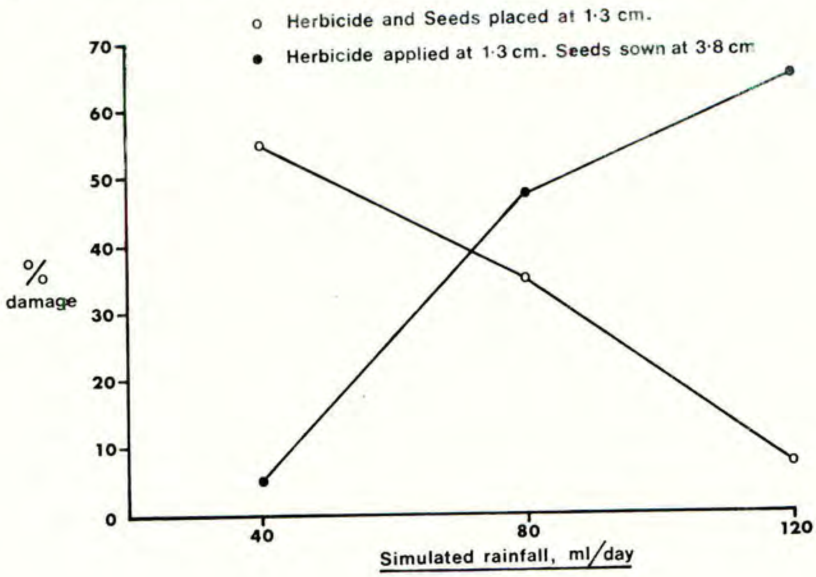
Table 7

Effect of sowing depth on activity of compound G. Herbicide, at 2 ppm, incorporated into top 2•5 cm of soil. % damage, visual assessment.

	Sowing depth (cm) 1.3	3.8	5.1
Barley W1	82	7	0
" W2	67	0	0
Wild oats W1	100	43	35
" " W2	98	42	35

For haloxydine itself, attempts at controlled placement can be upset by the effects of rainfall after application. The potential magnitude of such effects is illustrated in Fig. 2. Here, haloxydine was applied as a sub-surface layer; seeds of barley were sown either directly upon the chemical band, or at a position below the treated zone. Pots were then subjected to three rates of top watering. For seeds sown at the depth of the treated soil, damage was high at the low (non leaching) watering rate, but decreased as 'rainfall' increased. Conversely, for seeds sown below the treated zone, damage was low at the low watering rate, but increased with increased 'rainfall'. In the former case, therefore, the effect of watering appeared to be to dilute the chemical away from the zone of effective plant uptake, in the latter case, water moved the herbicide to the effective site of uptake.

Fig. 2. Effect of "Rainfall" on haloxydine activity against barley



With the discovery of the highly active, non-mobile benzyl ether (compound J), it was possible to achieve high levels of 'positional' selectivity in glasshouse experiments (Table 8). Here, seeds of barley and wild oats were sown 5 cm deep and chemicals were incorporated uniformly into the top 2.5 cm. By comparison with haloxydine, compound J shows much greater selectivity in this situation, and its activity was not affected by the two top watering rates used. Similar results were obtained with Spring and Winter wheat varieties. (Data unpublished).

Table 8

Positional selectivity, compound J v. haloxydine. % damage, visual assessment.

		haloxydine			J			
	Dose, ppm	0.25	0.5	1.0	0.25	0.5	1.0	2.0
Barley	W1	0	17	33	0	0	0	0
"	W2	0	12	40	0	0	0	0
Wild oats	W1	52	60	78	12	28	73	100
"	W2	68	92	100	10	27	47	100

Acknowledgements

Grateful thanks are extended to Dr C.D.S. Tomlin and Mr R.L. Sunley for synthesis of chemicals discussed in the text.

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NOTES

Proceedings 12th British Weed Control Conference (1974)

A PROVISIONAL ASSESSMENT OF THE INFLUENCE OF SOME APPLICATION FACTORS ON THE PERFORMANCE OF THREE POST-EMERGENCE WILD OAT HERBICIDES

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Summary. Three post-emergence wild oat herbicides, AC 84777, benzoylprop-ethyl and barban, as Carbyne B25, were applied to *A. fatua* (at two growth stages), spring wheat and spring barley, grown in pots under glasshouse conditions, to establish how herbicidal activity and selectivity could be influenced. Three volume ranges (c. 50, 160 and 450 l/ha) were applied with conventional hydraulic nozzles, each at three pressures (1.41, 2.11 and 2.81 bars). Barban and benzoylprop-ethyl were more active on *A. fatua* when applied in spray volumes of 52 and 170 l/ha at a pressure of 2.81 bars. Varying application factors were less important with AC 84777.

INTRODUCTION

For many years barban (as Carbyne) has been the most widely used post-emergence herbicide for the selective control of *Avena* spp. in cereals. It has been well established (Holly, 1960; Pfeiffer *et al*, 1960), that with barban certain application factors are important for its success. These are stressed in the leaflet supplied with the herbicide which states that volumes of spray liquid must be applied between 112 to 224 l/ha at a minimum pressure of 2.81 bars.

Benzoylprop-ethyl and 1,2-dimethyl-3,5-diphenylpyrazolium methyl sulphate (AC 84777) have now been introduced as post-emergence wild oat herbicides. Barban has also been marketed in a newer formulation as 'Carbyne B25'. The extent to which some readily adjustable spray parameters affect the subsequent activity of these herbicides on both *Avena fatua* (L.) Beauv. and two cereal crops was investigated in view of previous experience with barban (as Carbyne).

MATERIALS AND METHODS

Plant raising. Seeds of spring wheat (*Triticum aestivum*) cv. Kolibri, spring barley (*Hordeum vulgare*) cv. Sultan and *Avena fatua* were sown 1.2 cm deep in a sandy loam topsoil contained in 9 cm diameter plastic pots. The plants were grown in a temperate glasshouse. Three days before spraying plants furthest in size from the desired growth stage were removed to leave 5 per pot.

Herbicide application. A laboratory sprayer was used to apply the herbicides to the plants. This sprayer comprises a trolley capable of maintaining a uniform speed and a pressurised container with a single nozzle holder at the base. Each herbicide was applied at two doses using the commercial formulations supplied by the manufacturers. Three sizes of nozzle (800067, 8001 and 8003) from the Spraying Systems 'Teejets' range were selected to apply differing volume rates. The volume rates applied, as measured on a sample area of 60.8 cm^2 at a distance of 45 cm below the tip of each nozzle, were determined at three pressures, viz 1.41, 2.11 and 2.81 bars. The method of calibration has been described previously (Taylor and Richardson, 1972). The three species were arranged on spray benches so that there was again a vertical distance of 45 cm between the nozzle tip and the foliar canopy, this being the recommended operating height for these nozzles. There were 3 replicates of each treatment including unsprayed controls. Each herbicide was applied at two doses using the commercial formulations supplied by the manufacturers. The doses were adjusted to be either lower or higher than the commercial recommendations. Any difference in growth of the A. fatua after spraying, due to the mode of application of the herbicide, will be more easily observed at the lower dose. Similarly the higher dose may show differing effects on the crop species. Tergitol NPX, a non-ionic surfactant, was added to the herbicide AC 84777 to give a final concentration of 0.25% w/v. A further control using the same concentration of surfactant in water was included.

At the time of spraying the spring wheat had 3-4½ leaves/plant, the spring barley 2½-4½ leaves/plant, whilst the A. fatua deliberately sown to produce two different stages had 1½-2 leaves/plant and 3½-4½ leaves/plant.

Assessment. The fresh weight of foliage above ground level was determined 24 days after spraying.

ESULTS

Results are detailed in Tables 1, 2 and 3. For simplicity in presentation a statistical analysis was conducted for each species and growth stage. A separate, more detailed analysis for each dose of herbicide is available.

Barban suppressed growth of A. fatua at the 'early-stage' more effectively in the two lower volume ranges than in the higher. Increasing the pressure within these two ranges resulted in still greater activity. This trend was most noticeable with the combination of the lower volume range and earlier growth stage. Barban was least effective on the later growth stage of A. fatua when sprayed at a low pressure and/or high volume rate. Barley was tolerant of barban irrespective of mode of application. Some damage was detected on wheat with the high dose when applied in both lower and middle volume ranges. Within both these ranges, increasing pressure resulted in increased damage paralleling the effect found with A. fatua.

Benzoylprop-ethyl was observed to suppress the growth of A. fatua, proportionately more at the later, rather than the early growth stage. Plants were susceptible at all volume rates but the middle volume range was generally more effective. There is a trend which suggests that increasing pressure resulted in greater activity with both the lower and middle volume ranges. At the highest volume range, varying the pressure had little effect. Wheat was tolerant of benzoylprop-ethyl at 1.5 kg/ha. At 3.0 kg/ha some growth reduction did occur and this was greater with the lower and middle volume ranges but varying the pressure had no influence. There was a growth reduction of barley with all treatments, especially at the middle volume range. Raising the pressure at any volume with the highest dose increased damage.

In contrast to the other two herbicides varying the pressure or volume of application with the herbicide AC 84777 resulted in little general influence at either growth stage of A. fatua. Barley was tolerant to AC 84777 but wheat showed some sensitivity particularly at the higher dose. It was observed that at both doses in the middle volume range wheat was more sensitive at the lower pressure of application.

DISCUSSION

This experiment demonstrates that it is possible to alter biological response by manipulation of volume and drop spectrum as produced by different sizes of hydraulic nozzle and of pressure. These alterations are not consistent for all three species involved or for all 3 herbicides. This suggests scope for optimisation of weed control efficiency by modifying these factors and for improvement of selectivity.

Understanding of the factors involved must await more detailed experimentation in which there is concomitant measurement of retention of the phase of the application liquid in which the herbicide is carried. Superficially the 3 species have very similar leaf surfaces and morphology, so critical and detailed examination of differences between them seem likely to be needed. The differences between the 3 compounds seem more easily explicable by virtue of their differing types of formulation but again this requires more detailed examination than could be given in this experiment. The performance of these herbicides under laboratory conditions will need to be examined in the field.

Acknowledgements

We are grateful to Mrs. S. O'Keeffe and Mr. T.M. West for practical assistance.

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Table 1

Mean fresh weight (g) of 5 plants of *Avena fatua* 24 days after treatment

(a) sprayed at an early growth stage, $1\frac{1}{2}$ to 2 leaves

Volume rate, l/ha		68	57	52	144	158	170	457	425	462
Pressure, bars		1.41	2.11	2.81	1.41	2.11	2.81	1.41	2.11	2.81
	kg a.i./ha									
Barban (as Carbyne B25)	0.175	3.69	2.17	1.33	3.25	3.59	2.15	4.27	4.29	3.98
	0.35	2.36	1.30	0.79	1.75	1.40	1.31	4.03	3.85	3.30
Benzoylprop-ethyl	1.5	4.67	3.01	2.30	1.81	1.59	1.14	2.96	2.63	2.99
	3.0	1.74	1.02	0.73	1.23	0.80	0.57	0.84	1.45	0.64
AC 84777	0.5	2.53	1.39	0.97	0.70	1.16	0.93	2.02	2.25	2.00
	1.5	1.07	0.86	0.53	0.47	0.45	0.56	0.62	0.58	0.73
Surfactant control	-	4.17	4.58	5.11	4.69	4.97	4.33	4.50	4.25	4.93

S.E. of all treatment means $\pm$ 0.305

Untreated controls: mean 4.50

S.E.D. between controls and treatment means $\pm$ 0.204

(b) sprayed at a late growth stage, $3\frac{1}{2}$-$4\frac{1}{2}$ leaves

Volume rate, l/ha		68	57	52	144	158	170	457	425	462
Pressure, bars		1.41	2.11	2.81	1.41	2.11	2.81	1.41	2.11	2.81
	kg a.i./ha									
Barban (as Carbyne B25)	0.175	9.06	6.02	5.94	6.87	6.64	6.72	9.66	9.69	9.99
	0.35	6.79	3.43	5.76	5.65	4.79	5.59	9.53	7.98	8.37
Benzoylprop-ethyl	1.5	4.30	3.66	2.92	3.32	3.09	2.93	4.10	3.61	4.00
	3.0	3.33	2.86	2.90	2.50	2.63	2.81	2.87	2.53	2.29
AC 84777	0.5	4.12	2.91	3.23	2.60	3.54	3.13	2.89	2.94	3.43
	1.5	2.89	2.65	5.30	2.10	2.52	2.21	2.88	3.16	2.34
Surfactant control	-	11.43	10.88	10.87	12.38	10.87	12.63	11.25	10.92	10.37

S.E. of all treatment means $\pm$ 0.633

Untreated controls: mean 10.92

S.E.D. between controls and treatment means $\pm$ 0.421

Table 2

Mean fresh weight (g) of 5 plants of wheat cv. Kolibri 24 days after treatment at the 3 to 4½ leaf stage

Volume rate l/ha		68	57	52	144	158	170	457	425	462
Pressure, bars		1.41	2.11	2.81	1.41	2.11	2.81	1.41	2.11	2.81
Barban	0.175 kg a.i./ha	11.23	11.34	11.83	11.26	12.20	12.42	12.83	12.86	11.95
(as Carbyne B25)	0.35	11.18	8.90	8.70	11.33	9.47	9.60	12.00	11.89	12.28
Benzoylprop-	1.5	11.02	11.97	11.92	11.58	11.05	11.65	12.51	12.09	12.64
ethyl	3.0	9.56	10.40	9.99	10.69	10.34	10.07	11.45	10.66	10.90
AC 84777	0.5	11.69	11.26	10.65	7.21	9.93	11.49	11.97	12.03	12.07
	1.5	7.31	6.03	6.54	6.25	6.89	8.50	6.29	9.15	7.95
Surfactant control	-	12.44	12.64	12.50	11.69	12.63	12.54	12.57	12.75	12.21

S.E. ± 0.539 of all treatment means

Untreated controls: mean 12.78

S.E.D. between controls and treatment means ± 0.259

Table 3

Mean fresh weight (g) of 5 plants of barley cv. Sultan 24 days after treatment at the 3½ to 4½ leaf stage

Volume rate l/ha		68	57	52	144	158	170	457	425	462
Pressure, bars		1.41	2.11	2.81	1.41	2.11	2.81	1.41	2.11	2.81
Barban	0.175 kg a.i./ha	14.41	14.80	14.64	14.67	14.54	15.50	15.61	13.98	15.19
(as Carbyne B25)	0.35	14.15	14.75	14.81	13.92	15.11	14.98	15.28	14.93	13.83
Benzoylprop-	1.5	12.77	10.85	10.44	9.99	10.69	11.40	12.96	11.69	13.05
ethyl	3.0	11.13	9.84	8.99	9.64	8.30	6.78	10.11	9.31	8.10
AC 84777	0.5	14.60	15.30	14.95	15.23	14.75	15.75	14.62	14.72	14.19
	1.5	15.56	15.37	15.61	13.89	15.28	15.08	14.29	14.98	15.07
Surfactant control	-	15.12	14.87	14.32	15.03	15.43	15.25	14.95	14.42	15.51

S.E. ± 0.570 of all treatment means

Untreated controls: mean 15.02

S.E.D. between controls and treatment means ± 0.380

Proceedings 12th British Weed Control Conference (1974)

AN EVALUATION OF CYANAZINE MIXTURES WITH ADDED ADJUVANTS FOR THE CONTROL OF CHRYSANTHEMUM SEGETUM AND OTHER WEEDS IN CEREALS

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Summary In the two seasons 1973 and 1974 nine spring barley, two spring oat and one winter wheat trial were completed to evaluate the effectiveness of various adjuvants when added to cyanazine or mixture of cyanazine + MCPA for the control of corn marigold (Chrysanthemum segetum) and other difficult broad leaved cereal weeds.

A mixture of dinoseb + MCPA was used as a standard in the C.segetum trials, a dicamba CMPP MCPA mixture and cyanazine + MCPA were used as standards in the remainder of the trials.

The most effective standards were dinoseb + MCPA and cyanazine + MCPA. Consistently the best adjuvant, for C.segetum, general weed control and yield was that contained in the commercial formulation of triforine mildewicide; this when applied in mixture with a 25% reduced rate of cyanazine + MCPA gave acceptable control of corn marigold (C.segetum) and other weeds, with no crop effects.

INTRODUCTION

The most commonly occurring weeds in spring cereals in Scotland are, hemp nettle (Galeopsis tetrahit), chickweed, (Stellaria media), and polygonaceous weeds such as knotgrass, (Polygonum aviculare) and redshank, (Polygonum persicaria); earlier work (ref Luckhurst et al 1972) had shown that a relatively low rate of cyanazine in mixture with a phenoxy alkanoic acid herbicide was capable of giving good control of these and other weeds in cereals.

As a result of the extensive trial work completed, a mixture containing 6.25% cyanazine and 25% MCPA was marketed in Scotland in 1973.

An objective of the Scottish trial work in 1973 was to assess the compatibility of the commercial cyanazine + MCPA mixture with the commercially recommended rate of triforine mildewicide.

At two of the sites corn marigold (Chrysanthemum segetum) was the principal weed the effectiveness of cyanazine + MCPA mixture in controlling this weed was markedly improved by the addition of formulated triforine.

On the assumption that the wetter applied in the triforine treatment was responsible for the improvement, the 1974 trials in both Scotland and England described in this paper, were designed to evaluate the effectiveness of cyanazine + MCPA mixtures at 6.6% + 30% respectively with triforine as an adjuvant and with various surfactants without the mildewicide and at the same time to assess the value of the adjuvants when in mixture with cyanazine alone, both for the control of C.segetum and for general weed control.

METHODS AND MATERIALS

Disposition of Trials

Year	Weeds: Corn Marigold S.Barley	General S.Barley	General S.Oats	General W.Wheat
Scottish 73	2	-	-	-
74	1	4	2	-
English 74	2	-	-	1

Site Details

	SITE	LOCATION	VARIETY	CROP STAGE AT APP.
Barley	1	Morayshire	Ymer	F
	2	Inverness	Midas	G
	3	Perthshire	Midas	F - G
	4	Angus	Golden Promise	F - G
	5	Fife	Golden Promise	F - G
	6	Fife	Midas	G
	7	Stirling	Golden Promise	F - G
	8	Lincolnshire	Berac	I - J
	9	Northants	Proctor	G - H
Oats	10	Angus	Selma	E - F
	11	Perthshire	Astor	D - F
Wheat	12	Berks	Huntsman	G - H

Application times ranged from the two leaf stage of the oats and the first node stage of the barley and winter wheat. The control plots were wheel marked at each site. In the Scottish trials in 1974 some treatments were applied twice in order to simulate a spray overlap.

In the Scottish trials a count of individual weeds was taken over one square metre per plot (i.e. 4 throws of a $\frac{1}{4}m^2$ quadrat). In the English trials percentage ground cover of the principal weeds was assessed visually. On all sites at each assessment date crop damage was scored on the E.W.R.C. scale (1 = no damage 9 = complete crop death).

A specially modified combine was used to harvest $62.1m^2$ from each plot. The weights were corrected to 15% moisture and the treatment means are expressed as a percentage of the control.

The herbicide rates and mixtures are shown in table 1. All the rates given are in terms of active ingredient of the chemical, with the exception of the adjuvants which were added at 0.2% of the total volume of liquid applied. Treatments 4 and 5 were mixtures of cyanazine with MCPA + CMPP long chain amine formulations, the figure shown for these two mixtures is the total active ingredient of the MCPA + CMPP that was applied. Treatments were as follows:- (See Table 1).

Table 1

Treatments

NUMBER	HERBICIDE	RATE	SCOTLAND S. BARLEY 1973	SCOTLAND S. BARLEY 1974	SCOTLAND S. OATS 1974	ENGLAND S. BARLEY 1974	ENGLAND W. WHEAT 1974
(1)	dinoseb + MCPA	1.85+0.37	/	/			
(2)	cyanazine + MCPA	0.37+1.68	/	/	/		
(3)	" + "	0.27+1.26				/	/
(4)	" +(MCPA+CMPP)	0.37+(0.54)	/				
(5)	" + "	0.37+(0.27)	/				
(6)	" + MCPP+triforine	0.37+1.68+0.21	/				
(7)	" + " "	0.37+1.68+0.28		/			
(8)	" + " "	0.37+1.68+0.28 x 2		/			
(9)	" + " "	0.27+1.26+0.28		/			
(10)	" + " "	0.19+0.84+0.28		/		/	/
(11)	" + MCPA+aerosol OTB	0.27+1.26+0.2%		/			
(12)	" + MCPA+HVI 60	0.27+1.26+0.2%		/			
(13)	" + MCPA+Tween 20	0.27+1.26+0.2%		/			
(14)	"+MCPA+ Nonidet L.E.	0.27+1.26+0.2%		/	/		
(15)	" + " L.E.	0.37+0.2%		/			
(16)	" + " P40	0.28+0.2%				/	/
(17)	" + Aerosol OTB	0.28+0.2%				/	/
(18)	" + HVI 60	0.28+0.2%				/	/
(19)	" + Tween 20	0.28+0.2%				/	/
(20)	" + WDL4 *	0.28				/	/
(21)	" + 2,4-D	0.37+0.70		/			
(22)	" + CMPP	0.33+2.18		/	/		
(23)	" + CMPP+MCPA	0.33+1.5+1.3		/	/		
(24)	dicamba + MCPA+CMPP	1.76		/	/		

* cyanazine WDL4 is a suspension concentrate of cyanazine formulated in a non-phytotoxic oil.

RESULTS

Scotland 1973

All data was transformed by $y = \log (X + 1)$ before analysis, the detransformed means and least significant ratios are given in the table.

Table 2

Weed Control - number of weeds as a % of control (detransformed)

Site 1

Treatment	Chrysanthemum segetum	Spergula arvensis	Lycopsis arvensis	Overall
1	0.2	41.0	3.3	24.0
2	56.0	0.7	3.3	17.0
4	9.0	0.8	3.3	5.0
5	28.0	0.3	3.3	10.0
6	5.0	0.1	3.3	4.0
Control - No. of Weeds/m	170.7	381.5	30.3	677.0
(P=0.05)	1.59	3.19		1.54

Site 2

Treatment	C.segetum	Galeopsis tetrahit	Overall
1	2.0	1.4	1.0
2	37.0	1.6	14.0
4	7.0	1.6	6.0
6	1.0	1.4	3.0
Control - No. of Weeds/m^2	47.5	72.2	139.7
(P=0.05)	2.33		2.39

In trial No.1 treatment 6 gave the best overall weed control. Corn marigold (C. segetum) was only adequately controlled by treatments 1, 4 and 6, spurrey (Spergula arvensis) was well controlled by all treatments, with the exception of treatment 1, and every treatment controlled lesser bugloss (Lycopsis arvensis).

The addition of triforine to cyanazine + MCPA resulted in a marked improvement in the control of (C.segetum). Treatment 2 left 56 corn marigold/m^2 while treatment 6 reduced this number to 5.0/m^2. Crop effects recorded shortly after application disappeared at harvest.

In trial No.2 treatment 5 was not applied. In the comparison of treatments 2 and 6 the C.segetum control was improved from 37/m^2 to 1/m^2 by the addition of the wetter in the triforine and from 14/m^2 to 3/m^2 in overall weed control. There was an initial scorch to the crop from treatment 6, this had however, disappeared at harvest time.

Scotland 1974

Table 3

Weed control detransformed number of weeds as % of control

Site 3

Treatment	C. segetum	Stellaria media	Overall
1	0	4.0	1.7
7	2.2	7.4	2.6
9	6.1	10.5	5.2
10	3.3	5.9	4.7
11	1.6	5.8	2.3
12	29.5	11.3	11.9
13	8.8	4.4	3.8
14	2.4	5.0	2.2
15	4.2	8.8	3.4
Untreated Control mean no. of weeds $/m^2$	151	30	577
least significant ratios between treatment means (P=0.05)	3.37	2.69	2.32

Treatment 1 gave the best control of (C.segetum) but all treatments were significantly better than the Control. Treatments 11, 7 and 14 also gave a very good control of C. segetum leaving only 1.6, 2.2 and 2.4% respectively. All treatments gave an overall weed control significantly better than the untreated control, treatments 1, 11, 7 and 14 also gave the best overall weed control.

England 1974

Table 4

WEED CONTROL - % COVER OF WEEDS

	Site 8			Site 9
Treatment	C. segetum	Polygonum aviculare	Overall	C. segetum
16	7.5	10.0	25.0	18.0
17	12.0	9.3	26.0	11.0
18	14.0	6.3	26.0	39.0
19	20.0	6.3	33.0	22.0
20	16.0	9.3	31.0	50.0
3	21.0	4.3	31.0	63.0
9	8.3	2.3	13.0	7.3
Control	19.0	7.6	30.0	81.0
L.S.D. between 2 treatment means	8.7	6.2	12.0	18
Greatest value signif < control	12.0	3.2	22.0	67

The best control of <u>C.segetum</u> was by treatment 9 which also gives the best overall weed control. At site 9 treatment 9 was again markedly superior to any other treatment and was significantly better than treatments 3, 18 and 20. The addition of triforine to cyanazine + MCPA reduced the percentage cover of C.segetum from 63-7 and was highly significant. Of the other adjuvants used Nonidet P.40, Aerosol OTB and Tween 20 were the most effective.

At the site 9 some crop effects were seen at an early assessment, but as there were also crop effects in the untreated control plots no analysis was carried out. At the final assessment 57 days after application it was not possible to differentiate the earlier damaged plots.

Scotand 1974

Table 5

Weed control detransformed number of weeds as % of control

	S. barley sites 4-7				S. oats sites 10-11		W.wheat site 12
Treatment	4	5	6	7	10	11	12
2	1.1	8.7	5.6	9.9	6.0	0	
3							11
7	2.3	10.6	2.9	20.9			
8	1.0	1.9	0.5	7.6			
9	1.5	18.3	2.4	13.0			3
10	3.9	34.1	5.4	18.6			
11	1.6	13.8	7.0	24.4			
12	1.7	10.9	3.3	12.1			
13	1.5	13.6	4.3	18.1			
14	2.0	9.7	6.8	28.9	13.4	1.0	
15	2.0	14.9	10.5	23.0			
16							7
17							8
18							4
19							4
20							6
21	1.3	20.6	8.0				
22				9.6	4.7	0.8	
23	2.1	5.7	4.5	14.4	7.7	0.5	
24	1.5	10.6	6.0	15.9	7.9	0.8	
Untreated control mean No. of weeds /m²	299	255	483	373	111	259	72%
Least significant ratios between treatment means	2.41	2.24	2.53	2.45	1.80	3.61	

The control at all sites was highly significant and treatment 8 applied twice to simulate an overlap was better than any other treatment. There were no significant differences between treatments at site 4 but 23 was outstanding at site 5 where the cyanazine in treatment 10 was obviously reduced too much for the conditions. At site 6 treatments 7, 8 and 9 were superior while site 7 favoured treatments 2 and 22. Of the two standards used treatment 2 was consistently better than treatment 24. Generally the reduced rate of cyanazine/MCPA plus triforine, treatment 9, was comparable to the higher rate without the addition of triforine treatment 2. Of the adjuvants used 0.2% of HVI 60 (treatment 12), was the most consistent and was only marginally worse than the higher rate of cyanazine + MCPA without the addition of an adjuvant. There were visible crop effects from all the adjuvants in the form of discolouration and scorching this however soon disappeared, the worst crop effects were from the double application of cyanazine + MCPA +

triforine (treatment 8), this was reflected in the yield figures.

In the two spring oat trials reported, 10 and 11, all treatments were significantly better than the untreated controls, in both trials the commercial rate of cyanazine + MCPA, (treatment 2), was significantly better than the standard rate of the dicamba based product, (treatment 24), and in trial 10 significantly so. In neither trial was any advantage gained from the addition of Nonidet L.E. as an adjuvant, (treatment 14), in neither of the S. oat trials were there any crop effects from any treatment.

In the winter wheat site 12, the over wintering weeds were S.media and G.aparine and the spring germinating weeds were well controlled by all treatments especially 9 which reduced 72% ground cover of weeds to 3%.

Table 6

Mean yields as a % of the control (at 15% moisture)

	Site Nos.											
Treatment	1	2	3	4	5	6	7	8	9	10	11	Mean
1	97	138	115									
2	115	131		100	108	110	97					
3								90				
4	109	139										
5	116	138										
6	115	149										
7			108	98	108	107	92					
8				95	102	100	69					
9			112	99	112	110	101	95				
10			120	99	113	104	95					
11			108	94	106	108	90					
12			109	98	109	110	95					
13			107	100	110	110	93					
14			118	94	108	105	91					
15			115	96	102	111	92					
16								87				
17								92				
18								92				
19								89				
20								93				
21				98	107	112						
22							95					
23				96	114	112	96					
24				103	115	115	98					
Control yield in kg/ha	2058	2886	3546	7251	5106	5686	4866	3029				
L.S.D. between means	21	9		6			5					

At site 1, with the exception of the standard, (treatment 1), all treatments gave an increase in yield over the control but not significantly so, at site 2 all treatments were significantly better than the control, and treatment 6 was significantly better than any other treatment.

At site 4 only treatment 24 yielded better than the control but not significantly, treatments 11 and 14 gave significant yield reductions. At site 5 all treatments had markedly superior yields to the control, at site 7 only treatment 9, cyanazine + MCPA + triforine showed an increase in yield over the control, but was not significant. Treatments 7,8,10,11,12,13,14,15 and 22 had yields which were significantly lower than the control.

At site 8 the yields were exceptionally low, 3029 kg/ha, due to the extreme drought conditions, all treatments had yields which were lower than the untreated control, the best yield was from treatment 9.

DISCUSSION

The 1974 trials have confirmed the 1973 Scottish work with mixtures of cyanazine + MCPA + triforine. The control of C.segetum at site 3 was acceptable with treatment 7, triforine added to the full commercial rate of cyanazine + MCPA and while treatment 9 was slightly inferior, the mixture of triforine with 75% of the commercial rate of cyanazine + MCPA still gave an acceptable control of corn marigold (C.segetum) and other weeds. In trials 8 and 9, because of the excessively dry spring and summer in eastern England, neither trial had a heavy infestation of weeds although in both trials the application of the herbicides was delayed in the vain hope that there would be sufficient rain to induce weed growth. The poor degree of weed control at site 8 can be attributed to lack of crop competition because of dry weather. In the untreated plots the initial weed cover tended to prevent further germination, whereas in the treated plots further germination could occur.

The general weed control in sites 4-7 was more or less comparable from the reduced rate of cyanazine + MCPA + triforine to that from the full rate of cyanazine + MCPA without the triforine. However a further reduction in the rate of cyanazine + MCPA with the addition of triforine resulted in a marked falling off in effectiveness.

Of the other adjuvants H.V.1 60 was the most effective for general weed control but was the worst for the control of corn marigold (C.segetum).

The activity of cyanazine is enhanced by the addition of the phenoxy alkanoic groups and the mixture is further improved by all the adjuvants tested. However none with possible exception of Aerosol OTB was sufficient to improve the activity of straight cyanazine to a comparable level at the rate tested.

The addition of triforine to cyanazine + MCPA resulted in a greatly improved weed control, particularly in the case of (C.segetum) coupled in some cases with substantial yield increases. However yields tended to be reduced by the addition of other adjuvants. In view of the drought induced growth conditions in 1974 this work should be repeated in a year of more normal growth.

Acknowledgments

The authors wish to thank the many farmers who co-operated in providing trial sites. Thanks are also due to Shell Research Limited who carried out the statistical analysis.

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