Session 5C

Weed Control in Cereals

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THE DEVELOPMENT AND REGISTRATION OF FLUPOXAM IN WINTER CEREALS IN POLAND

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ABSTRACT

10 experiments were carried out in 1991 - 1993 to evaluate the efficacy of flupoxam + IPU ready mixed product applied pre-emergence, post-emergence in autumn and spring to control *Apera spica-venti* and broad-leaved weeds in winter wheat in Poland. Ready mixed product was selective for all treated cultivars (Almari, Alcedo, Gama and Reda). Rate of 80-120 g/ha of flupoxam + 800-1200 g/ha of IPU is sufficient to provide good control of *Apera spica-venti* and broad-leaved weeds.

INTRODUCTION

To achieve high yields of cereals the reduction of weed competition is necessary. In Polish conditions, in spite of common use of herbicides, increasing weed infestation in cereals has been observed (Adamczewski et al. 1987). Moreover, changes in weed infestation structure have been observed. Species like *Apera spica-venti, Galium aparine, Stellaria media, Viola arvensis, Veronica spp., Anthemis arvensis, Matricaria inodora, Lamium spp.* are predominant (Adamczewski et al. 1987, Rola 1991). In Polish soil and weather conditions in winter cereals dicotyledoneous weeds as well as *A. spica-venti* are present. New compounds like sulfonylureas (Adamczewski et al. 1988) or flupoxam (O'Keeffe et al. 1991) introduced in last decade control mainly broad-leaved weeds, so they do not fit perfectly into weed situation in winter cereals in Poland. To control weeds in winter cereals, herbicide controlling broad-leaved weeds and *A. spica-venti* is needed. The advantage of flupoxam is that it controls broad-leaved weeds commonly observed in Polish winter cereals. Isoproturon (IPU) is commonly used in Poland to control of *A. spica-venti*. In France mixture of flupoxam and IPU is used to control broad-leaved weeds and *Alopecurus myosuroides* and *Poa annua* (Cagnac 1992).

The purpose of the experiments carried out in Poland was to evaluate the efficacy on weeds of a ready to use mixture of flupoxam and isoproturon (IPU). This product was used in winter wheat, winter barley and winter triticale. This paper contains data for winter wheat.

MATERIALS AND METHODS

Experiments in winter wheat from 1991-1993 were performend in two different regions (Poznań and Wrocław) by two research institutes involved in weed science and biological efficacy trials for registration purposes. Two experiments in Poznań region were performed at the Experimental Station in Winnagóra on sandy clay soil with 1.6-1.8% humus content. Three experiments in Wrocław region were performed at Experimental Stations Laskowice, Karczyce and Smardzów on a black soil with 1.5-3.0% humus content. All experiments were carried out in randomised block design with four replications in Poznań region and with three replications in Wrocław region. Winter wheat cultivars Almari, Alcedo, Gama and Reda were sown at the end of September / beginning of October. The crops were harvested with a Hege combine harvester.

In these experiments MON 18590 (40 g/l flupoxam + 400 g/l IPU) and MON 18592 (50 g/l flupoxam + 400 g/l IPU) were used. Herbicides were applied by an air-pressurised plot sprayer equiped with XR11003 nozzles at 300 l of water per ha and 2-3 bars pressure.

Different rates and timings were used: pre-emergence, early post-emergence in autumn at 3-4 leaf stage of winter wheat, post-emergence in early spring after vegetation restarts or/and in late spring at tillering stage of winter wheat.

Evaluations of herbicide efficacy on broad-leaved weeds were done 3-4 weeks after treatment and on *A. spica-venti* after heading of winter wheat by counting the number of weeds in 4 x 0.25 m^2 quadrats per plot. At the same time the condition of weeds was evaluated. The number of weeds and their condition were the basis for estimation of percentage of weed control. Moreover, the phytotoxicity for crop was estimated.

RESULTS

Results achieved from 1991/1992 experiments are shown in Tables 1 and 2 and those from 1992/1993 experiments in Tables 3 and 4.

Selectivity

In the first year of trials high rates of flupoxam + IPU were used (Table 1, 2). The purpose of these experiments was to evaluate a selectivity for crop. Even high rate of flupoxam + IPU (240 g/ha + 2400 g/ha) were not phytotoxic for all four cultivars tested (Almari, Alcedo, Gama, Reda). The phytotoxicity for crops is unlikely even in case of accidental overdose of this product.

TABLE 1. Influence of flupoxam plus IPU on weed control and on the yield of winter wheat, Poznań region, average from 2 experiments, 1991/92.

Herbicide	Rate g AI/ha	% control (numbers) *Apera spica-venti*	*Viola arvensis*	*Veronica spp.*	*Stellaria media*	*Lamium purpureum*	Yield t/ha *
flupoxam + IPU[1)]	120 + 1200	82	96	99	100	88	8.08 c
flupoxam + IPU[1)]	160 + 1600	97	97	100	100	92	8.06 c
flupoxam + IPU[1)]	240 + 2400	98	100	100	100	97	7.84 bc
IPU[1)]	1500	81	43	48	98	46	7.60 b
unsprayed controls (weed density/m^2)	-	(18)	(31)	(64)	(12)	(14)	7.23 a
flupoxam + IPU[2)]	100 + 800	99	95	94	100	91	7.55 b
flupoxam + IPU[2)]	150 + 1200	100	98	99	100	93	7.63 b
IPU[2)]	1500	87	39	43	100	42	7.69 b
unsprayed controls (weed density/m^2)	-	(45)	(51)	(37)	(10)	(16)	6.45 a
flupoxam + IPU[3)]	100 + 800	93	95	67	91	84	8.05 b
flupoxam + IPU[3)]	150 + 1200	100	96	72	97	92	8.25 b
IPU[3)]	1500	100	36	36	92	35	8.01 b
unsprayed controls (weed density/m^2)	-	(14)	(22)	(21)	(23)	(10)	7.18 a

Time of application:
1) post-emergence, autumn at 3-4 leaf stage of winter wheat
2) post-emergence, early spring
3) post-emergence, late spring

* values with no letters in common are significantly different at the 95% confidence limit

TABLE 2. Influence of flupoxam plus IPU on weed control and on the yield of winter wheat, Wrocław region, average from 3 experiments, 1991/92.

Herbicide	Rate g AI/ha	% control (numbers) *Apera spica-venti*	*Viola arvensis*	*Galium aparine*	*Lamium amplexicaule*	*Anthemis arvensis*	Yield t/ha
flupoxam + IPU[1]	80 + 800	68	12	93	100	66	6.71
flupoxam + IPU[1]	120 + 1200	80	44	100	100	80	7.07
flupoxam + IPU[1]	160 + 1600	90	62	100	100	78	6.72
flupoxam + IPU[1]	240 + 2400	93	67	100	100	86	6.94
IPU[1]	1500	74	12	33	50	42	6.63
unsprayed controls (weed density/m^2)	-	(30)	(9)	(12)	(12)	(18)	6.34
flupoxam + IPU[2]	80 + 800	87	89	87	100	-	6.98
flupoxam + IPU[2]	120 + 1200	96	100	99	100	-	6.70
flupoxam + IPU[2]	160 + 1600	99	100	99	100	-	7.18
IPU[2]	1500	98	69	50	50	-	7.01
unsprayed controls (weed density/m^2)	-	(46)	(12)	(8)	(4)	-	6.33
flupoxam + IPU[2]	100 + 800	90	100	100	100	-	6.72
flupoxam + IPU[2]	150 + 1200	88	100	100	100	-	6.96
flupoxam + IPU[2]	200 + 1600	93	98	100	100	-	6.72
IPU[2]	1500	96	75	33	45	-	7.04
unsprayed controls (weed density/m^2)	-	(74)	(8)	(8)	(4)	-	6.26

Time of application: 1) post-emergence, autumn at 3-4 leaf stage of winter wheat
2) post-emergence, spring

Efficacy

Generally, *A. spica-venti* infestation of experiments was medium to high. Efficacy of *A. spica-venti* control depended on the rate and the time of application. Rate of 80 g/ha of flupoxam + 800 g/ha of IPU applied post emergence in autumn 1991 in Wrocław region was too low to achieve good control of *A. spica-venti*. Rate of 120 g/ha of flupoxam + 1200 g/ha of IPU applied post emergence in autumn 1991 in both regions did not control *A. spica-venti* completely either (Table 1 and 2). It is probable that new, spring germination of *A. spica-venti* occured and autumn applied product did not work in spring. However the same rate applied pre- or post-emergence in autumn 1992 gave very good control of *A. spica-venti*. Efficacy of *A. spica-venti* control at 100 g/ha of flupoxam + 800 g/ha of IPU applied in spring was very good. Higher rates of flupoxam + IPU controlled *A. spica-venti* very well irrespective of time of application. In the Poznań region flupoxam + IPU was applied in late spring at the end of tillering stage of winter wheat with very good results as well. Very good control of *A. spica-venti* was achieved by using standards: IPU, triasulfuron + chlortoluron, fluoroglycofen-ethyl + IPU, diflufenican + IPU.

TABLE 3. Influence of flupoxam plus IPU on weed control and on the yield of winter wheat, Poznań region, average from 2 experiments, 1992/93.

Herbicide	Rate g AI/ha	% control (numbers) *Apera spica-venti*	*Viola arvensis*	*Veronica spp.*	*Galium aparine*	*Stellaria media*	Yield t/ha *
flupoxam + IPU[1)]	80 + 800	90	96	92	78	100	6.12 bc
flupoxam + IPU[1)]	100 + 1000	91	97	98	91	100	6.15 bc
flupoxam + IPU[1)]	120 + 1200	95	98	99	92	100	6.17 bc
diflufenican + IPU[1)]	125 + 1250	97	100	99	100	100	6.08 b
flupoxam + IPU[2)]	80 + 800	97	100	96	85	100	6.10 bc
flupoxam + IPU[2)]	100 + 1000	99	100	98	92	100	6.24 c
flupoxam + IPU[2)]	120 + 1200	100	100	99	99	100	6.25 c
triasulfuron + chlorotoluron[2)]	15 + 785	92	75	90	85	100	6.01 b
fluoroglycofen-ethyl + IPU[2)]	30 + 1200	93	87	93	94	100	6.12 bc
unsprayed controls (weed density/m^2)	_	(42)	(43)	(60)	(12)	(7)	5.21 a

* values with no letters in common are significantly different at the 95% confidence limit

TABLE 4. Influence of flupoxam plus IPU on weed control and on the yield of winter wheat, Wrocław region, average from 3 experiments, 1992/93.

Herbicide	Rate g AI/ha	% control (numbers) *Apera spica-venti*	*Anthemis arvensis*	*Viola arvensis*	*Galium aparine*	*Stellaria media*	Yield t/ha
flupoxam + IPU[1)]	80 + 800	85	98	96	82	100	6.02
flupoxam + IPU[1)]	100 + 1000	93	99	97	82	100	6.12
flupoxam + IPU[1)]	120 + 1200	96	100	97	83	100	6.28
flupoxam + IPU[2)]	80 + 800	100	100	100	-	-	5.93
flupoxam + IPU[2)]	100 + 1000	99	100	100	-	-	5.96
flupoxam + IPU[2)]	120 + 1200	100	100	100	-	-	6.13
triasulfuron + chlorotoluron[2)]	15 + 785	100	100	75	-	-	6.06
fluoroglycofen-ethyl + IPU[2)]	30 + 1200	100	100	78	-	-	6.13
flupoxam + IPU[3)]	80 + 800	100	98	89	74	100	5.84
flupoxam + IPU[3)]	100 + 1000	100	97	92	73	100	5.95
flupoxam + IPU[3)]	120 + 1200	100	96	91	91	100	5.99
triasulfuron + chlorotoluron[3)]	15 + 785	100	100	100	90	100	5.87
fluoroglycofen-ethyl + IPU[3)]	30 + 1200	100	100	94	73	100	6.15
unsprayed controls (weed density/m^2)	_	(110)	(59)	(48)	(11)	(7)	5.89

Time of application:
1) pre-emergence
2) post-emergence, autumn at 3-4 leaf stage of winter wheat
3) post-emergence, spring

Main broad-leaved weeds on experimental fields were: *Viola arvensis, Veronica spp., Lamium spp., Galium aparine, Stellaria media* and *Anthemis arvensis*. Generally speaking, broad-leaved weeds were controlled very well by flupoxam + IPU product. Only in 1991/1992 season at Wrocław region *Viola arvensis* was not controlled sufficiently after post emergence autumn application. Probably, at spring time new germination of *Viola arvensis* appeared and autumn applied product did not work. In Poznań region at late spring application in 1992 *Veronica spp.* was controlled poorer than at autumn and early spring treatment. Probably, the *Veronica spp.* plants were too big and too old to be well controlled.

Besides the weeds mentioned in the tables other weeds like *Papaver rhoeas, Capsella bursa pastoris, Sinapis arvensis, Chenopodium album, Matricaria inodora* and *Polygonum spp.* were present at experimental sites. All aforementioned species were well controlled by flupoxam + IPU. The efficacy of IPU for broad-leaved weeds was poor.

Yield

Statistical analysis (Table 1 and 3 - Poznań region) show that yields of grain from plots treated with flupoxam + IPU were significantly higher than those of untreated plots. The differences between yields of treatments were statistically unsignificant. At Wrocław region increase of yield after flupoxam + IPU application reached 13 % and difference between treatments were low.

Similar results (not presented in this paper) were obtained for winter barley and winter triticale.

CONCLUSION

Results from two years of field experiments carried out at 5 location on winter wheat indicate that a ready to use mixture of flupoxam and IPU is selective on all tested winter wheat cultivars at pre-emergence as well as post-emergence autumn and spring application.

Rates 80 - 120 g/ha of flupoxam plus 800 - 1200 g/ha of IPU is sufficient to provide good control of *A. spica-venti* and broad-leaved weeds in winter wheat.

It is very likely that results from three years field experiments would be sufficient to register ready mix (flupoxam + IPU) product in Poland, so the Polish farmer will get a good, new winter cereals herbicide.

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AMIDOSULFURON - A NEW SULFONYLUREA FOR THE CONTROL OF *GALIUM APARINE* AND OTHER BROAD-LEAVED WEEDS IN CEREALS

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ABSTRACT

In UK field trials carried out over seven years, amidosulfuron at 30 g AI/ha gave consistently high levels of control of *Galium aparine* and other cereal broad-leaf weeds. Excellent control of *G. aparine* was obtained from applications made between the seedling stage in February and the flower bud visible stage in May or early June. Activity was maintained even during cold conditions, providing the weeds were actively growing. *Sinapsis arvensis, Capsella bursa-pastoris* and *Myosotis arvensis* were also controlled up to specific growth stages. The spectrum of control was extended by tank mixing with other herbicides such as HBN's or sulfonylureas. Amidosulfuron applied at single and double rates was found to be safe to a range of cereal types, and no susceptible cultivars or growth stages were identified in the trials carried out.

INTRODUCTION

Galium aparine is the most competitive broad-leaved weed of UK cereal crops (Wilson & Wright, 1990). Yield losses of up to 4.9 t/ha have been recorded and as few as 4 plants/m² can reduce wheat yields by 1 t/ha (Wilson & Wright, 1987). If left untreated, populations can increase dramatically as a single plant can produce over 1600 seeds (Froud-Williams & Ferris-Kaan, 1991). The post-emergence herbicides currently used to control *G. aparine* are reported to work consistently in April and May (Lutman *et al.*, 1987). However, more recent research (Baylis & Watkinson, 1991) found that the weed competes with the cereal crop throughout the growing season, reducing grain number early and reducing fill of the remaining grains later in the season. The ability to respond faster to available nitrogen has been suggested as the reason *G. aparine* is more competitive than wheat under the higher nitrogen regimes practised for that crop (Wright & Wilson, 1992; Baylis & Watkinson, 1991). These findings suggest that the weed should be controlled before April to maximise both grain sites per ear and nitrogen utilisation by the crop.

Amidosulfuron ('Eagle') is a new post-emergence sulfonylurea herbicide discovered by Hoechst AG and developed for broad-leaved weed control in cereals under the code number Hoe 75032. In contrast to other compounds from this group, it has very strong activity against *G. aparine* as well as giving good control of other broad-leaved weeds (Hacker *et al.*, 1990).

Uptake is mainly via shoots and translocation is both acropetal and basipetal (Hacker *et al.*, 1990). Moist soils are required for root activity (Mueller-Wilmes, 1993). Weed growth is stopped very quickly and, as with other sulfonylureas, complete kill of large plants can take up to six weeks. Susceptible weeds are controlled due to the inhibition of acetolactate synthase (Hacker *et al.*, 1990) and differential degradation in tolerant and susceptible species is suspected to be the main mechanism for the selective action of this herbicide (Köcher & Lötzsch, 1993).

Hacker *et al.*, (1990) reported on the chemical, physical, toxicological and degradation characteristics of amidosulfuron. Under standard laboratory conditions across a range of soil types it degraded rapidly with a half life of two to four weeks. Under field conditions, a half-life of twenty-five days was recorded from an April application in lysimeter studies. Degradation was found to be predominantly by biological action irrespective of soil texture or soil pH. Lentil root bioassay tests showed that the majority of the active ingredient remains in the top 20 cm soil layer (Fent *et al.*, 1992) and a five-year degradation study showed that following a spring application of amidosulfuron all following crops can be drilled in a normal rotation (Leterrier & Gavanier, 1992).

MATERIALS AND METHODS

Replicated small-plot trials were conducted in commercial cereal crops throughout England and Scotland to study the efficacy and crop tolerance of amidosulfuron.

Sixty-three trials targeted at *G. aparine* and twenty trials targeted at other broad-leaved weed species were conducted between 1987 and 1993 using a three replicate randomised-block design and a plot size of approximately $16m^2$. In addition, seven unreplicated trials were laid down in 1993 in England and Scotland to study the efficacy of amidosulfuron against *G. aparine* at a range of timings from February through to June.

A further seventy trials on the major UK cereal crops were conducted between 1989 and 1992 on weed-free sites, using a four replicate, randomised-block design and a plot size of approximately $12m^2$, to investigate tolerance to single and double doses of amidosulfuron applied at a range of crop growth stages. In addition, variety trials covering over one hundred and fifty different cultivars of wheat, barley, oats, durum wheat and triticale were carried out over four years at up to six locations throughout England and Scotland. At each location in each year, single and double dose rates were applied across 2m wide strips of a range of cultivars, without replication.

Biological compatibility of a range of tank mixtures was evaluated in small-plot trials using amidosulfuron alone and in tank-mix with each partner, both at single and double rates.

All treatments were applied using Van der Weij 'AZO' precision sprayers fitted with Teejet 11001, 11002 or 11003 nozzles delivering 112-300 l/ha of water at a pressure of 2.5 bar. Growth stages of the crop and weeds at application are included in the tables (Zadoks *et al.*, 1974; Lutman & Tucker, 1987). Herbicides used in the efficacy and tolerance trials were as follows:

Amidosulfuron (Hoe 75032) 75% w/w WG 30 g AI/ha; mecoprop-p (CMPP-P) 600 g/l AS 1,200 g AI/ha; fluroxypyr 200 g/l EC 200 g AI/ha; metsulfuron-methyl 20% w/w WG 6 g AI/ha.

Broad-leaved weed control in the efficacy and compatibility trials was assessed visually on a percentage scale (0% = no effect; 100% = complete kill) at one month after application or as appropriate if weed kill was slower. In the crop tolerance, variety and compatibility trials, visual crop vigour assessments using the same percentage scale were made at one week and one month after application and at GS31, 39 and 69 as appropriate. Yields were taken using a Hege small plot combine, corrected to 15% moisture and subjected to randomised complete block statistical analysis.

RESULTS

Efficacy trials

Amidosulfuron gave consistently high levels of *G. aparine* control when applied between the cotyledon stage and the flower bud visible stage (Table 1), and from applications made between mid-February and early June (Table 2.)

TABLE 1. Control of *G. aparine* with amidosulfuron applied at different growth stages

	Mean % control (No. of trials)			
Maximum growth stage at application	Hoe 75032	Fluroxypyr	CMPP-P	Untreated plants/m² [range]
6 whorls	97 (15)	99 (7)	92 (7)	32 [7-87]
50 mm	98 (13)	99 (4)	80 (3)	34 [4-67]
150 mm	100 (8)	-	93 (3)	27 (12-63]
250 mm	99 (15)	98 (7)	95 (6)	21 [3-67]
Flower bud	97 (12)	100 (11)	96 (8)	37 [6-100]

In addition to *G. aparine,* excellent control of *Sinapsis arvensis, Capsella bursa-pastoris* and *Myosotis arvensis* was obtained at the growth stages indicated (Table 3).

Crop Tolerance trials

No significant crop vigour effects were recorded at single or double the dose rate when amidosulfuron was applied to a range of winter and spring wheat, winter and spring barley, winter and spring oats, durum wheat, rye and triticale growth stages. This high level of safety was reflected in there being no statistically significant yield reductions from either the single or double dose treatments. In variety trials, none of the cultivars was identified as being susceptible.

TABLE 2. Control of *G. aparine* with amidosulfuron applied at different calendar timings

Application Timing	Soil Temp. (°C) 7 DAT @ 10cm range	Mean % control Hoe 75032	Fluroxypyr	No. of Trials	Maximum growth stage at application
Mid-February	2-6	98	93	4	8 whorls
Early March	3-6	99	94	4	100mm
Mid-March	4-8	96	83	5	100mm
Early April	5-7	99	88	6	250mm
Mid-April	7-10	100	94	7	300mm
Early May	9-11	99	100	6	300mm
Mid-May	8-13	96	98	7	Flower buds
Early June	12-15	90	98	7	Flowering

TABLE 3. Control of other broad-leaved weeds with amidosulfuron

Weed Species	Maximum growth stage at application	Mean % control (No. of trials) Hoe 75032	Metsulfuron -methyl	Fluroxypyr	Untreated plants/m² [range]
S. arvensis	6 leaves	100 (1)	-	100 (1)	13
	600 mm	99 (2)	-	100 (2)	9 [3-15]
C. bursa-pastoris	6 leaves	99 (3)	100 (3)	-	12 [4-26]
	600 mm	94 (2)	98 (1)	-	21 [4-38]
M. arvensis	6 leaves	97 (5)	100 (3)	-	23 [12-50]
	75 mm	93 (7)	95 (6)	-	29 [9-80]

Compatibility

Amidosulfuron was found to be compatible with deltamethrin, diclofop-methyl, fenoxaprop-p-ethyl, ioxynil + bromoxynil (Deloxil) and isoproturon (Arelon). There were no antagonistic effects on either broad-leaved or grass weed control and no crop vigour effects were recorded.

DISCUSSION

The level of control obtained with amidosulfuron over a wide range of growth stages of *G. aparine* (Table 1) was equivalent to fluroxypyr and superior to mecoprop-p. The results from applications made between mid-February and the end of April (Table 2) were superior to those obtained with fluroxypyr and equivalent to this reference product for treatments applied during May. Efficacy dropped marginally at the early June timing but it should be noted that the weed was past the label recommendation (flower bud visible stage) at some sites.

Amidosulfuron provides UK cereal farmers with a new option for the effective control of *G. aparine* from the cotyledon up to the flower bud visible stage. More importantly, it gives effective results from applications made as early as February (Table 2), providing the weed is actively growing. Consistent results at these early timings were achieved at a time when soil temperatures were between 2 and 8°C. Amidosulfuron therefore provides farmers with a more flexible strategy for controlling *G. aparine*. To minimise yield loss and maximise the crop's utilisation of available nitrogen, the weed can be treated in February and March, which is earlier than is practised with current standards. However, if weather or soil conditions prevent these early applications, amidosulfuron can be used right up to the flower bud visible stage. In addition, tests have shown the product to be rainfast after one hour (internal report), which further increases spraying opportunities in the UK.

Efficacy was not influenced either by the density of *G. aparine* (Table 1), the cereal species or the different climatic conditions encountered during the seven years of trials. Results were consistent with those achieved in Germany (Hacker *et al.*, 1992) and in France (personal communication). However, the application window appears to be wider under UK conditions than in France and this is believed to be due to generally cooler conditions and lower soil moisture deficits in the UK.

Amidosulfuron will also control *S. arvensis, C. bursa-pastoris* and *M. arvensis* present at application, and if a wider range of broad-leaved weeds have to be controlled, it can be tank-mixed with products such as ioxynil + bromoxynil or other sulfonylureas. Compatibility with a range of other crop protection products further increases the flexibility with amidosulfuron.

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DITHIOPYR; POTENTIAL USE IN EUROPEAN CEREALS.

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ABSTRACT

Dithiopyr, at use rates between 50g AI/ha and 200g AI/ha, has shown good utility as a cereal herbicide for Northern European agronomic systems. Broad-leaf weeds controlled with applications pre-emergence and early post-emergence include: *Stellaria media*, *Matricaria sp.*, *Veronica persica*, *V. hederaefolia*, *Legousia speculum-veneris* and *Viola arvensis*. Narrow-leaf weeds controlled at similar application timings include: *Apera spica-venti* and *Poa annua*, with 50-80% suppression of *Alopecurus myosuroides* and *Lolium rigidum*. Selectivity appears to be based on soil placement, similar to pendimethalin. However, there was some physiological tolerance seen for both wheat and barley, with barley being more tolerant than wheat. Dithiopyr has been shown to give full season control with autumn applications. The compound is very water insoluble 0.7 mg/l and there is little soil movement.

INTRODUCTION

Dithiopyr has been developed as an annual grass and small seeded broad-leaf weed herbicide for turf, ornamental plants and rice. It is highly active with use rates of 50g AI/ha to 200g AI/ha. It is very water insoluble (0.7 mg/l) (Colby et al., 1989) with very limited movement in the soil profile. It has a relatively long soil half life (DT_{50} 40 days) (S. Adams 1989). The mode of selectivity in rice has been shown to be soil placement (Parrish 1985).

Because dithiopyr has shown good annual weed control combined with long soil activity and little soil movement under the extreme wet conditions of paddy rice it was felt that dithiopyr might have utility as a autumn applied annual herbicide in Northern European cereals. Consequently dithiopyr has been evaluated for the past two years to determine its potential as a cereal herbicide in Northern European agronomic systems.

MATERIALS AND METHODS

Greenhouse testing was conducted using sterilized sandy loam soil with the addition of 30% sand. Applications were made using a track sprayer. Spray volume was 250 l/ha. All pots were seeded at a depth of 1 cm. Pre-emergence applications were made by putting newly sown 9x9 cm pots through the track sprayer. Incorporated treatments were made by putting 9x9x1 cm layers of soil through the track sprayer at the same height as the newly sown pots. The soil layers were then thoroughly mixed and placed as the top 1 cm of soil in newly sown pots. Thus, the seeds were directly exposed to chemically treated soil.

Field trials were of a randomized complete block design with three replicates. Plot size was 2x6 m. The formulation used was a 120g AI/l EC. Treatments were sprayed with a CO_2 propelled back pack sprayer with T-JET 8002 nozzles. The spray pressure was two bars. The water volume was 250 l/ha. Walking speed was 4.83 km/h.

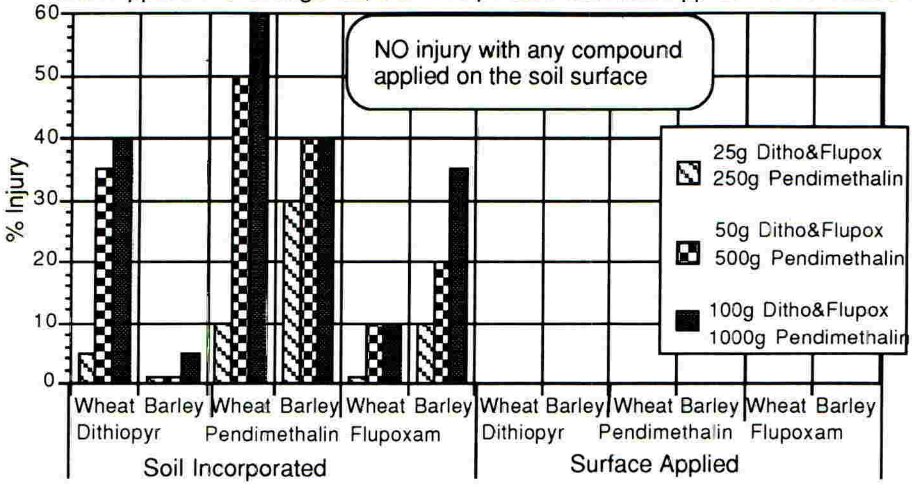
Weed control and crop safety were evaluated by visual assessment. Weed control and crop injury are expressed on a 0-100% injury scale where 100% injury is complete control or death of all plants. Injury to weeds of 85% or better is considered commercial control of weeds, unless otherwise noted. Crop injury of 15% or less is considered acceptable crop safety unless otherwise noted. Crop injury given was the maximum injury observed throughout the test.

RESULTS

Cereal safety

Soil placement is likely the major factor for dithiopyr selectivity in cereals. This is the same type of selectivity seen with both pendimethalin and flupoxam. In greenhouse tests, surface applications of dithiopyr, pendimethalin and flupoxam showed no injury to wheat or barley, whereas soil incorporated treatments of all three compounds caused conspicuous injury to both crops (Figure 1).

Figure 1. The Effect of Dithiopyr, Pendimethalin and Flupoxam on Wheat and Barley when Applied Pre-emergence, Soil Incorporated &Surface Applied. Greenhouse Test.



Dithiopyr was field tested for selectivity at rates as high as 600g AI/ha. Applications were made pre-emergence and early post-emergence to both wheat and barley. The highest safe rate of dithiopyr was 400g AI/ha. Post-emergence treatments were safer than pre-emergence treatments (Table 1).

In this trial, dithiopyr was compared to both pendimethalin and flupoxam. The differences between the injury seen with the pre-emergence treatments and the early post-emergence treatments, combined with the data on pre-emergence treatments and incorporated treatments in the greenhouse, indicate that all three herbicides have similar modes of selectivity. Crop safety for all three compounds is probably based on both the position of the herbicide in the soil and on the size of the cereal plant at application. The larger the crop plant the more safety.

Table 1. Wheat and barley injury caused by dithiopyr, pendimethalin and flupoxam applied pre-emergence and post-emergence to winter wheat and winter barley at Franc-Waret, Belgium, during the 1991-92 growing season.

	% Injury			
	Pre-emergence		Post-emergence	
	Wheat	Barley	Wheat	Barley
Dithiopyr				
100g AI/ha	0	0	0	0
200g	10	0	0	3
400g	18	13	7	0
600g	23	43	7	3
Pendimethalin				
1000g AI/ha	8	16	0	0
1500g	13	2	0	0
2000g	30	34	12	12
Flupoxam				
300g AI/ha	5	2	0	0
600g	15	20	15	20

The above data indicate that the potential highest use rate would appear to be between the 100g AI/ha and 200g AI/ha. That would give a 2x safety margin because injury was commercially acceptable at the 400g AI/ha rate.

Weeds controlled

Dithiopyr controls a broad spectrum of annual broad-leaf weeds (Table 2). The best control was achieved when dithiopyr was applied pre-emergence or early post-emergence, when the weeds were small. All weeds showed less control with larger plants. The control of *Matricaria sp.* was dramatically reduced when the application was made post-emergence.

Dithiopyr has been shown to be very effective in the control of many grass species like *Digitaria sp.*, *Echinochloa* sp. and *Setaria sp.* The most sensitive grass species in Northern European cereals appears to be *Apera spica-venti* (Table 3). *Poa annua* was also controlled at a rate of 100g AI/ha. Dithiopyr did not give commercial control of *Alopecurus myosuroides* at use rates of less than 250g AI/ha. A use rate of 100g AI/ha gave 50% to 80% suppression of *A. myosuroides* and *Lolium* sp. The application timing with grass weeds was similar to the pre-emergence and early post-emergence timing seen with the broad-leaf weeds.

TABLE 2. Broad-leaf weeds controlled by dithiopyr when applied in either winter wheat or winter barley.

Susceptible	Suppressed	Tolerant
Stellaria media (3)[1]	*Galium aparine* (8)	*Convolvulus sp* (1)
Veronica persica (8)	*Aphanes arvensis* Post (3)	*Matricaria sp* Post (5)
V. hederaefolia (4)		
Legousia speculum-veneris (4)		
Viola arvensis (2)		
Senecio vulgaris (3)		
Matricaria chamomilla (8)		
M. inodora (1)		
Aphanes arvensis (2)		
Lamium purpureum (2)		
Papaver rhoeas (3)		

[1]Number of trials considered in making the classification.

TABLE 3. Grass weeds controlled by dithiopyr when applied in either winter wheat or winter barley in Northern Europe.

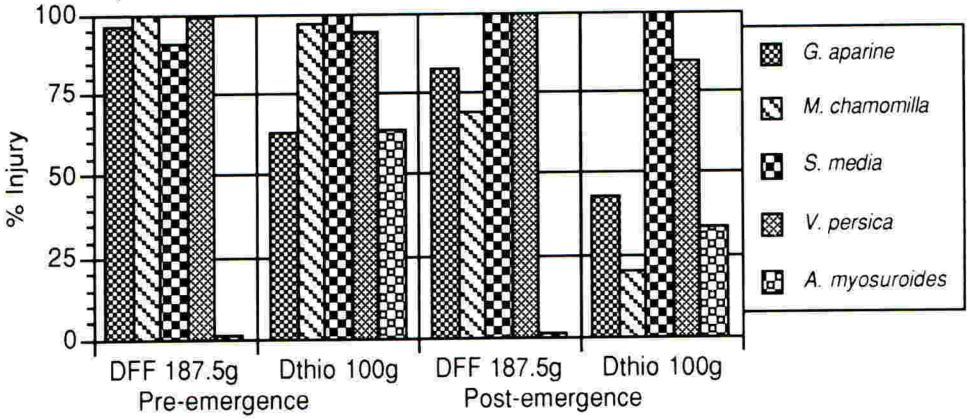
Susceptible	Suppressed	Tolerant
Apera spica-venti (4)[1]	*Alopecurus myosuroides* (12)	*Elymus repens* (5)
Poa annua (1)	*Lolium rigidum* (1)	*Avena fatua* (1)

[1]Number of trials considered in making the classification.

In side by side tests, dithiopyr showed a similar broad-leaf spectrum as diflufenican. However, at times it was somewhat less effective on species such as *Galium aparine* and *Matricaria sp.* (Figure 2).

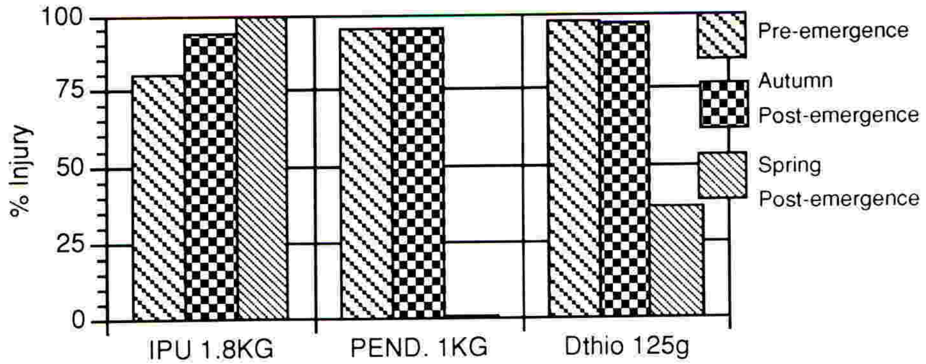
The grass spectrum of dithiopyr appears to be similar to that of pendimethalin (Figure 3). That indicates that dithiopyr would have a spectrum advantage as compared to diflufenican due to the increased control of grass species. The data show that dithiopyr has a broad-leaf spectrum like that of diflufenican, combined with a grass spectrum similar to pendimethalin.

FIGURE 2. Dithiopyr in a side by side test with diflufenican.
Apllications made pre-emergence and post-emergence. Belgium



Comparisons between the spring post-emergence applications of dithiopyr and pendimethalin would suggest that dithiopyr would have more post-emergence activity than pendimethalin, and hence a wider application window (Figure 3).

Figure 3. Dithiopyr control of *Apera spica-venti* compared to IPU and pendimethalin applied pre-emergence fall and spring post-emergence.



CONCLUSION

Dithiopyr has good selectivity on both winter wheat and winter barley as grown in Northern European agronomic systems. It has a broad-leaf weed spectrum similar to diflufenican and flupoxam. All these compounds have good efficacy on a broad spectrum of broad-leaf weeds but only suppression of *Galium aparine.* Dithiopyr also has a grass spectrum which is similar to pendimethalin's grass spectrum but much broader than either diflufenican or flupoxam.

Dithiopyr is a pyridine herbicide. It controls germinating seeds and small annual plants. It is very water insoluble (0.7 mg/l) with limited movement in the soil. The relatively long life in the soil allows autumn treatment to provide control throughout the season. The potential use rate for this compound in European cereals is likely around 100g AI/ha.

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CHEMICAL CONTROL OF GRASSES IN WHEAT

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ABSTRACT

Avena ludoviciana, Phalaris minor and Alopecurus myosuroides are among the main grasses in wheat in Iran.

In experiments carried out in 1991/1992 and 1992/1993 in Iran, clodinafop-propargyl (CGA 184927) at 0.08 and 0.064 kg AI/ha and fenoxaprop-p at 0.075 kg AI/ha provided more control of the grasses, in descending order, than other treatments. Control of the grasses resulted in high and significant yield increases, the highest being up to 130% for clodinafop-propargyl, as compared with control plots, in a commercial crop that was severely infested with P. minor and A. myosuroides.

INTRODUCTION

Annually about 6 million hectares are cultivated for wheat production in Iran, 35% of that being irrigated or highly rainfed. These areas are mostly infested with grasses.

Despite continuous expansion of chemical grass control during the last decade, high populations of new grass species continue to be a problem. Avena ludoviciana (and A. fatua) remain the most common grasses in wheat crops (Maddah, 1977). In addition, Phalaris minor has already become a common grass weed in several areas including Mazandaran, Gorgan, Kerman, Esfahan, Garmsar and Khuzestan (Mirkamali, 1987 and Montazeri, 1987). Severe infestations with Phalaris brachystachys have already been reported from eastern Sari (Mirkamali, 1988). Lolium spp. are dominant in several provinces including Fars, Systan-O-Baluchestan, and Garmsar. Alopecurus myosuroides has recently been introduced as one of the main grass species in several areas in Karaj, Garmsar, Kashan, Golpayegan and Arak.

Among factors affecting these changes in grass populations are the increasing tendency of farmers to cultivate more wheat crop than in the past in the rotation and also low efficacy of the commonly used multi-purpose grass killers, namely diclofop and tralkoxydim, seem to be main factors (Mirkamali, 1988 and Montazeri, 1992).

This study was conducted to compare commonly used selective grass killers with new ones in the wheat crop.

MATERIALS AND METHODS

Five trials were conducted in two provinces different in respect of climatic and cultural conditions. Experiments 1 and 2 were carried out in the years 1991/1992 and 1992/1993 at the Dashte-Naz Agricultural Organisation (S-DN) and Agricultural Research Station (S-ARS), respectively. Both experiments were located in eastern Sari, northern Iran. Wheat cvs. Golestan and Alborz were seeded in mid-November and mid-December at 160 kg/ha in rows 15 cm apart. Experiments 3, 4 and 5 were carried out in the year 1992/1993 at the northern (G-NA and G-NB) and southern (G-S) parts of the Garmsar agricultural province, south-east of Tehran. Wheat cv. Ghods was seeded in November at 180 kg/ha in a system of furrow irrigation, commonly practised throughout the area. All the experiments were naturally infested with the related grasses.

A compound fertilizer supplying 27 kg N and 75 kg P205 was applied to each seedbed prior to sowing in experiments 1 and 2, and 36 kg/ha N and 100 kg/ha P205 in experiments 3, 4 and 5. Nitrogen top dressing was applied at early shooting stage of the crop (Zadoks decimal code 30 and 31) at 23 kg/ha N in experiments 1 and 2, and at 35 kg/ha N in experiments 3, 4 and 5.

Information about the target grasses, their density and growth stages when applying herbicides are summarised in table 1.

TABLE 1. Location, plant density and growth stages prior to applications.

No	Loc.	Date of applic.	ALOMY		AVELU		PHABR		PHAMI		WHEAT	
			Plt /m2	Growth Stage*	Plt /m2	Growth Stage*	Plt /m2	Growth Stage*	Plt /m2	Growth Stage*	Plt /m2	Growth Stage*
1	S-DN	10.4.92	-	-	-	-	103	30-31	-	-	423	31-32
2	S-ARS	7.3.93	-	-	619	20-21	-	-	-	-	321	22-24
3	G-NA	1.2.93	136	12-14	138	12-14	-	-	56	12-14	420	21-22
4	G-NB	5.12.92	178	11-12	-	-	-	-	1845	11-12	362	12-14
5	G-S	5.12.92	-	-	1046	21-22	-	-	-	-	306	23-24

*. Zadoks decimal growth stages.

Plot size was 30 m2 in experiments 2, 4 and 5. Four replicates were arranged as complete randomised blocks. Plot sizes in experiments 1 and 3 were 2500 and 500 m2, respectively, in 2 replicates. Details on herbicides applied are shown in table 2.

The herbicides were applied by a tractor mounted sprayer at a pressure of 3 bar in experiment 1 and by a knapsack sprayer at a pressure of 2.5 bar in the other experiments. In all experiments fan jet nozzles 11002 were used delivering a spray volume of 200 l/ha.

In all experiments crop selectivity (2-3 weeks after herbicide application) and grass control (a few days before harvesting) were evaluated using a scale of 0-100, in which 0 = no injury on the crop/no control of the grasses and 100 = complete kill of the crop/100% control of the grasses. Crop yields were obtaine by sampling ten or five 1 m2

TABLE 2. Herbicides, formulations and rates of application.

Herbicide	Formulation kg AI/l	Rate of application kg AI/ha
* Clodinafop-propargyl (Proposed common name for CGA 184927)	0.08	0.048 0.064 0.080
* Fenoxaprop-p-ethyl	0.075	0.075
Diclofop-methyl	0.36	0.90 1.0
Tralkoxydim	0.10	0.30

* Each applied with the appropriate safener

areas within each plot of experiments 1 and 3, respectively and two 1 m2 areas within each plot of experiments 2, 4 and 5.

Data were subjected to analysis of variance. Bartlett's test and arcsine transformation were performed before statistical analysis was carried out. Means were separated by Duncan's Multiple Range Test at P = 0.05.

RESULTS

Grass control

As shown in Table 3, A. myosuroides was controlled 95, 98 and 100% by fenoxaprop-p at 0.075, clodinafop at 0.064 and 0.08 kg AI/ha, respectively. Tralkoxydim at 0.30 kg AI/ha did not control this grass weed satisfactorily (trial 4). In the semi-large scale trial either fenoxaprop at 0.075 kg AI/ha or clodinafop at 0.064 kg AI/ha controlled A. myosuroides by 99% (Trial 3).

Diclofop was not included in these two trials, but a survey conducted on farmers' fields in the Garmsar province showed that application of this herbicide at 1.1 kg AI/ha at very early growth stages of the grass would provide a relatively good control of it.

Fenoxaprop at 0.075 kg AI/ha, clodinafop at 0.064 and 0.08 kg AI/ha controlled A. ludoviciana by 99, 97 and 100% in experiment 5. In the semi-large scale trial (3) a 98 and 99% control of this grass species was achieved by fenoxaprop and clodinafop at 0.075 and 0.064 kg AI/ha, respectively.

TABLE 3. Percent grass control, using post-emergence herbicides

		Weed Species							
		ALOMY Exp.No.		AVELU Exp.No.			PHABR Exp.No		PHAMI Exp.No.
Herbicide	kg AI/ha	3	4	2	3	5	1	2	4
Diclofop	0.90	-	-	-	-	-	85	-	-
	1.0	-	-	91 cd	-	-	-	90 cd	-
Tralkoyxdim	0.30	-	60 cd	87 d	-	90 c	90	90 bcd	81 b
Fenoxaprop	0.075	99	95 bc	97 ab	98	99 ab	98	92 abc	95 a
Clodinafop	0.048	-	93 bc	95 abc	-	85 d	-	92 abc	91 a
Clodinafop	0.064	99	98 c	98 ab	99	97 bc	99	97 ab	93 a
Clodinafop	0.08	-	100c	100 a	-	100a	-	99 a	96 a
Control	0	0	0 a	0 e	0	0 e	0	0 e	0 c

Means within a column followed by same letters are not significantly different (P=0.05)

P. brachystachys was controlled 97 and 99% by clodinafop at 0.064 and 0.08 kg AI/ha (experiment 2). In large scale applications of clodinafop, fenoxaprop, tralkoxydim and diclofop at the given rates, control levels of 99, 98, 90 and 85% of this grass species were achieved (experiment 1). Against P.minor control levels of 91-96% were obtained by fenoxaprop or the given rates of clodinafop (experiment 4).

Crop selectivity

The herbicides at the applied rates did not produce clear phytotoxic symptoms on the wheat cultivars. Some chlorosis was observed in trial 5 where clodinafop had been applied at 0.08 kg AI/ha. This, however, was not the case in other experiments. Fenoxaprop at 0.90 kg AI/ha in a farmer field at the Garmsar province induced obvious phytotoxic symptoms on the wheat cv. Ghods. As cold also injured this wheat cultivar at early growth stages, detection of the herbicide symptoms became difficult.

Crop yields

Application of the herbicides in each of the experiments resulted in relatively high yield increases. In experiment 2, each of the treatments increased grain yields by more than

80%, as compared with the control plots. In trial 4 more than 90% yield increase was obtained following the application of fenoxaprop at 0.075 kg AI/ha. This increased to more than 100% when clodinafop was applied at 0.064 or 0.08 kg AI/ha. The highest yield increase was obtained in experiment 5 where the application of clodinafop at 0.08 kg AI/ha resulted in 130% grain yield increase. In general, highest yields were recorded following the use of clodinafop at 0.08 kg AI/ha with declining responses from the lower rates and from the fenoxaprop at 0.075 kg AI/ha.

TABLE 4. Grain yields, t/ha

Herbicide	kg AI/ha	Experiment Number				
		1	2	3	4	5
Diclofop	0.90	3.18	6.17 a	-	-	-
	1.0	-	-	-	-	5.70 ab
Tralkoxydim	0.30	3.23	6.25 a	-	6.70 b	-
Fenoxaprop	0.075	3.00	6.33 a	7.17	7.95 ab	5.75 ab
Clodinafop	0.048	-	6.22 a	-	7.67 ab	4.78 bc
Clodinafop	0.064	3.58	6.32 a	6.97	8.45 a	6.19 ab
Clodinafop	0.08	-	6.34 a	-	8.61 a	7.38 a
Control	0	2.72	3.41 b	4.55	4.12 c	3.60 c

DISCUSSION

Since wheat fields in Iran are mostly infested with Avena spp. and/or other grass species including Phalaris spp. A. myosuroides and Lolium spp., farmers are more interested in herbicides which have a wider grass spectrum, a wide window of application, good crop selectivity, and other desirable characteristics. Results from experiments, and from a survey in wheat fields of the farmers in Garmsar and other wheat producing areas infested with the grass species, showed that fenoxaprop, in cases where control of Lolium spp. is not targeted, and clodinafop have potentials to meet these requirements. This study showed that effective control of the grasses other than Avena spp., however, was somewhat critical. This means that application of the herbicides has to be made at earlier growth stages of the grasses. Otherwise, when they reached tillering stages and particularly when they were under drought stress, even higher application rates did not result in a satisfactory control of the target grasses.

ACKNOWLEDGEMENTS

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POSSIBILITIES FOR IMPROVING THE FOLIAR ACTIVITY OF ISOPROTURON

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ABSTRACT

The soil and foliar activity of isoproturon was examined on *Poa annua* and *Stellaria media* in pot experiments. The main activity was exerted through the soil on both species but the foliar activity was higher on *S. media* than on *P. annua*. The soil effect of isoproturon on *P. annua* was unaffected by adjuvants whereas the overall effect was improved indicating an increased foliar activity in mixture with adjuvants. In further experiments on *Lolium multiflorum* the highest activity was obtained in mixture with a tallow amine, a silicone polymer, a diglycolether sulfate and a broad-leaf herbicide consisting of ioxynil and mecoprop. In field trials adjuvants tended to improve the effect of spring-applied isoproturon on *L. perenne*, but they also seemed to reduce crop tolerance.

INTRODUCTION

Isoproturon is applied pre- or post-emergence in cereal to control mainly grassweeds but also some broad-leaf weed species. Its primary mode of action is through root uptake (Blair, 1978), but foliar activity can be of importance under certain circumstances, e.g. low soil humidity or extended foliage cover retaining the spray liquid. The objective of this study was to examine the influence of various adjuvants on the soil and foliar effect of isoproturon and on crop tolerance.

MATERIALS AND METHODS

P. annua and *S. media* (experiment 1) were grown outdoors in 1 l pots in a sandy loam soil. In experiment 2 *P. annua* was grown in a glasshouse. Isoproturon was applied as an overall spray, only to the foliage or only to the soil. After application the plants were placed in a glasshouse and they were watered every second day at the soil surface with a nutrient solution. *L. multiflorum* (experiment 3) was grown outdoors in 8 l pots in a soil:peat mixture (2:1 w/w) containing all necessary nutrients. The pots were subirrigated to avoid soil activity.

Isoproturon was applied as a commercial product containing 500 g AI/l at the 2-3 leaf stage of *L. multiflorum* and *P. annua* and at the 4 leaf stage of *S. media*. Adjuvants included in the experiments are listed in Table 1. Overall and foliar applications were made using a laboratory pot sprayer equipped with a boom fitted with two Hardi 4110-14 nozzles. The nozzles were operated at a pressure of 250 kPa and a speed of 5.0 km/h delivering a volume rate of 150 to 160 l/ha. Foliage application was performed by covering the soil surface with vermiculite and soil application was carried out by adding the herbicide to the soil surface in 25 ml of water. The plants were harvested 3 weeks after spraying. A randomized factorial layout with 3 replicates was used in all pot experiments.

TABLE 1. Adjuvants used in the experiments.

Adjuvant	Spray conc.	Composition	Abbreviation in text
Actipron	1.0%	98% mineral oil+2% emulsifier	mineral oil
Binol	1.0%	90% rape seed oil+10% emulsifier	vegetable oil
Lissapol Bio	0.1%	83% alcohol ethoxylate	alc. ethoxylate
Genapol LRO	0.5%	28% sodium alcohol diglycolether sulfate	diglycolether
Frigate	0.5%	80% tallow amine ethoxylate	tallow amine
Silwet L-77	0.5%	silicone polyalkyleneoxide polymer	sil.polymer
Mylone Power	1.0[a]	160 g/l ioxynil+480 g/l mecoprop	ioxynil/CMPP
Oxitril	1.0[a]	200 g/l ioxynil+200 g/l bromoxynil	ioxynil/bromoxynil

[a] l/ha

Field trials were carried out on a sandy loam soil. In experiment 4 *L. perenne* was grown in 6 m^2 plots. Applications were made in autumn and efficacy was assessed by spectral reflectance measurements performed 1 month after application (Christensen, 1993). Crop tolerance was examined in winter wheat and winter barley (experiment 5) and in addition, the efficacy was measured on *L. perenne* in the winter wheat part. The plot size was 25 m^2 and a split-plot design with 3 replicates was used. Applications were made in autumn at the 1.5-2.5 leaf stage and in spring at the 3-4 leaf stage of the cereals. *L. perenne* was harvested and dry weight was measured on 1 m^2 pr plot 3 weeks after spring application. Grain yields of winter wheat and winter barley were determined at harvest and corrected to 85% dry matter content. In all trials an experimental field sprayer equipped with Hardi 4110-14 nozzles operating at a pressure of 250 kPa delivering a spray volume of 200 l/ha was used.

The results of experiment 1, 4 and 5 were subjected to an analysis of variance and standard errors (experiment 1) or LSD_{95} values (experiment 4 and 5) are given as appropiate. The results of experiments 2 and 3 were analysed by a nonlinear regression model. Dose-response curves were estimated using a logistic model describing fresh weight (U) as a function of dose (z):

$$U = C + \frac{D - C}{1 + \exp(2 * b * (\log(ED_{90}) + \frac{0.5 * \ln(9)}{b} - \log(z)))}$$

The parameter D denotes the upper limit at zero dose, C the lower limit at large doses and b the slope.

RESULTS AND DISCUSSION

Soil and overall activity of isoproturon was identical on *P. annua* indicating a negligible foliar activity. This was confirmed by the lack of foliar activity of even the highest dose of isoproturon. In contrast, isoproturon applied to the foliage of *S. media* reduced fresh weight 50 to 70% (Fig.1). The higher foliar effect on *S. media* could be due to a better penetration of active ingredients, a larger retention of spray liquid on the more horizontal leaves or the different location of the shoot apex on mono- and dicotyledons.

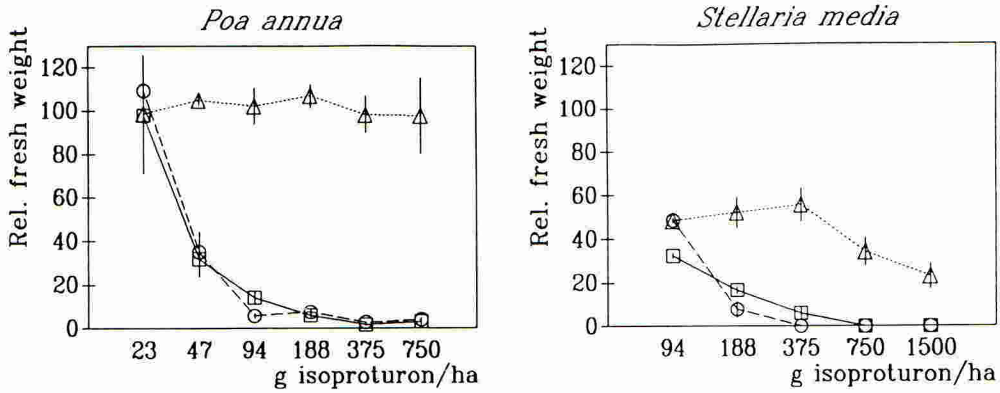

FIGURE 1. Effect of isoproturon on *Poa annua* and *Stellaria media* when applied as an overall spray (□——□), only to the foliage (△·····△) or only to the soil (○----○). Vertical bars represent standard errors. (Experiment 1).

It is well documented that adjuvants can enhance the foliar activity by affecting wetting properties, evaporation, foliar penetration and translocation (Hull *et al*, 1982) but knowledge of their influence on soil activity is limited. The influence of adjuvants on soil and overall activity of isoproturon was examined on *P. annua* in experiment 2. The results showed that the overall effect was significantly increased in mixture with diglycolether, sil. polymer and ioxynil/CMPP (Table 2). The fact that the soil activity was unaffected by adjuvants indicates that the adjuvants only improved the foliar activity. Séverin (1988) found that the efficacy of isoproturon on pot-grown wheat and rye grass was increased in mixture with a cocktail including liquid nitrogen fertilizer, isophoron, oil, emulsifier, alcohol and a wetting agent. Improved activity in mixture with oils and wetting agents has also been reported on pot-grown *Bromus sterilis* (West and Clay, 1988).

The influence of several adjuvants on the foliar activity of isoproturon was examined on *L. multiflorum* (Table 3). Alc. ethoxylate, diglycolether, sil. polymer, tallow amine and ioxynil/CMPP reduced the dose required for a 90% reduction of fresh shoot weight significantly whereas the vegetable oil and ioxynil/bromoxynil had no influence on activity.

The average of 2 field trials showed no significant effect of adjuvants on the activity of autumn-applied isoproturon, however the effect tended to be somewhat better in mixture with alc. ethoxylate and ioxynil/CMMP (Table 4).

TABLE 2. Required dose of isoproturon to reduce fresh shoot weight of *P. annua* 90% compared to control. Figures in parenthesis are 95% confidence intervals. (Experiment 2)

Adjuvant	ED_{90} (isoproturon g AI/ha) Overall effect	Soil effect
None	225.6 (152.5-298.6)	174.6 (124.9-224.3)
Diglycolether	111.3 (64.8-157.9)	188.6 (140.1-237.1)
Sil. polymer	87.8 (42.0-133.7)	238.8 (152.5-325.1)
Ioxynil/CMPP	95.6 (57.8-133.3)	252.4 (160.6-344.3)

TABLE 3. Foliar activity of isoproturon ± adjuvants on *L. multiflorum*. Figures in parenthesis are 95% confidence intervals. (Experiment 3).

Adjuvant	ED_{90} (isoproturon g AI/ha)
None	1180.5 (793.9-1567.2)
Mineral oil	858.3 (632.6-1083.9)
Vegetable oil	1104.9 (834.4-1375.3)
Alc. ethoxylate	776.7 (547.4-1005.9)
Diglycolether	514.9 (382.8-647.0)
Sil. polymer	725.4 (485.0-965.8)
Tallow amine	328.2 (213.7-442.8)
Ioxynil/CMPP	543.3 (351.1-735.5)
Ioxynil/bromoxynil	1038.0 (726.3-1349.8)

Comparisons of efficacy and crop tolerance of autumn- and spring-applied isoproturon alone and with adjuvants are shown in Table 5 and 6. Full control of *L. perenne* was obtained at both doses after autumn application whereas a lower level of control was recorded after spring application. A small and insignificant increase in efficacy was observed in mixture with adjuvants after spring application at the lowest dose (Table 5). Grain yield results of winter wheat showed a tendency to a reduced tolerance to spring-applied isoproturon when applied in mixture with the tallow amine and alc. ethoxylate (Table 6). Visual damage of winter barley was noticed after autumn application probably due to frost the night after treatment. This also explains the lower yields of autumn compared to spring treatments. The

TABLE 4. Response of *L. perenne* to post-emergence application in autumn of isoproturon ± additives. Means of 2 field trials. (Experiment 4)

Adjuvant	% reduction isoproturon g AI/ha 312.5	625.0	1250
None	51	76	89
Alc. ethoxylate	68	80	90
Mineral oil	57	72	91
Diglycolether	53	79	89
Ioxynil/CMPP	71	77	89
LSD_{95}	ns.	ns.	ns.

results revealed a tendency to yield reductions when isoproturon was applied in mixture with adjuvants in autumn as well as in spring (Table 6). In additional trials visual damage was observed in winter wheat and winter barley after autumn application of isoproturon in mixture with a mineral oil, however, this did not cause any yield reduction in winter wheat whereas a significant reduction of winter barley yield was found in mixture with the mineral oil as well as the tallow amine (data not shown).

TABLE 5. Response of *L. perenne* in winter wheat to post-emergence applications of isoproturon ± adjuvants. (Experiment 5)

Adjuvant	% reduction of shoot dry weight isoproturon g AI/ha			
	625	1250	625	1250
	Autumn		Spring	
None	98	100	83	96
Alc. ethoxylate	99	100	91	98
Tallow amine	99	100	91	98
LSD_{95}	ns.	ns.	ns.	ns.

The results with pot-grown plants showed that it is possible to increase the foliar activity of isoproturon with adjuvants. The field data showed only minor effects of adjuvants but a tendency to an increased effect was found. The results indicate that under practical conditions foliar activity probably only constitutes a negligible part of the overall effect in the autumn when soil humidity typically is high. However, foliar activity can be of importance in the spring when conditions at and after application are often very dry. An additional factor

TABLE 6. Crop tolerance to autumn and spring application of isoproturon ± adjuvants. (Experiment 5)

Adjuvant	Yield (t/ha) Winter wheat isoproturon g AI/ha 1250 Autumn	2500 Autumn	1250 Spring	2500 Spring	Winter barley 1250 Autumn	2500 Autumn	1250 Spring	2500 Spring
Untreated	6.37	6.37	6.37	6.37	8.30	8.30	8.30	8.30
None	7.80	7.56	7.86	8.02	8.29	8.20	8.95	8.19
Alc. ethoxylate	8.02	7.79	8.18	7.30	7.83	8.05	8.34	8.00
Tallow amine	8.43	7.85	7.29	7.23	7.86	8.20	8.55	8.26
Mineral oil	8.00	8.65	8.48	8.07				
LSD_{95}	0.59	0.83	0.59	0.83	ns	ns	ns	ns

causing foliar activity to be more important in the spring than in the autumn is, that the increase in leaf area from autumn to spring and the change in growth habit from erect towards more prostrate in the same period probably increases the proportion of the spray liquid retained on the foliage.

Isoproturon is often applied in mixture with broad-leaf herbicides to give a broad spectrum of weed control and it is noteworthy that one of the broad-leaf herbicides improved foliar activity to the same extend as the most effective adjuvants. Adjuvants also seemed to increase the risk of crop damage although no significant yield reduction was found. The crop tolerance to isoproturon in mixture with adjuvants and broad-leaf herbicides needs to be further investigated.

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A NOVEL MIXTURE OF FLUROGLYCOFEN-ETHYL WITH ISOPROTURON FOR THE CONTROL OF *GALIUM APARINE* AND OTHER IMPORTANT WEEDS IN WINTER CEREALS

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ABSTRACT

HOE 1024 is a new herbicide developed by Hoechst containing fluoroglycofen-ethyl and isoproturon for use in winter wheat and winter barley. During 1991/92 and 1992/93 extensive small-plot and grower-applied trials throughout England and Scotland demonstrated that the product controlled *Galium aparine* and other important broad-leaf weed species of winter cereals viz *Stellaria media, Matricaria* spp, *Veronica* spp, and *Viola arvensis*, together with *Poa annua*. Speed of activity due to the fluoroglycofen-ethyl component was very rapid with weeds often being killed within 7-14 days, even under cold conditions. Control of *Alopecurous myosuroides* and *Avena* spp. was achieved with tank-mixtures of isoporturon or fenoxaprop-p-ethyl. HOE 1024 was found to be safe to winter wheat and winter barley when applied from two leaves up to GS31, with no varietal susceptibility, following applications at recommended and double dose rates made in water volumes from 100 l/ha to 300 l/ha.

INTRODUCTION

HOE 1024 (trade name 'Competitor') is a new herbicide developed by Hoechst for the control of a wide range of annual grass and broad-leaf weeds in winter wheat and winter barley. It is formulated as a WDG containing isoproturon (60% w/w) and fluoroglycofen-ethyl (1.5% w/w) and is applied at 2 kg/ha of product.

Isoproturon is a substituted urea herbicide which controls weeds mainly through root uptake with some contact activity. It is effective against many annual grasses, including *Poa, spp., Alopecurus myosuroides* and *Avena* spp. Some broad-leaved weeds are also susceptible; the major ones being *Stellaria media, Matricaria* spp, *Papaver* spp. and *Chrysanthemum segetum* (Hewson, 1974; Read & Hewson, 1988). However, important cereal weeds such as *Galium aparine, Veronica* spp. and *Lamium* spp. are not controlled.

Fluoroglycofen-ethyl is a member of the diphenyl ether group of herbicides. Its chemical properties, mode of action and biological performance have been described by Maigrot *et al* (1989) and West (1993). Weeds are killed largely by contact action on the leaves, with little or no residual activity. Several broad-leaved weeds are controlled by fluoroglycofen-ethyl; important ones being *G. aparine, Viola arvensis, Lamium* spp. and *Veronica* spp., although *S.media* and *Matricaria* spp. are less well controlled.

In combining these two active ingredients, HOE 1024 brings together their complementary modes of action and weed spectra to provide a product which controls all the major cereal broad-leaf weeds during the autumn, winter and early spring. At this time of year, market research (Farmstat, 1992) shows that the five major broad-leaf weeds that cereal farmers seek to control are *G. aparine, S. media, Matricaria* spp., *Veronica* spp. and *V. arvensis*.

The extensive small-plot and grower-applied trials work described in this paper demonstrates the activity of HOE 1024 on these important weeds. Also described are the use of HOE 1024 in tank-mixture with isoproturon or fenoxaprop-p-ethyl to broaden the weed spectrum and the safety of the product to the crops, including extensive varietal screening.

MATERIALS AND METHODS

From 1991 to 1993 small-plot trials were conducted on commercial crops of winter wheat and winter barley throughout England and Scotland. Applications were made during the autumn, winter and early spring using hand-held Van der Weij AZO sprayers with four flat fan 110° nozzles on 2m booms operating at a pressure of 2.5 bars and a water volume of 100-300 l/ha. The active ingredients and formulation of the products used in the trials were as follows:- fluoroglycofen-ethyl (1.5% w/w) + isoproturon (60% w/w) WDG (HOE 1024), isoproturon (50% w/w) SC, fenoxaprop-p-ethyl (60 g/l) EW, diclofop-methyl (378 g/l) EC, deltamethrin (25 g/l) EC, manganese sulphate WP, diflufenican + isoproturon (20:500: and 50:500 g/l) SC.

There were ninety efficacy trials sprayed from December to April at crop stages from GS11 to GS31 (Zadoks *et al*, 1974). These trials had three replicates with the treatments fully randomised and a plot size of approximate 16m². Control of *Avena* spp. and *A. myosuroides* was determined by counting the seed heads once all had emerged in a number of random quadrats. *Poa annua* and broad-leaf weed control was assessed visually on a percentage scale (0% = no control, 100% = complete kill) as appropriate after application. The growth stage of broad-leaf weeds was described using the scale of Lutman and Tucker (1987).

Sixty-four crop tolerance trials were carried out with applications made between December and April at crops stages from GS11 to GS31. These were fully randomised with four replicates and a plot size of approximately 12m². The trials were on weed-free sites and all products were applied at single and double the recommended rates. Visual crop vigour assessments using a percentage scale (0% = no effect, 100% = complete kill) were made at one week and one month after application, and at GS31, 39 and 69 as appropriate. Crop yield was measured by harvesting with a small-plot combine.

Variety trials at seven sites over two years covered thirty-two winter wheat and thirty-eight winter barley varieties. Single and double the recommended rates were applied across 2m wide unreplicated variety strips. Crop vigour was visually assessed as for crop tolerance trials.

The compatibility of HOE 1024 in tank-mixture with diclofop-methyl, deltamethrin, manganese sulphate, isoproturon + deltamethrin and diclofop-methyl + deltamethrin was tested at single and double rates of all products on unreplicated strips at four sites.

Applications of HOE 1024 through farm sprayers to 1 ha plots were also made during 1992/93. There were twenty-nine sites throughout England and Scotland with applications made from February to April in water volumes of 100 to 250 l/ha. Weed control was assessed as described for the small-plot trials.

RESULTS

HOE 1024 gave excellent control of a range of weed species when applied alone (Table 1) and in tank-mixture with isoproturon or fenoxaprop-p-ethyl (Table 2).

HOE 1024 occasionally caused a white speckled discolouration of the crop leaf, however this was transient and crop yields from the tolerance trials at single and double rates of application were not significantly different from the untreated. No varietal susceptibility was recorded from applications at single or double the recommended dose. No unacceptable crop effects or antagonism of weed control occurred when HOE 1024 was tank-mixed with isoproturon, fenoxaprop-p-ethyl or the other products tested.

Applications of HOE 1024 + isoproturon in 100 l/ha of water in comparison to 200 l/ha of water gave no significant differences in control of *P. annua, A. fatua, A. myosuroides, G. aparine, S. media, Matricaria* spp., *Veronica* spp. or *V. arversis*, and so detailed results are not presented. With HOE 1024 alone, no differences in efficacy or crop safety relating to application water volume were found on the large-scale grower trials. These trials gave a mean control of 90% or more for the five broad-leaf weed species listed in Table 3 .

TABLE 1. Weed control in winter cereals with HOE 1024

Species	% Control (Range)				
	Fluoroglycofen -ethyl + isoproturon (30 + 1200 g AI/ha)	Diflufenican + isoproturon (100 + 1000 g AI/ha)	Range of weed GS at appl.	Untreated Plants/m² (Range)	Number of trials
Galium aparine	98(93-100)	75(47-97)	5-100	13(4-20)	9
Stellaria media	98(88-100)	98(90-100)	5-100	21(4-56)	13
Matricaria spp.	99(95-100)	99(90-100)	5-50	39(4-120)	10
Veronica spp.	100	100	10-16	10(6-14)	3
Viola arvensis	99(93-100)	91(50-100)	10-14	41(5-80)	6
Poa annua	99(92-100)	98(90-100)	11-21	43(10-80)	13

TABLE 2. Weed control with HOE 1024 in tank-mixture with isoporturon or fenoxaprop-p-ethyl

Weed species	Rate g AI/ha	% Control (Range) *Stellaria media*	*Matricaria* spp.	*Veronica* spp.	*Viola arvensis*	*Poa annua*	*Alopecurus myosuroides*	*Avena fatua*
(Fluoroglycofen-ethyl + isoproturon) + isoproturon	(30+1200) + 807	99 (90-100)	93 (93-100)	98 (89-100)	99 (93-100)	99 (88-100)	95× (65-100)	97□ (90-100)
(Fluoroglycofen-ethyl + isoproturon) + fenoxaprop-p-ethyl	(30+1200) + 41.25 - 55.0	-	-	-	-	-	99◇ (93-100)	99▲ (95-100)
Isoproturon	2017 - 2412	95 (38-100)	97 (80-100)	-	-	99 (93-100)	94° (74-100)	83* (20-100)
Diflufenican + isoproturon	100 + 2500	98 (70-100)	97 (85-100)	96 (72-100)	98 (90-100)	98 (83-100)	94 (60-100)	90 (4-100)
Range of weed GS at application		5-150	10-100	5-100	5-16	10-24	10-30	10-30
Untreated. Plants, seed heads/m² (Range)		12 (4-20)	26 (3-100)	14 (3-30)	18 (8-40)	67 (11-30)	159 (33-471)	67 (4-260)
Number of trials		37	13	32	18	12	48	19

▲ = results from 10 trials □ = results from 12 trials ◇ = results from 15 trials
* = results from 16 trials × = results from 37 trials ° = results from 39 trials

TABLE 3. Weed Control from large-scale grower trials with HOE 1024

Species	% Control Fluoroglycofen-ethyl + isoproturon (30 + 1200 g AI/ha)	Range of weed GS at appl.	Number of trials
Galium aparine	92	20-100	15
Matricaria spp.	95	12-50	13
Veronica spp.	97	12-100	21
Viola arvensis	90	12-16	7
Lamium purpureum	91	13-18	4

DISCUSSION

HOE 1024 has been shown to be very active, even under cold winter conditions, on a range of important broad-leaf weeds, both in small-plot trials and through commercial sprayers using a wide range of water volumes at application. The high level and speed of activity achieved on difficult-to-control weeds such as *Veronica* spp. *V. arvensis* and *G. aparine* confirm results previously obtained with fluoroglycofen-ethyl (Maigrot *et al* 1989). The presence of isoproturon in HOE 1024 broadens the spectrum of the product to give excellent control of *S. media, Matricaria* spp. and *P. annua*. The increase in control of *G. aparine* over that obtained with isoproturun + diflufenican was particularly marked. The high levels of weed control obtained from HOE 1024 in the large-scale grower trials, were comparable to the small-plot work and demonstrates the suitability of HOE 1024 for use in a wide range of commercial situations.

Additional isoporoturon in tank-mixture with HOE 1024 gave control of *A. myosuroides* and also increased the size at which many of the broad-leaf weeds could be controlled (Table 2). For example from GS100 to GS150 for *S. media*, GS50 to GS100 for *Matricaria* spp. and GS16 to GS100 for *Veronica* spp. HOE 1024 was also compatible with fenoxaprop-p-ethyl. This mixture gave excellent control of *A. myosuroides* and *A. fatua* in addition to the weeds controlled by HOE 1024. These mixtures therefore give a very useful approach for combined grass and weed infestation.

The other tank-mixtures described in the results section will give practical benefits to the farmer using HOE 1024 in the autumn, winter or early spring when insecticide and other herbicides also need to be applied.

The crop tolerance trials demonstrated the product to have a good margin of crop safety with no evidence of differential varietal susceptibility. This would be expected since both isoproturon and fluoroglycofen-ethyl at the appropriate rates have previously each been found to be safe to these crops (Hewson, 1974; Maigrot *et al*, 1989). The transient white speckling was of no commercial significance and is typical of effects caused by fluoroglycofen-ethyl alone (Maigrot *et al*, 1989).

The complementary action of the active ingredients, the fast speed of action even under cold conditions and flexibility to mix with other products, particularly isoproturon and fenoxaprop-p-ethyl, ensure that HOE 1024 will be of considerable benefit to the cereal grower.

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WEED CONTROL IN WHEAT WITH HOE 1028 - A COMBINATION OF FENOXAPROP-P-ETHYL AND ISOPROTURON

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ABSTRACT

Trials carried out in wheat throughout England and Scotland with a novel formulation (Hoe 1028) combining isoproturon (300 g/l) with fenoxaprop-p-ethyl (14 g/l) showed high and consistent levels of control of *Alopecurus myosuroides, Avena fatua, Poa annua, Stellaria media* and *Matricaria* spp. Both autumn and spring applications gave more consistent control of *A. myosuroides* and *A. fatua* when compared to isoproturon applied alone. The combination also enabled fenoxaprop-p-ethyl to be used earlier in the autumn with the isoproturon content providing activity against later-germinating weeds. Crop tolerance trials showed the formulation to be selective in all varieties of winter and spring wheat tested.

INTRODUCTION

Fenoxaprop-ethyl is formulated with the safener fenchlorazole-ethyl as a selective post-emergence grass-weed herbicide for use in wheat providing very high levels of control over a wide range of weed and crop growth stages (Palmer & Read, 1991). More recently, the optically-active isomer, fenoxaprop-p-ethyl has been developed using half the dosage rate, both racemate and isomer being very effective against the major grass-weeds of cereals viz. *Alopecurus myosuroides* and *Avena fatua* (Huff *et. al.* 1989). Other species such as *Apera spica-venti, Phleum pratense, Phalaris paradoxa* and *Poa trivialis* are also very susceptible but, as with other aryloxy-phenoxy and oxime graminicides, *P. annua* and broad-leaved weeds are not controlled (Palmer & Read, 1991).

In contrast, the residual and foliar-acting herbicide isoproturon is very effective against *P. annua* and major cereal broad-leaved weeds such as *Stellaria media* and *Matricaria* spp. as well as continuing to form a major part of the strategy for control of *A. myosuroides* (Hewson & Read, 1985; Read & Hewson, 1988). As such, it provides an ideal complementary mixture partner for fenoxaprop combining the foliar activity of fenoxaprop with the residual activity and additional spectrum of isoproturon. It enables fenoxaprop to be used earlier in the autumn with any later germinating weeds being controlled by the isoproturon component. It also overcomes soil and/or weather factors that can limit the effectiveness of isoproturon (Read & Hewson, 1988).

This paper presents results of field trials carried out by Hoechst UK Limited with a formulated mixture of fenoxaprop-p-ethyl plus isoproturon (Hoe 1028) for the control of weeds in wheat.

MATERIALS AND METHODS

All trials were carried out on commercially-grown winter or spring wheat in England and Scotland covering a range of locations and cultivars. A total of eighty-two efficacy trials was carried out over two or three autumn/winter and spring seasons from 1991 to 1993. The timing of applications was targeted according to weed growth stage (Lawson & Read, 1992; Lutman & Tucker, 1987). Autumn/winter applications were mainly applied between December and early February with grass-weed stages between one leaf and three tillers. Spring applications were made mainly in March and April with grass weeds between the one leaf and leaf sheath erect stage. Trials were designed as randomised blocks with three replicates and a plot size of $16m^2$ (Zadoks et al, 1974). A further one hundred and ten trials were carried out on weed-free sites over the same seasons on a range of winter and spring wheat varieties to investigate their tolerance to single and double doses of Hoe 1028 applied at a range of crop-growth stages. These trials were also designed as randomised blocks but with four replicates of each treatment and a plot size of $12m^2$.

Applications to all the trials were made using a hand-held van der Weij AZO small-plot precision sprayer operating at 250 kPa pressure delivering 200 l/ha using four flat fan nozzles spaced 50 cm apart on a 2m boom. Chemical treatments used in the trials and their active ingredient content were Hoe 1028 (fenoxaprop-p-ethyl + isoproturon; 14 + 300 g/l suspo-emulsion) and Isoproturon ('Arelon', 553 g/l SC).

Counts of grass-weed seed heads were carried out as soon as all had emerged, using $0.5m^2$ quadrats. Broad-leaved weed counts were made at least four weeks after application and overall weed control was assessed on a percentage scale. In all the tolerance trials, crop vigour was assessed at one week, three weeks and monthly intervals following application, using a percentage scale. Yields were taken using a Hege small-plot combine harvester.

RESULTS

Efficacy trials

Data is presented separately for autumn/winter (Table 1) and spring (Table 2) applications.

Tolerance trials

In all trials crop vigour effects were minimal even when double doses were applied. Where slight transient effects were noted, isoproturon also gave similar results and no significant yield losses were recorded. Detailed results are therefore not presented.

DISCUSSION

Autumn application gave good control of all weeds, the rates providing dosages of fenoxaprop consistent with those reported elsewhere to give high levels of grass-weed control from autumn application (Palmer & Read, 1991, Read & Hewson, 1990). The reduced dosage of isoproturon also maintained good control of weeds not controlled by

TABLE 1. Mean percentage control (and range) of annual grass and broad-leaved weeds in winter wheat 'autumn/winter' application

Treatment	Rate (l/ha)	Alopecurus myosuroides (GS 10-23)	Avena fatua (GS 10-14)	Poa annua (GS 55-23)	Stellaria media (GS 5-50)	Matricaria spp. (GS 14-16)
Hoe 1028	3.0	98(95-100)[7]	99(98-100)[5]	98(95-100)[5]	93(90-100)[5]	100
	4.0	98(93-100)	99(93-100)	99(96-100)	96(90-100)	100
Isoproturon	4.5	93(78-100)	94(76-100)	-	96(84-100)	-
Plants, heads/m² on control		190(90-460)	79(4-93)	24(8-60)	11(5-20)	40(30-50)
Number of trials		13	8	8	7	2

TABLE 2. Mean percentage control (and range) of annual grass and broad-leaved weeds in winter wheat 'spring' application

Treatment	Rate (l/ha)	Alopecurus myosuroides (GS 21-31)	Avena fatua (GS 11-30)	Poa annua (GS 11-26)	Stellaria media (GS 16-600)
Hoe 1028	4.0	96(85-100)	98(85-100)	88(84-100)	94(89-97)
	5.0	98(96-100)	99(97-100)	95(88-100)	96(92-100)
Isoproturon	3.75	87(57-100)	58(13-100)	-	95(90-98)[4]
Plants, heads/m² on control		220(51-600)	120(17-260)	130(33-500)	11(10-15)
Number of trials		16	16	5	5

[4, 5, 7] = number of trials

fenoxaprop viz. *P. annua, S. media* and *Matricaria* spp. whilst the fenoxaprop content provided additional consistency against *A. myosuroides* and *A. fatua* when compared to isoproturon alone. This was almost certainly due to the foliar action of fenoxaprop counteracting the tendency for isoproturon to give variable results under certain soil and weather conditions.

With early-spring applications, the superiority Hoe 1028 over isoproturon was even more marked against *A. myosuroides* and *A. fatua.* As with autumn application, the level of control of these two weeds was dependent on weed stage, the mean percentage control combining results from a wide range of growth stages. The results of these trials show that with Hoe 1028 it is possible to considerably reduce the dosage of isoproturon without compromising the control of the most important annual grass-weeds. This will allow farmers to maintain their weed control strategies at a time when the need to reduce potential environmental contamination has highlighted the desirability of reduced isoproturon applications.

ACKNOWLEDGMENTS

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ALOPECURUS MYOSUROIDES CONTROL USING FENOXAPROP-ETHYL DOSE ADJUSTMENTS, ADJUVANTS & MIXES

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ABSTRACT

From the spring of 1990 until the autumn of 1992 a trial series based in the Eastern Counties tested levels of control of Alopecurus myosuroides using the active ingredient fenoxaprop-ethyl both alone and in mixtures with a range of adjuvant types. In the second year, these experiments also evaluated tank mixes, with the addition of a residual herbicide. Finally, various dose rates of fenoxaprop were applied in sequence against A. myosuroides, with seed from the remaining plants tested for resistance to fenoxaprop and chlorotoluron.

Full doses of fenoxaprop gave the best control of A. myosuroides, although at reduced rates the addition of adjuvants consistently improved control and led to cost savings. Tank mixing with other products gave further improvements in control. Sequential use of low doses of fenoxaprop could contribute to the development of partial resistance of A. myosuroides to this chemical. The practical use of these results by agronomists/advisers is discussed.

MATERIALS AND METHOD

Trials in East Anglia seeking to improve control of Alopecurus myosuroides (blackgrass) in wheat, were begun in the spring of 1990 with three experiments testing two timings - SERIES 1. Full and reduced doses of fenoxaprop-ethyl plus wetters were compared. In the autumn of that same year a further set of trials was laid down to look at three factors; autumn use plus adjuvants, autumn use in mixtures with other herbicides and sequential use - SERIES 2A. This was followed by three trials in the spring of 1991 which were a follow-up to the first series, called SERIES 2B.

In the autumn of 1991 the programme was split into three separate trial groups, on each of three sites. SERIES 3A, 3B and 3C tested adjuvants, mixes with mainly soil acting herbicides and sequential treatments respectively.

Products and adjuvants used:-

ACTIVE INGREDIENT	PRODUCT NAME	ABBREVIATION USED IN TEXT
Fenoxaprop-ethyl	Cheetah R	Fenoxaprop
Soyal phospholipids	LI 700	S. phospholipids
Polyoxyalkene glycol	Galion	P. glycol
97% Mineral oil	Various	Mineral oil

In the course of two years, 30 distinct application timings were made to six varieties of wheat, at crop stages ranging from two leaves (Zadoks 12) in autumn up to the second node detectable stage (Zadoks 32) in the spring. Crop growth stages were defined by the decimal growth stage key (Tottman & Broad 1987). All applications were made with a modified Van der Weig sprayer with 80 degree fan jets and at a water volume of 200 l/ha using a pressure of 2.8 bar. Crop effects were assessed to indicate the damage caused by mixtures and the commercial acceptability of those effects.

Assessment of A. myosuroides was made by a head count using 25 by 25 cm quadrants (four per plot), during late May or early June. All plots were 12 by 3.2 m with two or three replicates depending on the site and area available. The exception to this was the Wickhambrook site in SERIES 1 where the plots were 12 by 2m.

In the final year of sequenced application (SERIES 3C) some attempt was made to assess the potential for increased resistance to herbicide in A. myosuroides (Clarke & Moss 1991). Seed of A. myosuroides was taken from a limited number of treated plots and the untreated control. These were later compared for levels of tolerance to fenoxaprop and chlorotoluron.

RESULTS

Work on additives.

The mean values of percentage control of A. myosuroides, from the addition of three adjuvants at a low fenoxaprop dose rate are shown in Table 1. These are compared to the low dose alone and the full dose rate as defined on the product label. Here the low dose was 40-60 g AI/ha compared to the full dose of 120-180 g AI/ha.

Some adjuvants clearly improved the control of A. myosuroides more than others.

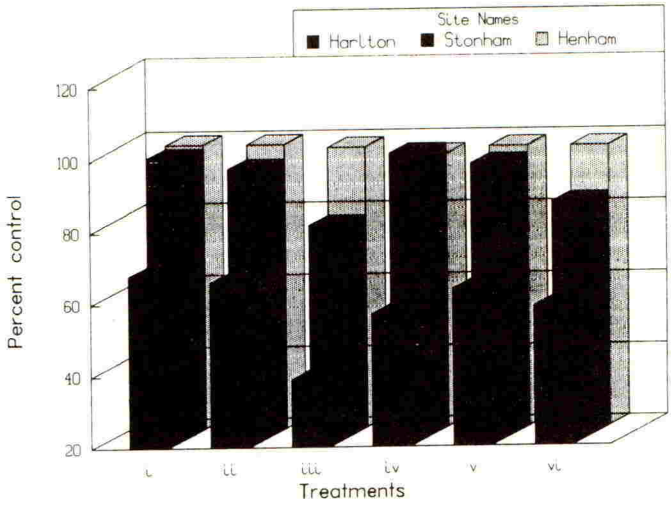
TABLE 1. Mean percentage control of A. myosuroides across all trial series with adjuvants and doses compared.

Series	Rate of Fenoxaprop, g AI/ha (and use of adjuvants)				
	40-60 (No adjuvant)	40-60 (+ S. phospholipids)	40-60 (+ Mineral oil)	40-60 (+ P. glycol)	120-180 (No adjuvant)
1	52	68	73	71	74
2	89	97	94	98	97
2B	-	93	95	96	95
3A	72	81	84	86	88
Mean	71.0	84.7	86.5	87.5	88.5

The mineral oil and P. glycol were consistent in improving control by 15.5% and 16.6% respectively when contrasted to the same dose of fenoxaprop without the additive. S. phospholipids were less effective but still gave a respectable average improvement of 13.7%. As can be seen in Table 1 the top levels of control of A. myosuroides were achieved using the full recommended dose of active ingredient.

There was considerable site variation in the performance of fenoxaprop as demonstrated in Figure 1. Treatments (i.), (ii) and (iii) compare full, three/quarter and half doses without wetter across the three sites. It was clear that at the Harlton site control fell to below 40% with the lowest rate of AI whereas at Henham the performance was 98% control against A. myosuroides, at this dose-rate. The effects of weather conditions and the weed growth stage could have contributed to this difference.

FIGURE 1. Control of A. myosuroides using fenoxaprop and adjuvants at various rates.



Treatments (iv), (v) and (vi) showed the effect of adding mineral oil, P. glycol and the acidifying penetrant S. phospholipids respectively, to the low dose of fenoxaprop. Here the sites which demonstrated least effect from the reduced doses "unaided" showed most response to the use of adjuvants. At Harlton the presence of P. glycol increased control by 25% and at the Stonham site control was enhanced by 20% with the addition of mineral oil.

Mixtures of fenoxaprop and mineral oil with other herbicides.

There were ten residual type herbicides mixed with the fenoxaprop and by way of summarising, Table 2 contrasts three of these "tank-mixes" at just two sites. In this series the half dose of fenoxaprop (60 g AI/ha.) plus mineral oil and cypermethrin was chosen to represent the commercially acceptable mixer with the residual herbicide.

TABLE 2. A. myosuroides seed head numbers and % control, using fenoxaprop + mineral oil + cypermethrin with other herbicides at two sites.

		HARLTON		HENHAM	
Chemical "Mixer"	Dose g AI/ha.	Head-count (per sq m)	% Control	Head-count (per sq m)	% Control
Fenoxaprop mix		580	76	26	97
+ Trifluralin	1128	514	79	4	99
+ Simazine	250	164	93	6	99
+ Chlorotoluron	3500	322	87	2	99
Untreated		2424	-	962	-
LSD's		63	-	47	-

At Henham, where the fenoxaprop + mineral oil + cypermethrin tank-mix (without the residual) had given 97% control, there was little room for improvement. Yet each product shown in Table 2 improved control to 99%. It was clear from this work that at Harlton the enhancements could be ranked. For example, where simazine was added this gave the largest significant increase in control, whereas trifluralin demonstrated the least increase, and where chlorotoluron was added the response in A. myosuroides control was intermediate.

It was interesting to report that when simazine or trifluralin were used in the mix the effects on the crop at all three sites were considered to be acceptable. However the addition of chlorotoluron produced levels of damage that were intolerable in terms of potential economic loss. This effect was thought to be associated with increased foliar uptake of chlorotoluron through the de-waxing processes of the mineral oil.

Sequences of fenoxaprop mixed with adjuvant oil.

At the Henham site, three sequenced applications of fenoxaprop at quarter, third or half the recommended doses produced 99 or 100% control of A. myosuroides. Two sequenced sprays of the "one-third" dose also gave similar control. In this treatment, doses were applied in late December and again in early May. Following this latter treatment there were sufficient seed-heads remaining to have samples of A. myosuroides tested for resistance to fenoxaprop and chlorotoluron.

TABLE 3. Summary of Henham resistance tests.

Treatment	Resistance Category Fenoxaprop	Resistance Category Chlorotoluron
Nil	"S"	"S"
Two x 1/3 dose	**	"S"

N.B. "S" = susceptible ** = partial resistance

In this situation, partial resistance was indicated following the two by one third dose fenoxaprop treatment, although the same sample remained susceptible to chlorotoluron.

DISCUSSION

The results presented were taken from a detailed and on-going product evaluation trial series. The overall aim was to provide comprehensive and up to date information to independent advisers on the most cost effective strategies for blackgrass control.

The Agronomists' pragmatic approach to A. myosuroides was considered by Keen (1991) when he outlined constraints to reducing herbicide costs. In particular the lack of guidance with regard to the use of adjuvants AND of tank-mixing options was cited. Similar views have been expressed when Crop Consultants have gathered and considered how best to improve farm productivity by reducing the variable costs of grass weed control.

What are the basic factors required for successful cost-effective A. myosuroides control?

1. A clear definition of optimum timing of the herbicide.
2. The choice of the correct dose rate.
3. The use of tank-mix partners to improve reliability of control.
4. Selection of a sustainable herbicide strategy which reduces the likelihood of build-up of herbicide tolerance.
5. Knowledge of the influence of weather patterns on herbicide performance.

All of these factors are carefully considered before an independent agronomist provides advice on herbicide selection and timing. Cussans (AAB 1981) suggested that our industry could have made more efficient use of herbicides. He expressed the clear dichotomy which was as relevant today as then, that the two approaches to herbicide use have existed. First, those who used products with strict adherence to the label instructions on rate and method. Second, agronomists and farmers who were more inclined towards the selection of dose appropriate to weed size and economic control.

The consultant in this latter circumstance would have carefully studied the results on several occasions over several seasons before these observations were reported back to colleagues. Further, it would have been important for the farmer to be made aware of changes from the manufacturers' label rate, such that deviation from the anticipated result would be explained. Situations were recalled where the full dose was applied at an inappropriate weed stage or when a low dose plus additive failed, due to a prolonged period of frost following treatment. Both have happened on some occasions when applying fenoxaprop against A. myosuroides.

Recently, Orson (1993) reviewed the Levy-funded trials and experiments on integrated cultural and chemical strategies for weed control in cereals. His opinion was that any likely reductions in costs made possible by cultural improvements would tend to result from reductions in doses of AI's but not necessarily a reduced number of applications.

The independently funded work reported here has demonstrated that fenoxaprop can be used with adequate crop safety, outside the manufacturers' guidelines. It has provided participating agronomists in the Eastern Counties with the confidence to mix this active ingredient at appropriate dose rates with specific adjuvants or residual herbicides and improve the reliability of control of A. myosuroides. The trial series has also indicated the possibility of quite rapid build-up of fenoxaprop tolerance or partial resistance in the A. myosuroides population. This is being followed up on one site by an experiment comparing a range of similar active ingredients on the break crop in the rotation.

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VARIATION IN METRIBUZIN RESPONSE BETWEEN WHEAT CULTIVARS AND BROMUS DIANDRUS (GREAT BROME).

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ABSTRACT

The response to metribuzin herbicide of wheat cultivars "Anton" and "Yécora" and Bromus diandrus, was assessed by analysing differences in dry weight and by a kinetic study of fluorescence induction in the first leaf. Biological assays have been carried out in nutrient solution. It was observed that the tolerance (weight measurement) of "Yécora" and "Anton" is 8 and 4 fold respectively compared to the tolerance of B. diandrus. The results obtained with these species suggest that metribuzin translocation from roots to leaves of plants plays a key role in the tolerance of wheat to this herbicide.

INTRODUCTION

Bromus diandrus, a roadside species in Spain, is invading cereal fields (García-Baudin, 1984; Riba et al, 1990), and their control is difficult by common selective herbicides (Sixto et al. 1984).

Metribuzin (4-amino-6-(1,1-dimethylethyl)-3-(methyl-thiol)-1-2-4-triazin-5(4H)one) is an inhibitor of photosynthesis widely used to control weeds in several dicotyledonous crops (Hardcastle, 1974; Fortino & Splittstoesser, 1974; Graf & Ogg, 1976). This herbicide is also of interest to control brome in winter cereals (Peeper, 1984), although the occurrence of differences in sensitivity among cultivars (Runyan et al., 1982; Schroeder et al., 1986; Wicks et al., 1987; Baker & Peper, 1990) makes it necessary to study the crop tolerance to metribuzin.

In this work we compared two wheat cultivars which are field tolerant to 0.3 kg. AI/ha of metribuzin (Villarroya et al., 1992), "Yécora" (Triticum aestivum l.) and "Anton" (Triticum turgidum L.) with B. diandrus by means of plant dry weight inhibition and by photosystem II (PSII) inhibition.

MATERIAL AND METHODS

Herbicide treatment

Germinated seeds, with the coleoptile between 2 and 3 mm long,were placed on a plastic grid in beakers filled with 175 ml of nutrient solution (Hewitt, 1963). The beakers were wrapped in black cardboard to protect them from light. The seedlings, five per beaker and ten replicates per treatment, were grown in a growth chamber with 16 h, at 24±1°C and 70% RH. When the plants reached stage 12 (Tottman, 1987) the nutrient solution was replaced by a similar nutrient solution containing 0, 0.10, 0.15, 0.25, 0.50, 0.75, 1 and 1.5 ppm of metribuzin, for B. diandrus and 0, 0.15, 0.25, 0.50, 0.75, 1, 1.5, 2 and 3 ppm of herbicide for wheat cv."Anton" and cv."Yecora", the plants were maintained in this solution for 24 h.

The responses were scored as the differences in the dry weight increases (P_7-P_0) of the assayed species using the Probit method. The Probit-log regression lines of the doses for the three species were compared following Finney (1971)

The aerial part of the plants, in half of the containers, was sampled after this 24 h treatment period (T=0) and the plants dry weight (P_0) was obtained by desiccation at 100°C in an oven. The other half of the containers was mantained for a further seven days in a herbicide free nutrient solution, in the same growth conditions, and then aerial part plants dry weight (P_7) was obtained. The difference P_7-P_0 was used to evaluate the herbicide effect.

Chlorophyll fluorescence measurements

Chlorophyll fluorescence was measured in plants treated with 0, 0.50 and 1 ppm of metribuzin after 24 h of treatment (T=0) and 1, 2, 4 and 6 days after treatment.

The fluorescence measurements were obtained by means of a Hansatech LD1 detector and a computer program, similar to one described by Ducruet et al. (1984). 10 measurements were performed per treatment at the times indicated. The quantitative estimate of the inhibitions was determined by the ratio FI/FP, as indicated by Cadahia et al. (1982).

RESULTS AND DISCUSSION

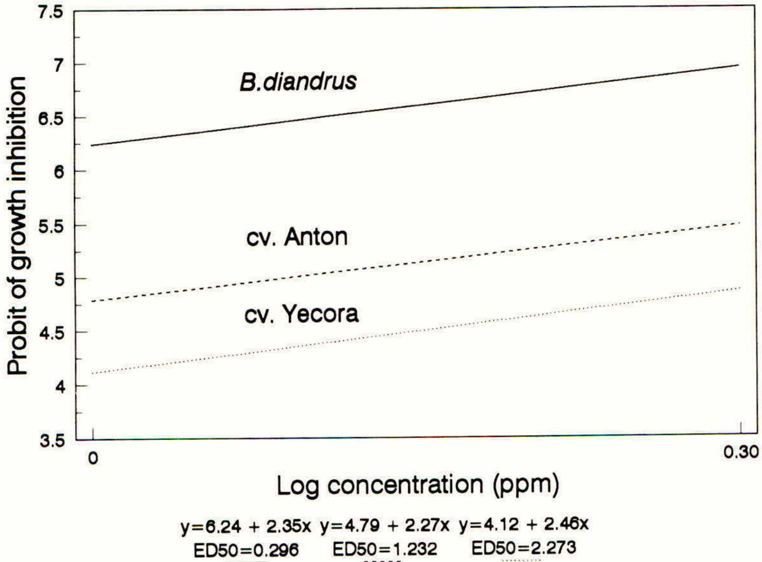
The required dose of the herbicide for 10% (ED_{10}), 50% (ED_{50}) and 90% (ED_{90}) inhibitions of the dry weight of the aerial part of the assayed species compared to the untreated are shown in Table 1. Using the method of forced parallelism of Finney (1971), the Probit-log regression lines (Fig.1) showed significant differences ($P \leq 0.05$).

The results showed that the 50% plant growth inhibition doses were significantly and substantially different for the three assayed species, being 8 and 4 times smaller for the wheat cultivars "Yecora" and "Anton" than for B. diandrus, respectively. Likewise the 90% growth inhibition dose of metribuzin for B. diandrus is similar to the 10% dose for the wheat cultivar "Yecora".

TABLE 1. Sensitivity of "Yecora", "Anton" and B. diandrus to metribuzin

Specie	Inhibition %	ED pmm	confidence limits
T. aestivum cv. "Yecora"	10	0,68	0.51 - 0.83
	50	2.27	2.01 - 2.69
	90	7.54	5.51 -12.44
T. turgidum cv. "Anton"	10	0.34	0.24 - 0.42
	50	1.23	1.10 - 1.38
	90	4.52	3.59 - 6.26
B. diandrus	10	0.08	0.05 - 0.12
	50	0.30	0.24 - 0.35
	90	1.04	0.83 - 1.42

FIGURE 1. Probit-log regression lines of "Yecora", "Anton" and B. diandrus response to metribuzin.



PSII inhibition

Table 2 shows the fluorescence scores using the ratio FI/FP for the three assayed species obtained troughout the test.

TABLE 2. PSII inhibition in leaves of cereal cultivars and B. diandrus, after 24 h of metribuzin treatment

Days	Doses ppm	*T. aestivum* "Yécora"	*T. turgidum* "Antón"	*B. diandrus*
	0	0.52±0.02	0.48±0.01	0.57±0.02
0	0.5	0.57±0.05	0.60±0.07	1.00
	1	0.64±0.05	0.97±0.03	1.00
	0	0.55±0.03	0.49±0.01	0.56±0.02
1	0.5	0.59±0.05	0.64±0.06	1.00
	1	0.73±0.09	0.97±0.06	1.00
	0	0.52±0.01	0.56±0.04	0.58±0.02
2	0.5	0.61±0.07	0.71±0.07	1.00
	1	0.80±0.07	0.97±0.02	1.00
	0	0.56±0.04	0.57±0.03	0.62±0.02
4	0.5	0.58±0.03	0.71±0.06	1.00
	1	0.79±0.07	0.90±0.03	1.00
	0	0.53±0.02	0.57±0.02	0.60±0.04
6	0.5	0.60±0.05	0.70±0.06	1.00
	1	0.74±0.07	0.84±0.05	1.00

Values (FI/FP) are mean of ten replicates

The chlorophyll fluorescence scores showed that with 0.50 ppm of metribuzin a complete inhibition of PSII occured in *B. diandrus* at T=0. This inhibition persisted throughout the test. In the wheat cultivars no inhibition appeared in "Yecora" and only minor symptoms in "Anton". A 1 ppm dose produced, at T=0 a large inhibition in *B. diandrus* and also in the wheat cultivar "Anton", which persisted throughout the test.There was only a partial inhibition of the cultivar "Yecora".

These results suggest that, tolerance to metribuzin in wheat is not due to detoxification ocurring in the leaves, as reported for other inhibitors of PSII, like chlortoluron (Cadahia *et al*., 1982; Cabanne *et al*., 1985; Tadeo *et al*., 1989). It is concluded that the herbicide, for some reason, is not translocated from the roots to the leaves. This has been suggested before using other methodologies (García-Baudín et al., 1990). The weak detoxification of metribuzin in the leaves of tolerant wheat cultivars, has been shown and will be reported in a paper to be published soon (Ducruet et al., 1983).

Susceptibility to metribuzin, expressed as dry weight of the plants, is positively correlated with PSII inhibition expressed as ratio FI/FP at all times assayed (R^2=0.83 at T=0; R^2=0.82 at T=1; R^2=0.81 at T=2; R^2=0.89 at T=4; R^2=o.97 at T=6)

In summary we conclude that fluorescence induction and herbicide effect on the dry weight of plant, grown in nutrient solution, considered by different authors to be suitable techniques to study susceptibility of cereals and grass weeds to phenylurea herbicides, is also applicable to metribuzin.

We point out as well the possibility of the use of metribuzin to control B. diandrus in tolerant wheat cultivars.

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METRIBUZIN USE IN U.S. FIELD CORN

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ABSTRACT

Metribuzin has been registered in the U.S. as an effective post emergence replacement for atrazine in field corn. Metribuzin provides effective control of a similar spectrum of dicot weeds to atrazine at 12% of the current atrazine use rate.

INTRODUCTION

Metribuzin, currently distributed in the US by Miles Inc. under the trade name SENCOR®, is widely used in soya beans, alfalfa, wheat and potatoes. It is also presently registered for pre-emergence use in field corn in the mid-western states of Iowa, Kansas, Missouri, Nebraska and South Dakota.

In 1988 Miles began researching the possibilities of using low rates of metribuzin post-emergence in field corn. The current pre-emergent rates for soya beans (0.4 - 0.7 kg AI/ha) were reduced (0.05 - 0.11 kg AI/ha) for post-emergent weed control in corn. For maximum broad sprectrum weed control, mixtures with 2,4-D (0.18 - 0.28 kg AI/ha), dicamba (0.28 - 0.56 kg AI/ha) or bentazone (0.56 kg AI/ha) were tested. Post-directed applications (herbicides directed under the crop canopy to the base of corn plants to reduce corn injury and control larger and/or later germinating weeds) can tolerate higher metribuzin rates. Here combinations of metribuzin (0.1 - 0.15 kg AI/ha) plus bromoxynil were tested.

REGISTRATIONS

A SLN (Special Local Need) registration (24(c)) was issued by Iowa, Nebraska and South Dakota in 1991 and over 100,000 acres of corn were treated. The purpose of the SLN was to offer corn growers an effective atrazine alternative. The results indicated that metribuzin offered the farmer excellent weed control and adequate crop selectivity. For added flexibility and weed spectrum, a tank-mixture of metribuzin plus dicamba (0.28 - 0.56 kg AI/ha) was added to the label in 1992 and states Kansas and Michigan approved the SLN. Missouri, Ohio, Indiana, Texas, Virginia and Minnesota approved the SLN in 1993. Currently Miles is completing necessary requirements to allow for Federal Registration.

RESULTS

Early trials indicated that metribuzin had good post-emergence activity on important broadleaf annuals in field corn including: ABUTH (*Abutilon theophrasti*), AMASS (*Amaranthus* species), AMBEL (*Ambrosia elatior*), CHEAL (*Chenopodium album*), DATST (*Datura stramonium*), IPOSS (*Ipomea* species) and XANST (*Xanthium strumarium*). However, trials using metribuzin alone indicated two problems: 1) if the weeds were not uniformly small (less than two-three leaf stage) control was often less than satisfactory and 2) if the rates were high enough for consistent weed control, crop injury resulted. The addition of crop oils and/or surfactants increased weed control at the lower metribuzin rates (0.07 to 0.140 kg AI/ha) but in 42% of the trials the corn phytotoxicity was also increased to an unacceptable limit.

Mixtures with 2,4-D

The addition of a tank-mix partner to metribuzin was necessary to broaden the spectrum so metribuzin could be safely used at the lower rates. Bentazone, dicamba, bromoxynil and 2,4-D were all tested in various rates and combinations. The results from these mixtures were generally positive as the weed control and crop safety were improved. The mixture with 2,4-D became a logical choice because of the activity spectrum in combination with metribuzin, price considerations, application flexibility, wide product availability and popularity. In Table 1 metribuzin is compared to 2,4-D alone and in combination. The results show an increase in weed control over either product applied alone.

TABLE 1. Comparison of metribuzin, metribuzin + 2,4-DA (amine) and 2,4-DA alone applied at the 2-4 leaf stage of corn through years 1989-1992. Only metribuzin + 2,4-DA and 2,4-DA comparisons are orthogonal.

Rate kg AI/ha	metribuzin 0.105	metribuzin + 2,4-DA 0.105 + 0.28	2,4-DA 0.28
Corn injury	2 (48)	3 (66)	2 (66)
Weed Species	------------------	% Weed Control	------------------
ABUTH	82 (32)	94 (53)	67 (53)
AMASS	81 (29)	95 (38)	76 (38)
AMBEL	54 (9)	92 (29)	85 (29)
CHEAL	64 (22)	90 (36)	70 (36)
DATST	77 (6)	92 (15)	78 (15)
IPOSS	20 (10)	95 (13)	93 (13)
XANST	46 (11)	89 (13)	81 (13)

( ) = the number of observations.

Lower rates of 2,4-D were also successfully tested. Decreased 2,4-D rates are important because of the reduced corn injury (i.e. brittle stocks and root fasciation) which can occur following labelled 2,4-D applications, reduced drift potential and lower costs. The current

2,4-DA label allows 0.28 to 0.56 kg AI/ha. In combination with metribuzin the rate of 2,4-DA gave excellent weed control at the lowest labelled rate (Table 1) and also acceptable weed control at 0.18 kg AI/ha 2,4-DA or a 30+% rate reduction when combined with metribuzin (Table 2). The results with 2,4-D LVE (low volatile ester) were similar. The current labelled rate of 2,4-D LVE is 0.28 kg AI/ha. When 2,4-D LVE rates were reduced 30+% to 0.180 kg AI/ha and combined with metribuzin, the weed control continued to be excellent (Table 2). Most weeds showed an increase in weed control over 2,4-D alone with the metribuzin addition regardless of 2,4-D formulation used and even at the reduced rates. Most noticeable was the increase in control of ABUTH and DATST which are especially probablematic for the 2,4-D's alone. Both weeds were controlled by the mixture.

TABLE 2. Percent weed control of reduced 2,4-D amine and LVE rates in combination with metribuzin compared to normally labelled 2,4-D rates. The percent weed control values below are orthogonal only when comparing 2,4-D to the similar metribuzin mixture.

	---------2,4-D Amine---------		---------2,4-D LVE---------	
	2,4-D	metribuzin + 2,4-D	2,4-D	metribuzin + 2,4-D
Rate kg AI/ha	0.28	0.105 + 0.18	0.28	0.105 + 0.18
Corn injury	1 (20)	2	5 (23)	4
Weed Species	------------------ % Weed Control ------------------			
ABUTH	72 (16)	98	78 (16)	96
AMASS	82 (15)	88	81 (10)	98
AMBEL	88 (15)	86	91 (14)	93
CHEAL	72 (10)	93	95 (11)	99
DATST	84 (8)	100	77 (11)	97
IPOSS	88 (3)	99	72 (3)	98
XANST	82 (5)	96	95 (7)	99

( ) = the number of observations
Corn was in 2-4 leaf stage at application

Comparison of metribuzin to atrazine market standards

One of the most popular and economic post corn materials used in the US for broadleaf weed control is atrazine plus crop oil or an in-can product containing atrazine such as bentazone + atrazine (Laddok® in a 1:1 ratio), dicamba + atrazine (Marksman® in a 1:2 ratio) or bromoxynil + atrazine (Buctril + Atrazine® in a 1:3 ratio). Two of the most popular in-can mixtures, bentazone + atrazine and dicamba + atrazine, were used to compare the effectiveness of metribuzin as a replacement for atrazine. Bentazone + atrazine is normally applied at 2-3.5 pts/A (pints/Acre) which gives an average atrazine or bentazone rate of 0.46 to 0.81 kg AI/ha. The dicamba + atrazine in-can at the registered application rate of 3.5 pts/A results in an atrazine application of 1.0 kg AI/ha and dicamba at 0.54 kg AI/ha. In these trials the atrazine was replaced with metribuzin (0.105 kg AI/ha) and compared to the atrazine in-can mixtures. The normal rate of bentazone (0.56 kg AI/ha) in the in-can mixture and a reduced rate of dicamba (0.42 kg AI/ha) was used. Earlier trials indicated the full rate of dicamba was not necessary. The results were compared for commercial weed control and crop safety (Table 3).

TABLE 3. Percent weed control of bentazone or dicamba + metribuzin compared to bentazone or dicamba + atrazine in-can mixtures. Percent weed control values below are orthogonal only when comparing metribuzin to the respective atrazine containing in-can mixture.

	--- Orthogonal treatments ---		--- Orthogonal treatments ---	
	bentazone +atrazine	bentazone +metribuzin	dicamba +atrazine	dicamba +metribuzin
Rate kg AI/ha	0.58 + 0.58	0.56 + 0.105	0.5 + 1.0	0.42 + 0.105
Corn injury	2 (84)	6	5 (25)	4
Weed Species	----------------- % Weed Control -----------------			
ABUTH	92 (57)	95	97 (19)	96
AMASS	94 (29)	94	98 (11)	97
AMBEL	96 (17)	87	100 (7)	100
CHEAL	97 (26)	83	100 (13)	98
DATST	99 (7)	98	100 (1)	100
IPOSS	96 (10)	79	100 (9)	100
XANST	81 (17)	78	100 (5)	100

( ) = the number of observations
Corn was in 2-4 leaf stage at application
All bentazone + atrazine in-can applications contained a recommended surfactant

The results in Table 3 indicate that atrazine can be effectively replaced by metribuzin without sacrificing weed control or crop safety. Weed control was essentially the same regardless of mixture used except for the control of CHEAL and IPOSS with the bentazone + metribuzin mixture. Neither bentazone nor metribuzin is particularly active against these two weeds and it is reflected in the lower control values. Comparing the weed control of dicamba + atrazine to dicamba + metribuzin, the values are essentially equal. It is also important to note, the 16% reduced rate of dicamba in the metribuzin + dicamba mixture, which did not appear to influence crop safety or weed control.

Comparisons of 2,4-D + metribuzin to the atrazine standards

Since the preferred mix partner for metribuzin is 2,4-D, the comparison of this mixture to the standards bentazone or dicamba + atrazine was important. In Table 4 both are compared in side-by-side comparisons. Weed control with the metribuzin + 2,4-D mixture was essentially equal to that of both the dicamba and bentazone + atrazine in-can mixtures. Only AMBEL with the dicamba + metribuzin combination appeared somewhat lower than its atrazine in-can counterpart. On the contrary, 2,4-D + metribuzin appeared to improve weed control for XANST over the bentazone + atrazine in-can product.

Crop safety averages are essentially equal. However, individual trial data indicate the bentazone + atrazine in-can mixture is overall safer for corn. In the 69 side-by-side trials used in Table 4 only 2 trial comparisons with the bentazone + atrazine mixture had corn injury that was rated above 10%. In the same 69 trials with metribuzin + 2,4-D, 10 of the 69 trials had injury at 10% or higher. In comparison to the dicamba + atrazine mixture, dicamba + atrazine had, in the 49 side-by-side trials, 7 trials with 10% or greater corn injury. In these same 49 orthogonal trials, metribuzin + 2,4-D had 12 trials with 10% injury or more. Overall, the metribuzin + 2,4-D has a tendency to more crop injury, but the injury is normally transient and disappears by later rating dates.

TABLE 4. Percent weed control of metribuzin + 2,4-D compared to bentazone or dicamba + atrazine in-can mixtures. The percent weed control values below are orthogonal only when comparing metribuzin + 2,4-D to the respective atrazine containing in-can mixtures.

	-- Orthogonal treatments --		-- Orthogonal treatments --	
	bentazone +atrazine	2,4-D +metribuzin	dicamba +atrazine	2,4-D +metribuzin
Rate Kg AI/ha	0.58 + 0.58	0.18 + 0.105	0.5 + 1.0	0.18 + 0.105
Corn injury	2 (69)	5	5 (49)	6
Weed Species	------------------ % Weed Control ------------------			
ABUTH	93 (46)	97	93 (38)	95
AMASS	94 (29)	96	99 (22)	96
AMBEL	95 (16)	91	99 (15)	90
CHEAL	97 (21)	96	100 (22)	95
DATST	99 (5)	99	100 (1)	100
IPOSS	97 (10)	97	99 (13)	96
XANST	86 (13)	96	96 (11)	96

( ) = the number of observations
Corn was in 2-4 leaf stage at application
All bentazone + atrazine in-can applications contained a recommended surfactant

CONCLUSIONS

1. Metribuzin combinations post emergence will provide effective control of problem broadleaf weeds ABUTH, AMASS, AMBEL, CHEAL, DATST, IPOSS and XANST in US field corn with good crop selectivity.

2. A reduction or elimination of atrazine can occur without sacrifice of weed control or corn safety.

3. When mixed with metribuzin, current 2,4-D labelled rates can be reduced by 30+% while maintaining weed control levels.

4. The mixture of 2,4-D, bentazone, dicamba or bromoxynil with metribuzin offers application timing flexibility beginning with 2 leaf corn up through 12 inch high corn and post directed options.

5. No additional crop rotational restrictions are necessary.

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EARLY COMPETITION OF AVENA FATUA OR GALIUM APARINE AND TRITICUM AESTIVUM WITH DIFFERING SOIL TYPES AND SOWING TIMES

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ABSTRACT

A single large outdoor replacement series pot experiment investigated the competition between *Triticum aestivum* and either *Avena fatua* or *Galium aparine* from the autumn until February. The experiment investigated the relative importance of growth of weed species, soil type and relative time of emergence of weeds and crop. Non-linear modelling provided four parameters (aggressivity and pure stand yield of both wheat and weeds). There was little indication that competition for resources was occurring as most aggressivities were near or less than one; nor was relative sowing date important in determining aggressivity. The light sandy clay loam soil gave the greatest pure stand wheat dry weight; there was a similar effect on *A. fatua* with early sowings.

INTRODUCTION

Following early growth in winter cereals, a range of management practices can be employed in the spring, to alleviate any limitations on dry weight accumulation imposed by residual weeds or soil composition. These can include control of weeds by herbicides and fertilisation. During this early period, it is important to know what the reduction in growth is likely to be compared to an optimised crop. Of the many methods for studying crop/ weed interactions (Fresco *et al.*, 1988; Rooney, 1991), the replacement method (De Wit, 1960; Harper, 1977; by which a crop plant is replaced by a weed plant from zero up to the number of crop plants in a pot) has the advantage of relying on equal soil volumes, and, thus, initially an equal nutrient and water supply.

The current single experiment was designed to examine the relative importance for growth of soil-type, time of emergence of crop relative to weed, and weed species by measuring dry matter accumulation and leaf area between September and February.

MATERIALS AND METHODS

Germination conditions and experimental design

Pedigree seeds of *Triticum aestivum* cv. Fenman (winter wheat), *Avena fatua* (wild oat), and *Galium aparine* (cleavers) of similar diameter, were pre-germinated 2, 5 and 8 days before sowing, respectively, in 13-cm diameter pots at a depth of 2 cm in surface irrigated soil. Weed seeds were sown on four dates at two weekly intervals (-2 w, 0 w, 2 w and 4 w) and wheat was sown on the second occasion (0 w) on 3rd October. The pots were spaced and embedded in sand outdoors to give 245 plants m^{-2}; they received natural rainfall, except just before sowing. Two types of soil were used, a light sandy clay loam, Brize Norton, Oxford called brash soil or a heavy silty clay, plot 38, Long Ashton called heavy soil.

The experiment was a split-plot design, laid out as three adjacent blocks each consisting of 12 rows x 8 columns of pots, giving 96 pots per replicate, ie. 288 pots. Each block was subdivided into 12 main plots. The treatments formed a 2 x 2 x 6 x 4 factorial set, consisting of all combinations of soil-type (brash or heavy) x weed species (*A. fatua* or *G. aparine*) x relative density (weed: wheat ratios 0:5 1:4, 2:3, 3:2, 4:1, 5:0) x relative sowing date of weed compared to crop (-2, 0, 2, 4) weeks. Main plot treatments were soil type x relative density. Treatments were randomised within each block and plot giving eighteen replicates per weed species, soil type and sowing date combination.

Sampling

The two soils were analysed for water holding capacity, ammonia, nitrate, total N, organic matter, pH, phosphate, potassium and magnesium according to standard procedures (personal communication, ADAS, Westbury-on-Trym). The experiment was terminated in mid-February when roots began to appear through the bottoms of pots, about the five leaf stage in wheat. Soil was separated from plants and frozen for subsequent full analysis using selected pots. Remaining soil was washed from roots leaving plants intact. Dry weights of roots and shoots (75°C for 48h) were determined separately for each plant species.

Statistical analysis

The de Wit (1960) non-linear model (in the form of the equations of Machin & Sanderson; 1977) was fitted by minimising the residual sum of squares (Ross, 1980). The correlation coefficient between the species was assumed to be zero. This gave estimates of the replacement parameters, crop or weed free yield and aggressivity (also called resource capture capacity or relative crowding coefficient; de Wit, 1960). Essentially,

$$y = \frac{M k x}{(k - 1) x + 1}, \quad M, k > 0; \qquad z = \frac{N (1 - x)}{(p - 1) x + 1}, \quad N, \quad t > 0 \quad \ldots 1, 2$$

where x is the proportion of the wheat plants in the pot. The pot yield of wheat is y; the pot yield of *A. fatua* or *G. aparine* is z. M is the wheat yield in a pot containing only wheat plants (the pure stand yield), and N is the corresponding pure stand yield for *A. fatua* or *G. aparine*. The aggressivity, for wheat relative to weed and weed relative to wheat, is k and 1/p, respectively. Log_e transformed dry weights were used to stabilise the variance. Aggressivities were statistically tested for significant difference from 1.

RESULTS

Composition of soil

The plant-free brash and heavy soils differed in classification and the content of all constituents, particularly P, except pH and K concentration. During the winter (September to February) mineralisation in the soil resulted in a change in nutrient ion concentration in both soils, particularly an increase in ammonium N in the heavy soil. In the brash soil, there was significantly less nitrate N with *A. fatua* ($P < 0.002$), irrespective of sowing time, compared to that with wheat plants. In brash soil with *G. aparine*, there was a significant depletion of P ($P < 0.002$) and also a reduction in nitrate N compared with wheat ($P < 0.05$). There was more ammonium N in heavy soil containing the first sowing of *A. fatua* compared to wheat ($P < 0.02$). The depletion of other nutrient concentrations were not significantly affected.

Replacement series parameters of wheat and weeds: dry weight

The aggressivity of wheat (k) was often not significantly different to one ($P < 0.05$), in the sixteen combinations of weed species, sowing date and soil type (Table 1). This indicated that these species were not competing for resources. Occasionally, wheat had an aggressivity significantly greater than one, indicating competition for the same resources, but there were no consistent treatment effects. Relative sowing date had little effect on the aggressivity of either weed species.

The estimate of weed-free wheat yield (M) was greater when wheat was grown with *G. aparine* on a brash soil than when grown with *A. fatua* on a heavy soil, irrespective of the time of sowing of weed relative to wheat ($P < 0.05$). In addition, the estimate of *A. fatua*-free wheat yield (M) was greater on brash than heavy soil when *A. fatua* was sown 2 to 4 w after wheat ($P < 0.05$). Wheat-free weed dry weight (N) declined with later sowing date of weed relative to wheat; it was generally greater in *G. aparine* than *A. fatua*. The estimate of wheat-free *A. fatua* dry weight (N) was greater on brash compared to heavy soil 0 to 2 w sowing of weed relative to wheat ($P < 0.05$). Making comparisons by replacing dry weight with area gave similar results.

DISCUSSION

Although roots had reached the bottom of the pots when the experiment was terminated in February, the aggressivity of weed species were significantly greater than one in only six per cent of the treatments (Table 1). For the majority of treatments,

TABLE 1. Estimates of parameter values of the model $y = M k x / ((k - 1)x + 1)$ and $z = N (1 - x) / ((p - 1)x + 1)$ where y and z are the yields in dry weight (g) of wheat and weed respectively, M and N are the pure stand yields in dry weight of wheat and weed, x is the frequency of y and z and k and 1/p are the aggressivity of wheat and weed respectively; standard errors in parentheses on 3 d.f.

Weed	soil	sow	M	N	k	1/p
A. fatua	brash	-2w	1.35(0.09)	1.64(0.13)	1.01(0.86)	1.05(0.05)
G. aparine	brash	-2w	1.98(0.24)	2.26(0.32)	0.66(0.18)	0.69(0.11)
A. fatua	heavy	-2w	1.46(0.21)	2.58(0.22)	2.83(1.68)*	0.29(0.02)
G. aparine	heavy	-2w	1.35(0.13)	2.52(0.14)	0.96(0.24)	0.74(0.02)
A. fatua	brash	0w	1.32(0.12)	1.06(0.05)	2.07(0.73)*	0.25(0.02)*
G. aparine	brash	0w	2.12(0.13)	2.06(0.58)	0.60(0.08)	0.16(0.07)*
A. fatua	heavy	0w	1.44(0.13)	0.59(0.14)	1.19(0.32)	0.40(0.20)*
G. aparine	heavy	0w	1.68(0.38)	1.74(0.11)	0.64(0.35)	0.30(0.03)*
A. fatua	brash	2w	1.66(0.19)	0.20(0.02)	1.72(0.67)	0.35(0.07)*
G. aparine	brash	2w	1.85(0.15)	0.49(0.09)	1.19(0.15)	0.24(0.08)*
A. fatua	heavy	2w	1.09(0.19)	0.14(0.01)	2.18(1.39)	0.99(0.16)
G. aparine	heavy	2w	1.46(0.25)	0.54(0.07)	1.58(1.00)	0.53(0.09)
A. fatua	brash	4w	1.71(0.10)	0.13(0.02)	1.11(0.18)	0.41(0.11)*
G. aparine	brash	4w	1.39(0.10)	0.19(0.01)	2.97(1.05)*	0.55(0.02)
A. fatua	heavy	4w	1.25(0.12)	0.18(0.15)	1.24(0.36)	0.16(0.19)*
G. aparine	heavy	4w	1.39(0.47)	0.18(0.04)	1.01(1.01)	1.04(0.33)

* Values of k and 1/p are significantly different from 1 ($P < 0.05$).

weeds were not competing with wheat for resources. This contrasts with the marked dry weight competition between *A. fatua* and wheat near maturity (Martin & Field, 1988; Cousens *et al.*, 1991; Rooney, 1991). Percentage yield loss per weed was greater in *A. fatua* than *G. aparine* when averaged over the whole growing season or near maturity, respectively (Wilson & Wright, 1990). Wheat yield loss was greater with high N, when *A. fatua* or *G. aparine* were present (Wright & Wilson, 1992).

The light sandy clay loam (brash) and silty clay (heavy) soils differed in most mineral ion concentrations so it was not possible in this study to determine which particular attributes caused the observed effects. However, the greatest weed-free wheat dry weight occurred in the brash. This soil had the highest P concentration while the difference in N, although significant, was small. Wheat-free weed dry weight was less affected by soil type, although for early sowing dates, *A. fatua* produced greater dry weight on light sandy clay loam compared to heavy silty clay. Competition for N and P have been reported to reduce the growth of wheat relative to other weeds (Welbank, 1963; Bhaskar & Vyas, 1988).

It is suprising that the relative sowing date of wheat and weeds had such little effect on their respective aggressivities. Such differences are important for final yield so that they must become apparent later (Ross & Harper, 1972; Hawton & Drennan, 1980; Peters & Wilson, 1983; O'Donovan *et al.*, 1985; Gonzalez Ponce, 1987; Martin & Field, 1988). Clearly, the lack of competition between *A. fatua*, *G. aparine* and wheat suggests that herbicides are not necessary until at least the spring when crop and weed density together is 245 plants m^{-2} or less. Further research could examine early competition at higher densities.

ACKNOWLEDGEMENTS

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Session 5D

Postgraduate Student Posters

Session Organiser	Mr M ASKEW
Posters	5D-1 to 5D-11

GROWTH ANALYSIS OF CHLOROTOLURON RESISTANT AND SUSCEPTIBLE BLACK-GRASS

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ABSTRACT

Susceptible and resistant *Alopecurus myosuroides* (black-grass) populations were treated with chlorotoluron, and ED_{50} values of 1 and >35 kg ai ha^{-1} were obtained. The susceptible population showed marked inhibition in growth and tillering.

INTRODUCTION

The problem of resistant *A. myosuroides* in England is increasing, with populations exhibiting some cross-resistance to herbicides with different modes of action (Moss & Cussans, 1991). There is accumulating evidence for the role of cytochrome P-450 dependant monooxygenase enzymes in herbicide metabolism by tolerant species (Fonne-Pfister and Kreuz, 1990). However,it is possible that by concentrating on metabolism other factors may be overlooked. To this end, we have attempted to characterise the resistance by growth analysis prior to physiological studies.

MATERIALS AND METHODS

Blackgrass seed from Peldon, Essex (U.K.) (resistant) and Herbiseed Ltd, Berkshire (U.K.) (susceptible) was sown in J Arthur Bowers compost and plants were raised under glasshouse conditions (20/17^{0}C, 14 hour day). Plants were sprayed at the 2 leaf stage with chlorotoluron (as the formulated product Dicurane 500SC) at a range of concentrations using a Mardrive laboratory pot sprayer (fixed nozzle, 80^0 flat fan tip, 200 l ha^{-1}, 3 bar pressure, spray height 450mm.) In the dose response experiments, plants were harvested after 14 days. Sequential harvests were also taken over a 14-17 day period for growth analysis.

RESULTS AND DISCUSSION

The initial comparison between the resistant and susceptible populations showed no difference in relative growth rate, leaf-weight ratio, leaf density and percentage water content. The development of resistance, therefore, has not reduced plant fitness nor altered development.

The effect of chlorotoluron, at increasing doses, on susceptible and resistant *A. myosuroides* populations is shown in figure 1. The ED_{50} values (the dose required to reduce fresh weight by 50%) were calculated to be 1 Kg ai ha^{-1} for susceptible and >35 Kg ai ha^{-1} for resistant plants. This is comparable to results gained for the Peldon population in simulated field conditions (Clarke & Moss, 1991).

The susceptible population showed a significant stunting of growth after treatment at field rate (3.5 Kg ai ha^{-1}). Tillering (see figure 2) and leaf production were completely inhibited in most plants. This was matched with little increase in dry weight and leaf area. Growth inhibition occurred before chlorotic symptoms were visible. The leaf density, percentage water content and leaf-weight ratio remained constant over the two weeks following treatment. When resistant plants were given the same treatment their growth and development were completely unaffected.

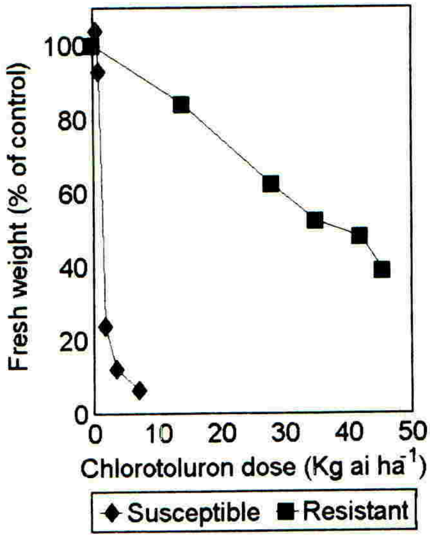

Fig.1. Dose response curves for susceptible and resistant *A.myosuroides*.

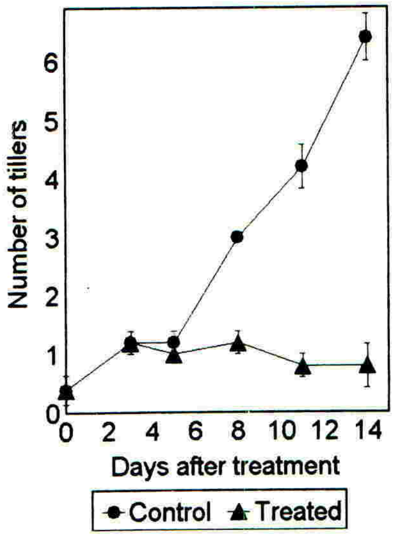

Fig.2. The effect of chlorotoluron on tillering by susceptible *A.myosuroides*.

These results will form a basis for further investigation into the mechanism(s) of resistance by studying photosynthesis and metabolism.

ACKNOWLEDGEMENTS

We would like to thank Dr S.R. Moss for providing the Peldon seed and the Polytechnics and Colleges Funding Council for financial support.

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POSSIBLE HERBICIDE:OZONE POLLUTION INTERACTIONS IN UNITED KINGDOM CROPS

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ABSTRACT

The treatment of spring oilseed rape (*Brassica napus* L. cv "Galaxy") with diclofop-methyl followed by a two day exposure to ozone, produced an antagonistic interaction. However, interactions were additive for the cultivar "Starlight" indicating varietal differences. Visible symptoms were distinctly different following treatment by ozone or diclofop-methyl.

INTRODUCTION

Ozone pollution episodes (>80 nl l^{-1}) occur in the U.K. during spring and summer (P.O.R.G., 1987), and coincide with the application of post-emergence herbicides. The potential interaction between ozone pollution and herbicides are the subject of this study. Preliminary investigations have concentrated on the interactions between ozone and five herbicides (diclofop-methyl, phenmedipham, clopyralid, metazachlor and mecoprop-p) on three spring sown U.K. crops (barley, oilseed rape and sugar beet). The results from one experiment involving diclofop-methyl and ozone on spring oilseed rape are described in this paper. Further results are discussed in Sanders *et al.*, 1993.

MATERIALS AND METHODS

Spring oilseed rape plants (*Brassica napus L.* cvs. "Galaxy" and "Starlight") were raised under greenhouse conditions (22°C, 14h day, natural light, sub-irrigation) and thinned to 2 seedlings per pot. Diclofop-methyl (as the formulated product, Hoegrass) was applied at the 2-3 leaf stage, at field rate (3.0 l ha^{-1}) using a Mardrive laboratory pot sprayer (flat fan 80°, 240 l ha^{-1}, 3 bar) to 16 pots per cv.. Three days after spraying, the treated plants were exposed to either ozone or charcoal filtered air in a controlled environment exposure facility. The four chambers were ventilated with air initially drawn through a Purafil and charcoal filter to remove ambient pollutants. Ozone, generated by passing oxygen over a u.v. lamp, was introduced into two of the chambers. The plants were subjected to a two-day ozone episode at 100 nl l^{-1} for 7 h d^{-1}. Seven days after fumigation the plants were assessed for visible injury.

RESULTS AND DISCUSSION

Symptoms of ozone injury were a distinctive chlorotic flecking of the leaf, whilst diclofop-methyl induced small circular chlorotic lesions indicative of contact injury. "Galaxy" treated with ozone developed chlorosis on 46% of the total leaf area of the first leaf, whilst diclofop-methyl induced 17% injury (fig.1). When treated with the herbicide followed by an ozone exposure, plants showed 39% total injury, which was lower than the expected injury if the two individual effects had been additive (i.e. 63%). However, an additive response occurred in "Starlight" implying a varietal difference. Results from a similar experiment using sugar beet (*Beta vulgaris* L. cv. "Saxon") and phenmedipham also suggest a less than additive interaction (Sanders *et al.*, 1993).

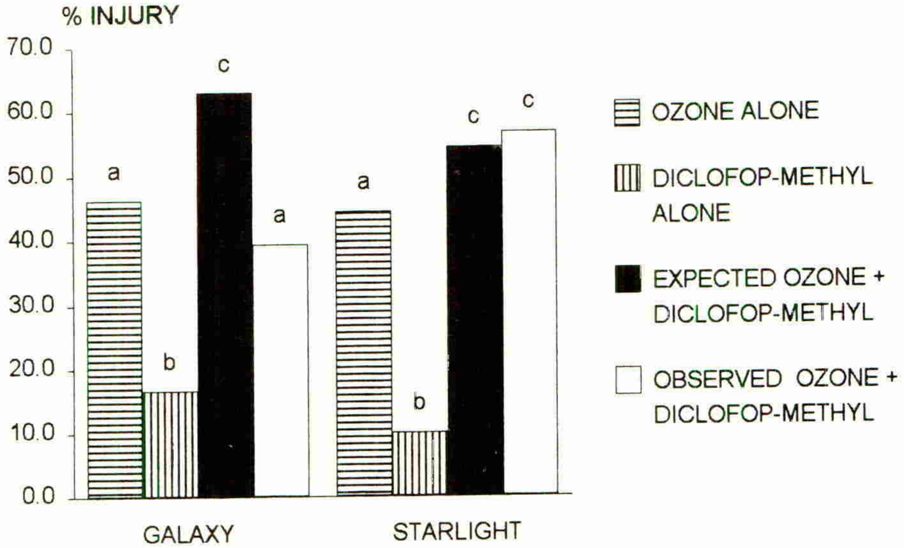

Fig.1 The effects of diclofop-methyl and ozone pollution on percentage visible injury of spring oilseed rape cvs "Galaxy" and "Starlight". Columns with different letters were significantly different from each other (p = 0.05, Duncan's Multiple Range Test).

Further work aims to understand the physiological basis of these interactions. Studies into the effects of timing of the ozone episode and herbicide application on the interactions will be conducted. In addition, the possibility of a chemical interaction between ozone and herbicides will be investigated.

ACKNOWLEDGEMENTS

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TOWARDS THE ISOLATION AND PURIFICATION OF A GLUCOSYLTRANSFERASE FROM *GLYCINE MAX* INVOLVED IN HERBICIDE DETOXIFICATION

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ABSTRACT

Purification of a glucosyltransferase associated with herbicide metabolism is currently in progress. Kaempferol glucosyltransferase activity has been partially purified from a crude leaf homogenate by ammonium sulphate precipitation and phenyl-sepharose chromatography, and when purified to homogeneity, will be used to develop an ELISA for plant screening.

INTRODUCTION

Two glucosyltransferases have been isolated in this laboratory (Leah *et al.*, 1991 and 1992) from *Glycine max* (cv. Fiskerby V) that can glucosylate 6-hydroxybentazon *in vitro*, a product of the catalytic action of cytochrome P_{450} monooxygenases on the herbicide bentazon (Sterling and Balke, 1989). One enzyme isolated from first trifoliate leaves, is a soluble kaempferol *O*-glucosyltransferase (K-GT, km 0.09mM) with a pH optimum of 6.3 and a molecular weight of 44,600. The second, found in etiolated tissue, is a membrane bound p-hydroxyphenylpyruvate *O*-glucosyltransferase, (km of 0.11mM) with a pH optimum of 7.5 and molecular weight of 53,000. These compare with other soluble and membrane bound glucosyltransferases reported in the literature (Zimowski, 1992). Knowledge of the distribution of such enzyme classes may provide valuable information regarding the sensitivity or resistance of weeds and crops to herbicides. In order to develop a quick and sensitive screening protocol an antibody probe will be necessary for the production of an enzyme linked immunosorbent assay (ELISA). The progress towards purification is reported in this paper.

MATERIALS AND METHODS

Soybean plants were grown in greenhouse conditions (22°C, 14h day, sub-irrigation) and first trifoliate leaves were harvested, frozen in liquid nitrogen and stored at -70°C. The leaves were powdered with insoluble polyvinylpyrrolidone 20%(m/m), liquidized in a minimum volume (~1kg/l) of extraction buffer (50mM MES, 3mM dithiothreitol, 3mM EDTA, 0.1M KCl, 0.05%(V/V) Tween 80, pH 6.3) and squeezed through muslin. The resulting homogenate was centrifuged at 17,500g for 20 min and ammonium sulphate (70% saturation) was slowly mixed with the supernatant, which was then stirred on ice for 30 min and recentrifuged.

The pellet was resuspended in a minimum volume of chromatography buffer (50mM MES, 1mM dithiothreitol, 30% saturation ammonium sulphate, pH 6.3), applied to a phenyl-sepharose CL-4B column, and eluted with decreasing ammonium sulphate and increasing

20%(V/V) ethylene glycol gradients. Aliquots of the fractions were desalted on coarse sephadex G-25 and assayed for K-GT activity using a modified method of Jain, *et al.* 1989. The reaction mixture consists of 2μl of ^{14}C UDP-glucose containing 1850Bq (9.47GBq/mmole), 1mM UDP-glucose and 4mM kaempferol with addition of 100μl extract containing 20-200μg of protein to initiate the assay (total volume of 120μl). The tubes were incubated at 30°C for 1 hour and the reaction stopped by addition of 1ml of ice cold water. The reaction mixture was filtered through ion exchange paper (three Whatman DE-81 discs), washed with three 5ml volumes of distilled water, and the amount of unreacted ^{14}C UDP-glucose which had bound to the paper was assessed by liquid scintillation counting. Active fractions were pooled, dialysed overnight against 25mM TRIS-HCl, 1mM dithiothreitol, pH 7.4, and applied to a Q-sepharose ion exchange column in order to separate active fractions on the basis of charge. Aliquots were again desalted and assayed for activity.

RESULTS AND DISCUSSION

Initial purification results from phenyl-sepharose chromatography are encouraging, and it is proposed to continue chromatographic separation with gel filtration steps following ion exchange. SDS-PAGE and native gel techniques will be used to assess purity. The pure protein will be used to raise antibodies and to develop an ELISA.

ACKNOWLEDGEMENT

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EFFECT OF TIME OF WEED REMOVAL ON TRANSPLANTED AND DIRECT-SEEDED MAIZE

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ABSTRACT

Time of weed removal was examined in transplanted and direct-sown maize, grown in field plots during 1991. Transplanted maize was more competitive than direct-seeded maize and suppressed weed growth substantially. Plant losses due to weeds were evident 6 weeks after sowing, by which time weeds had accumulated 98 kg N/ha in their tissue. Uncontrolled, weeds decreased grain yield by 40% in transplanted and by 80% in direct-sown crops.

INTRODUCTION

The critical time for controlling weeds in direct-sown maize is reported to be during the first 6 weeks after planting (WAP), when its canopy cannot shade inter-row weeds effectively (Varshney, 1991). A single weeding 40 days after sowing (DAS) decreased weed density and dry weight at harvest by 50% and diminished nutrient removal compared to unweeded treatments (Varshney, 1991). In the U.K. maize is grown for forage; grain production is unusual owing to the insufficient grain filling period. However, transplanting may ensure its safe production. The purpose of this investigation was to determine the effect of time of weed removal on the yield of transplanted and direct-seeded maize grown for grain.

MATERIALS AND METHODS

Maize transplants cv. De Kalb 198 were grown in modules containing seed compost in a glasshouse (20°C min. temperature) for 20 days and then "hardened off" outside for 5 days before transplanting in the field. The experiment was conducted on a silty-clay loam at Sonning near Reading. Main plot treatments consisted of weeds removed at 3, 6 or 9 WAP, unweeded and a weed-free control. Each main plot was split for direct-sowing and transplanting, and replicated three times. In mid-May, 25 day-old transplants or seeds were planted, 5 cm deep in rows 6m long with 0.6m inter-rows and five rows per plot. After establishment the crop was thinned to 100,000 plants/ha and 60 kg N/ha was applied as ammonium nitrate 50 DAP. Mustard (*Sinapis alba*) seed was broadcast at 10 kg/ha to supplement the indigenous weed flora. Weeds were sampled at 3, 6 and 9 WAP and at crop maturity in October, from two random 0.6m^2 quadrats. In early October, crop density, crop fresh weights and ears/plot were assessed for 3m of the central 3 rows. Ten random plants per sub-plot were dried at 80°C for 24h and dry weights determined. Dried samples of both crop and weeds were milled for N analysis.

RESULTS AND DISCUSSION

When weeding was delayed for 9 weeks or more there was approximately 20% reduction in survival of sown-maize whereas all transplants survived. Vegetative dry weights of transplanted maize were unaffected until weeding was delayed beyond 9 weeks, whereas for sown-maize dry weight reductions occurred if weeding was delayed beyond 6 weeks. Plant height showed a similar response. Maize grain yield was decreased by about 80% in unweeded direct-sown crops and by 40% in unweeded transplanted maize. Yield losses due to weeds were not evident unless weeding was delayed beyond 6 weeks. Weed dry weight increased throughout much of the growing season but at a greater rate in direct-seeded than in transplanted maize. Nitrogen accumulation by weeds increased rapidly over the first 6 weeks of growth attaining 98 kg/ha in direct-sown maize.

The results indicate that maize grown from transplants may attain grain maturity in the U.K. and that yield reduction due to weeds may be less than for direct-sown crops.

TABLE 1. Effects of time of weed removal on transplanted and direct-seeded maize, Sonning Farm, University of Reading (U.K.), 1991.

	Weed-free	Time of Weeding (Weeks) 3	6	9	Not Weeded
Final crop density/m^2					
Seed	9.2	9.4	9.0	7.0	7.4
Transplant	10	10	10	10	10
LSD = 1.02					
Non-ear (DW) (g/m^2)					
Seed	537	599	462	291	398
Transplant	627	606	557	636	489
LSD = 119.13					
Grain yield (DW) g/m^2)					
Seed	419	596	525	103	99
Transplant	740	700	691	480	418
LSD = 219.15					
Weed (DW) g/m^2)					
Seed	0	160	222	393	523
Transplant	0	95	126	188	436
LSD = 85.48					
N uptake by weeds (g/m^2)					
Seed	0	7.6	9.8	11.4	10.3
Transplant	0	4.1	5.0	5.6	8.9
LSD = 2.05					

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VARIETAL COMPETITIVENESS OF AUTUMN AND SPRING-SOWN FIELD BEANS (*VICIA FABA* L.) WITH VOLUNTEER BARLEY

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INTRODUCTION

Volunteer crops as weeds are currently a widespread problem (Whitehead & Wright, 1989). The occurrence of volunteer cereals has increased in recent years as a consequence of shorter rotations. Uncontrolled, their presence may cause yield reduction in subsequent crops. The objective of this investigation was to determine the effects of volunteer barley on the yield of autumn and spring-sown field beans and whether cultivars differ in their competitive ability.

MATERIALS AND METHODS

Field experiments were designed to investigate the effects of volunteer barley competition on the yield of autumn and spring-sown cultivars of *Vicia faba*. Seeds of cvs. Bourdon, Banner and Punch were sown at a density of $40/m^2$ on 6 December 1990 in replicate plots ($4m^2$) with or without volunteer barley cv. Marinka broadcast at a density of $200/m^2$. A similar experiment was sown on 19 April 1991, with cvs. Victor, Troy, and Gobo.

RESULTS & DISCUSSION

Autumn-sown experiment

Competition with volunteer barley significantly ($P<0.001$) reduced above ground biomass. Both cvs. Punch and Bourdon produced significantly ($P<0.01$) more biomass than Banner (Table 1). Similarly competition significantly ($P<0.001$) reduced the number of pods/plant but seeds per pod were unaffected. Punch produced most and Banner least. Competition with volunteer barley reduced seed yield, the greatest yield obtained with Punch and the least with Banner (Table 2). However, thousand seed weight was unaffected.

TABLE 1. Effects of volunteer barley competition on above ground biomass (g/m^2) and pods/plant of autumn-sown field beans (Pods/plant in parentheses)

Cultivar	Volunteer barley competition		Mean
	Present	Absent	
Bourdon	1121 (7.6)	1415 (8.9)	1268 (8.3)
Banner	982 (6.7)	1272 (8.2)	1127 (7.4)
Punch	1172 (9.0)	1513 (11.6)	1343 (10.3)
Mean	1092 (7.8)	1400 (9.5)	

S.E.D. (15 df) cultivar 54.2 (0.4) competition 44.2 (0.3)

TABLE 2. Effect of volunteer barley competition on seed yield of autumn-sown field beans (g/m^2)

Cultivar	Volunteer barley competition		Mean	S.E.D.
	Present	Absent		cultivar
Bourdon	510.5	647.0	578.7	
Banner	432.2	544.2	488.2	23.8
Punch	573.7	725.5	649.6	
Mean	505.5	638.9		
S.E.D. competition	19.4			

Spring-sown experiment

Crop biomass was significantly ($P<0.05$) reduced by competition (Table 3). Victor had the greatest and Troy the least biomass. Victor also produced most pods and Troy the least. Grain yield was significantly ($P<0.05$) reduced by competition; Victor yielded most and Troy least (Table 4).

TABLE 3. Effect of volunteer barley competition on above ground biomass g/m^2 and pods/plant of spring-sown field beans (pods/plant in parentheses).

Cultivar	Volunteer barley competition		Mean
	Present	Absent	
Victor	980 (8.3)	1074 (9.4)	1027 (8.9)
Troy	433 (2.8)	635 (5.0)	534 (3.9)
Gobo	930 (5.9)	950 (5.5)	940 (5.7)
Mean	781 (5.6)	886 (6.6)	
S.E.D. (22 df) Cultivar = 80.6 (0.61) competition = 46.5 (NS)			

TABLE 4. Effect of volunteer barley competition on seed dry weight (g/m^2) of spring-sown field beans.

Cultivar	Volunteer Barley Competition		Mean
	Present	Absent	
Victor	345.7	362.7	354.2
Troy	165.0	213.3	189.2
Gobo	267.0	353.3	310.2
Mean	259.2	309.8	
S.E.D. (df 22) Cultivar = 33.6 Competition = 19.4			

Cultivars Bourdon, Banner and Punch did not differ in their competitive ability despite the shorter straw height of Punch, although barley yield was greatest in Punch. Likewise barley yield was greater in Troy and Victor and least in Gobo. Both Troy and Victor are short-strawed and early maturing, whereas Gobo is long strawed, possibly offering greater competition. Hence, where volunteer barley is likely to occur, judicious varietal selection may offer opportunity for its suppression without yield penalty to the crop.

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COMPETITION BETWEEN *CIRSIUM ARVENSE* (L.) SCOP. AND SPRING BARLEY

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ABSTRACT

Plant height, shoot fresh and dry weights and density of creeping thistle were significantly reduced (P<0.001) when grown in association with spring barley than when grown alone. Application of 80 kg N/ha significantly (P<0.05) increased weed density in the absence of the crop.

INTRODUCTION

Resilience of *Cirsium arvense* (L.) Scop. to control measures can be attributed largely to its capacity for vegetative regeneration. However, *Cirsium arvense* appears to be susceptible to competition from shading by crops which may reduce root and shoot growth significantly albeit the competitive ability of various crops differs considerably. Nonetheless, depending on the competitive ability of the crop, creeping thistle may respond more to nitrogen application than the crop through increased shoot biomass and root development. Consequently, a knowledge of weed-crop competition is essential in order to improve the design and effective use of cultural control methods, thereby reducing cost of weed control. The objective of this study was to investigate the spatial dynamics and demography of a population of *Cirsium arvense* under cropped and uncropped situations.

MATERIALS AND METHODS

Creeping thistle root fragments 4 to 6 mm diameter and 10 cm long were planted at 2 densities (5 and 10 fragments) at a depth of 9 cm on 7 April, 1992 at the centre of 2 x 3 m plots. The experiment conducted at the University of Reading Field Unit, Shinfield, on a site free of creeping thistle history, was of a randomized complete block design with 2 levels of nitrogen. Spring barley cv. Blenheim was sown at 175 kg/ha on 13 April, 1992 and nitrogen applied at 40 and 80 kg/ha on 30 May, 1992. Data on shoot weights and density were logarithmic and square root transformed respectively prior to analysis of variance.

RESULTS & DISCUSSION

In association with spring barley, *Cirsium arvense* shoot height was highly significantly (P<0.001) reduced by about 50% relative to plants free of interspecific competition, irrespective of nitrogen regime (Table 1a). Shoot weight of *C. arvense* in association with the crop was significantly (P<0.001) less than that without interspecific competition (Table 1b.)

TABLE 1. Effect of nitrogen and interspecific competition with spring barley on creeping thistle plant height, shoot fresh weight and shoot density

	Nitrogen (kg/ha)						
	40			80			
treatment	root density 5	root density 10	mean	root density 5	root density 10	mean	sed
(a) Plant height (cm)							
weed + crop	42.5	43.8	43.2	41.7	47.2	44.5	
weed alone	78.1	87.8	83.0	82.0	85.6	83.8	
mean	60.3	65.8		61.9	66.4		5.39
(b) Shoot fresh weight (g/plot)							
weed + crop	1.3	1.4	1.4	1.2	1.3	1.3	
weed alone	3.2	3.4	3.3	3.4	3.5	3.5	
mean	2.3	2.4		2.3	2.4		0.08
(c) Shoot density/plot							
weed + crop	2.0	2.5	2.3	1.7	2.1	1.9	
weed alone	4.5	5.2	4.9	5.6	6.1	5.8	
mean	3.3	3.9		3.6	4.1		0.19
sed			0.19				

sed nitrogen x competition 0.27

The ability of creeping thistle to produce new shoots when in association with barley was significantly ($P<0.001$) less than that growing alone (Table 1c). The potential to produce new shoots was significantly greater ($P<0.05$) at the high density than that at the initial low density (Table 1c). In the absence of interspecific competition shoot production increased significantly ($P<0.01$) with increased nitrogen whereas the opposite was observed in competition with spring barley (Table 1c). New root formation was severely impaired in the presence of the crop whilst in the absence of a crop root expansion was significantly enhanced at the higher level of nitrogen. The highly significant reductions in shoot and root measurements following competition with spring barley are in agreement with observations of other workers (Marshall, 1990). Nitrogen application failed to enhance the growth of the weed in competition with barley but in contrast decreased shoot weight and density.

The greater the density of the initial infestation the greater is its ability to regenerate even when in competition. It is apparent from this study that creeping thistle is highly sensitive to competition from spring barley and this may offer a means of weed suppression as an integral component of an integrated weed management strategy.

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COMPARISON OF CELL CULTURE AND WHOLE PLANTS IN HERBICIDE BIOASSAYS

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ABSTRACT

Ranking potency of herbicides (chlorsulfuron, metsulfuron methyl, ethametsulfuron methyl, imazamethabenz and glyphosate) at ED_{50} was similar both in cell culture and in whole plants of *Daucus carota* L., *Triticum aestivum* L., *Stellaria media* L., *Chenopodium album* L. and *Avena sativa* L. Low doses of herbicide (< "No effect level") stimulated growth in both types of assays, but stimulation was greatest in cell cultures. Dose response curves had the same shape in both systems, but cell culture were more susceptible than were whole plants. Image processing of callus growth was, when compared with classical methods, more precise at measuring small differences in responses because of its ability to distinguish between intermediate levels of callus growth.

INTRODUCTION

This paper reports on the test of the hypothesis that cell cultures respond to herbicides in a similar way as whole plants. Hence, a system for studying dose-response relationships in cell cultures was developed. The results from this system were compared with whole plant bioassays.

MATERIAL AND METHODS

Cell suspensions of *Daucus carota* L. cv. Topscore and Nobo, and *Triticum aestivum* L. cv. Kanzler, were plated on herbicide containing solid media, and incubated in growth chambers (Olofsdotter *et. al*, 1993). Following three weeks culture, callus growth was evaluated by counting callus clumps and by image processing (Olofsdotter, 1993).

Whole plant assays were done in greenhouse, using *Daucus carota* L. cv. Topscore and Nobo, *Triticum aestivum* L. cv. Kanzler, *Stellaria media* L., *Chenopodium album* L. and *Avena sativa* L. Plants were sprayed when the dicotyledonous species had 2-4 true leaves and the monocotyledon species had 2-3 leaves. Fresh weight and dry matter were determined two weeks after spraying.

Commercial herbicide formulations containing glyphosate, chlorsulfuron, metsulfuron methyl, ethametsulfuron methyl and imazamethabenz were used.

Dose response curves of y on dose(z) were a four parameter logistic model (Streibig 1992).

$$y = \frac{D-C}{1+\exp[b*(\log(ED_{50})-\log(z))]}+C$$

where D denotes the upper and C the lower limit of response at low and high doses, respectively. ED_{50} defines the dose required to decrease the response by 50% relative to untreated and is equal to a response $(D+C)/2$. The parameter b is proportional to the slope of the curve at ED_{50}. In this study the lower limit C was excluded when C was estimated to zero. This was the case in all cell culture assays and provided better estimates of the remaining parameters.

RESULTS

Dose response curves in whole plants and in cell cultures followed the same pattern. Apart from the glyphosate wheat assays, where significant growth stimulation occurred at low doses, dose-response curves for all plant species/cell suspensions could be described by the model.

The regression of both number and area of cell colonies of carrot and wheat calluses on glyphosate, revealed wheat cells to be more susceptible than carrot cells, as was the case in whole plant assays. For whole plant assays the relative potency (Streibig, 1992) was 1.3 at ED_{50}. In cell suspensions relative potency was 1.7 or 2.4 for counting and image processing respectively.

Ranking the sulfonylureas according to herbicide potency showed the same ranking in cell suspensions as in whole plant assays; Chlorsulfuron was the most potent, followed by metsulfuron methyl at almost the same level, and ethametsulfuron as the least potent herbicide.

Both in whole plant assays and in cell culture low doses of herbicide cause stimulation of growth. This was only significant in glyphosate-wheat assays. Nevertheless stimulation occurred in all cell suspensions assays, but could not be satisfactorily described by any model.

Herbicide concentrations cannot be compared directly because of the differences in assay systems. However, concentrations in cell suspensions were much lower than the concentrations used in whole plant assays. The ED_{50} value for chlorsulfuron in carrot cell suspension was 0.2 $\mu g\ l^{-1}$.

Image processing was much more precise and faster than classical counting techniques. The results showed that image processing could detect a decrease in growth earlier than could counting. This resulted in lower ED_{50} values when the evaluation was done with image processing, compared with classical counting in the same experiment.

DISCUSSION

This study indicates that cell suspensions can be used in candidate herbicide screening as earlier suggested by Gressel (1987). Plating cell suspensions on a herbicide-containing solid media gave results comparable with whole plant assays, and thereby offers many possibilities for use in agricultural and environmental science. This technique e.g. is already used for screening glyphosate resistant sugerbeets (Danisco pers. com.). A screening system using the benefits of cell suspensions, such as less time and labour consuming, in combination with traditional whole plant assays for further investigations could be the platform for a herbicide pre-screening programme. As an example within environmental science, cell suspensions could be used to detect sulfonylurea residues in water, soil water and surface runoff.

ACKNOWLEDGEMENT

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EFFECTS OF SALINITY AND SOIL MOISTURE STRESSES ON THE UPTAKE, TRANSLOCATION & BIOLOGICAL ACTIVITY OF GLYPHOSATE IN *Echinochloa crus-galli* (L.) Beauv.

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ABSTRACT

It was observed that some herbicides had reduced activity when applied to weeds growing in saline soil in North-West China. The activity of glyphosate on *Echinochloa crus-galli* was reduced when the plants were grown in soils containing 0.1% and 0.5% sodium chloride in the greenhouse. The uptake and translocation of glyphosate in the plants grown at the two salt levels were reduced compared with those in the plants grown under normal conditions in which no salt was added. Soil moisture stress also reduced the uptake and translocation of the herbicide. However, the combined effect of salinity and soil moisture stress did not show a greater reduction in both uptake and translocation at any salt levels.

INTRODUCTION

Xinjiang, a bordering province in north-west of China, has an extreme continental climate, with a wide range of temperature changes (-40 °C — 40 °C) and very low annual precipitation. Agriculture relies on irrigation which in turn has resulted in the accumulation of salt in the soils. The use of herbicides to control weeds under such conditions often shows unsatisfactory results, but little is known about the effect of soil salinity, especially, when combined with low soil water potential, on the absorption and translocation of glyphosate in plants. This study was designed to evaluate the effect of salt and water stresses on glyphosate biological activity on control and on uptake and translocation in *E. crus-galli*.

MATERIAL & METHODS

E. crus-galli plants were propagated from seeds in soil at 30% moisture in a greenhouse, were subsequently thinned and transferred into 30% or 10% (w/w) soil moisture regimes and maintained at these levels till harvest. When the plants were at 3 leaf stage, sodium chloride (NaCl) was applied in the soils at levels of 0.0, 0.1 and 0.3% or 0.5%. Ten days later, 0.4 kg a.e./ha commercial glyphosate was applied to the 4/5 leaf-stage plants, then they were harvested 10 days after herbicide treatment and dry weight was determined. For uptake and translocation studies, 2 µl of ^{14}C glyphosate (0.007 µCi/µl) was placed on the upper surface of each newly expended leaf, and the plants were analysed after 0, 4, 8, 24, 48,72 hrs intervals, the residue of ^{14}C glyphosate on leaf surface was removed as described by Price (1982) and the radioactivity was determined by liquid scintillation counting (LSC).

RESULTS

Table 1 shows that glyphosate activity on *E. crus-galli* was reduced by salt or by drought stress alone. When combined, even at midium level of salt stress, its activity was significantly reduced. Salt reduced 27.5% and 40% of uptake at 0.1% and 0.3% salt levels respectively upto 24 hour treatment. Drought stress alone reduced uptake by 10%. When combined with salt, however, there was no significant reduction on the uptake. Salt, drought and the combination of the two showed similar effect on translocation of glyphosate in *E. crus-galli* as on the uptake, but drought stress alone gave a higher reduction on translocation (Fig. 1).

Table 1. Effects of Salinity and Drought on Glyphosate activity on Dry Weight (g) of *Echinochloa crus-galli*

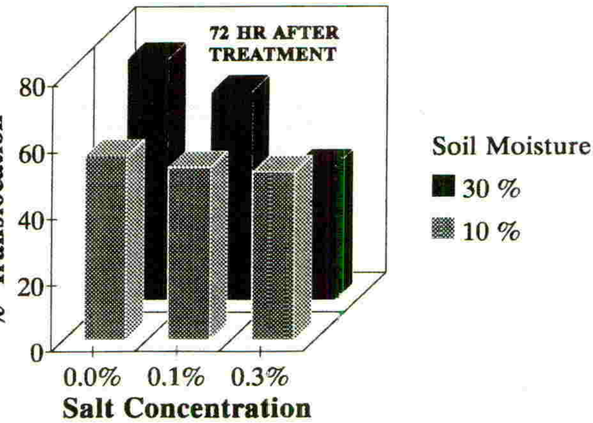
% Salt in Soil	Soil Moisture Content (%): 30		15		10	
	Herbicide Concentration (kg a.e./ha)					
	0	0.4	0	0.4	0	0.4
0.0	0.86 aA	0.50 aB	0.47 aB	0.29 aC	0.23 aC	0.15 aC
0.1	0.78 aA	0.44 aB	0.34 bB	0.25 aB	0.21 aB	0.13 aB
0.5	0.16 bA	0.14 bA	0.09 bA	0.06 bA	0.06 bA	0.05 aA

Note: Means followed by the same lowercase letters (column) or capital letters (row) are not significantly different at 5% level according to Duncan's MRT.

DISCUSSION AND CONCLUSION

These results support the observation of poor herbicide performances in Xinjiang province. It was clear that salinity not only depressed *E. crus-galli* plant growth, but slowed down glyphosate uptake, translocation in the plant as well. Drought stress has been shown to reduce glyphosate activity, absorption and translocation (Ahmadi *et al.*, 1980), but did not increase the salt effect at higher concentration. This study suggests that reduced glyphosate activity under stressed conditions resulted from the reduced uptake and translocation to its site of action, but whether the reduced uptake and translocation are directly related to each other need further studies.

FIG 1. TRANSLOCATION OF GLYPHOSATE IN *E. crus-galli* UNDER SALT AND DROUGHT STRESSES



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PRELIMINARY SURVEY ON WEED POPULATION DURING SET-ASIDE AND ARABLE FARMING AFTER CYCLES OF MAIZE-WHEAT ROTATION IN ITALY

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ABSTRACT

Weed densities after 3 cycles of a maize-wheat rotation and after one and three year set-aside periods were compared. In the plot cultivated and treated with a herbicide at a reduced application rate, common amaranth, black nightshade and knotgrass predominated. Weed densities increased in set-aside periods. With the general rotation regime the dominant species were those usually found in maize-wheat rotation, such as scarlet pimpernel, black bindweed and common poppy. Disc harrowing in spring combined with an additional tillage practice at the end of August was required to prevent seeding of these weeds. The occurrence of resistant weeds such as field pansy in the three year set aside plot must be taken into consideration when the set-aside land is returned to arable farming.

INTRODUCTION

At the end of 1991 in Italy some 571,489 ha were set aside. The rules required that fertilizers and pesticides were not to be used for five years. The indigenous flora has usually provided adequate ground cover during set-aside. Regulations changed in June 1992 and since then some farmers have adopted a general rotation regime, ie 15% of the arable land is set aside each year and must remain uncultivated from 15th December to 15th July. This preliminary trial was laid down to evaluate weed frequency during cultivation, and after one and three year set-aside periods following cycles of a maize-wheat rotation.

MATERIALS AND METHODS

Experimentation occurred in the Po valley (Northern Italy) on a silty loam soil (AL) after three cycles of maize-wheat rotation (Table 1). The order of rotation was maize-wheat and wheat was the final crop before set-aside.

TABLE 1 Soil management, fertilizer and pesticide used in the last six years

Soil cultivation	Fertilizer kg/ha	Herbicide (maize) AI	Herbicide (wheat) AI	Irrigation (maize)
ploughing, rotary-harrowing; hoeing + ridging (maize only)	N 260 (maize) N200 (wheat) P 140 (both)	alachlor + terbuthylazine, metolachlor + terbuthylazine	isoproturon + mecoprop, isoproturon + ioxynil + mecoprop	yes

The three (SA3) and one year (SA1) set-aside plots were ploughed in August 1990 and 1992 respectively and set aside. They were disc harrowed once a year at the end of May. Plots with normal application (NA) and reduced application (RA) of herbicide were ploughed in August 1992, sown with maize in April 1993 and sprayed with metolachlor + terbuthylazine.

The NA plot was sprayed the day after sowing at a rate of 1500g metolachlor/ha + 750g terbuthylazine/ha. A 16 m sprayer with 40 atomizer nozzles was used to apply herbicides. Water volume was 300 l/ha and pressure 2.53 bars. The RA plot was band sprayed during sowing with 600g metolachlor/ha + 300g terbuthylazine/ha using a tractor-mounted sprayer with 5 atomizer nozzles positioned directly above the drill coulter, in 150 l water/ha and at a pressure of 2.53 bars.

Weed species frequencies were recorded by listing the presence of the species on a rectangular grid using the Raunkiær method (Cappelletti, 1964) with a circle (0.05 m^2) placed at each point. The size of the sampling area was set according to a linear analysis along the field diagonal (Daget & Poissonet, 1971) to reach a constant weed density. Measurements were made in early to mid-May 1993 except for the NA plot in which herbicide treatment obviated weeds.

RESULTS AND DISCUSSION

The weed density increased during set-aside periods (Table 2).

TABLE 2 Frequency (% of 28 circles) of the dominant weed species

Species		SA3 (24)†	SA1 (22)	RA (11)
Amaranthus retroflexus	common amaranth	0	17.8	78.6
*Anagallis arvensis + A. foemina**	scarlet + blue pimpernel	0	71.4	0
Avena fatua	wild oat	42.8	0	0
Convolvolus arvensis	field bindweed	46.4	0	0
Fallopia convolvolus	black bindweed	0	53.5	53.5
Papaver rhoeas	common poppy	10.7	51.7	0
Polygonum aviculare	knotgrass	17.8	5.3	57.1
Solanum nigrum	black nightshade	0	3.6	75
Viola arvensis	field pansy	60.7	3.6	0

† in brackets () the number of species recorded in each plot are reported.

* considered together since during the survey most of the plants were not flowering.

NA Plot: No weeds were recorded in the NA plot as rainfall the day after sowing rendered the treatment very effective.

The weed species found in the RA and SA1 plot were those which commonly affect cereal cultivations. By combining a herbicide reduced application rate with hoeing and ridging, none of the weeds reported would threaten maize crops. With the general set-aside regime weed species that develop are controlled by disc harrowing but they then reproliferate. If a field is not re-cropped after 15th July an additional tillage practice is required in August to prevent the seeding of weeds.

Wild oat and field pansy found in SA3 could threaten winter cereals and perennial knotgrass is difficult to control in maize-wheat rotation. Field pansy has almost disappeared from the fields and is also tolerant of several herbicides such as terbacil, ioxynil and bentazon (Doohan *et al.*, 1992). The increase in weed density and change in species need to be considered when set-aside land is returned to arable farming.

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THE EVOLUTION OF HERBICIDE RESISTANCE: DELIBERATE SELECTION FOR CHLORSULFURON RESISTANCE IN PERENNIAL RYEGRASS

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ABSTRACT

Herbicide resistant phenotypes of perennial ryegrass (*Lolium perenne*) were discovered when a previously unexposed population underwent intense selection using chlorsulfuron. Resistant phenotypes in the range of 5 - 250 x 10^{-6} in the original unselected population, were detected using a hydroponic selection screen with post-emergence addition of chlorsulfuron. The relative resistance of survivors showed considerable variability in the response to chlorsulfuron. The most resistant individuals achieved half the growth of unsprayed plants at ten-fold field application rate. Characterisation of the resistance suggests that the trait is inherited, confers cross-resistance to isoproturon and diclofop-methyl and is not due to an altered acetolactate synthase (ALS) enzyme.

INTRODUCTION

In the last decade there has been significant worldwide increase in the evolution of graminicide resistance. Understanding the pattern and process of herbicide resistance involves analysis of both genetic and ecological factors underpinning this phenomenon. These include : the initial frequency of resistance alleles in unselected populations; inheritance mechanisms; the selection pressures imposed by herbicides; and relative fitness differentials between resistant and susceptible phenotypes. This paper reports initial findings into the process of evolution of herbicide resistance in a plant population previously unexposed to herbicide. A cultivar of *Lolium perenne,* Devon Eaver was screened for resistance to chlorsulfuron. This cultivar is an old land race which retains high genetic diversity.

MATERIALS AND METHODS

Mass screening

Sensitivity to chlorsulfuron was determined using two dose-response bioassay systems: a) herbicide applied as a post-emergence spray to seedlings grown in soil within the glasshouse environment; and b) herbicide supplied as a post-emergence additive to hydroponic nutrient culture into which seedlings were directly rooted. Since plant responses were less variable in hydroponic culture, a protocol for mass screening of seedlings in the glasshouse was based on this technique. Seeds were sown (1 x $10^5/m^2$) onto cotton muslin supported on a floating bed of plastic beads in nutrient solution giving a screening density of 3 x 10^4 seedlings/m^2. Sheets of muslin stretched across metal frames held within the framework of glasshouse benches made possible the mass screening. Chlorsulfuron was introduced into the nutrient solution when seedlings were at the three leaf stage using two rates of chlorsulfuron, 9550 and 1445 μg AI/litre giving estimated kill of 99.99% and 90% respectively. Putative resistant plants (individuals retaining a central green shoot, and a substantial root system) were selected after 4 weeks exposure to herbicide, transferred to nutrient solution and with confirmation of active growth, potted on into John Innes seed compost.

Putatively resistant plants were assessed by response to herbicide, population response to selection, relative sensitivity to acetolactate synthase, and genetic analysis.

Dose Response Characterisation

Selected clonally propagagated plants were raised in a controlled environment and sprayed with chlorsulfuron (0.3 to 300 g AI/ha). In a subsequent experiment cross-resistance was investigated by single dose spraying with chlorotoluron (963 g AI/ha), isoproturon (788 g AI/ha), imazapyr (188 g AI/ha), sethoxydim (169 g AI/ha) and diclofop-methyl (285 g AI/ha). Response to herbicide was expressed as the proportional change in fresh weight per plant.

Population response to selection

Tillers of putative resistant plants arising from the mass selection at the lower dose were tested in the glasshouse for response to chlorsulfuron (46 g AI/ha after 3 weeks growth followed by a secondary application of 230 g AI/ha at 6 weeks) and compared with untreated controls. Relative resistance to chlorsulfuron was expressed as the proportional gain in fresh weight of treated plants with respect to their performance when unsprayed.

Biochemical Analysis

Extracts of young leaves and tillers from confirmed resistant plants were further purified by precipitation with ammonium sulphate and assayed by the usual methods for acetolactate synthase (ALS).

Genetic Analysis

Selfed progeny were produced by bagging inflorescences of mature resistant plants in the glasshouse. Seedlings were raised and sprayed with chlorsulfuron (5 to 250 g AI/ha).

RESULTS AND DISCUSSION

Mass selection at 9550 µg AI/litre of chlorsulfuron (seedlings screened *c.* 5.7 x 10^5) yielded 3 survivors (coded R1, R2 and R3) in contrast to selection at 1445 µg AI/litre (seedlings screened *c.* 4 x 10^5) which gave 95 individuals (coded r1, r2 ..... r95). Biotypes R1, R2 and R3 showed a logistic decline in fresh weight gain to logarithmically increasing dose of chlorsulfuron and the resistant to susceptible ratio at GR_{50} (g AI/ha) were 4.2, 2.2 and 3.1 respectively. The relative resistance scores of biotypes r1 - r95 ranged from -0.215 to 0.544, where a score of 1 indicates equivalent growth of sprayed and unsprayed plants. These scores were normally distributed with mean of 0.167 and variance 0.022. Biotypes R1 and R2 when tested under the same regime had resistance scores of 0.12 (R1) and 0.18 (R2) and the mean score of susceptible plants was -0.018. Selfed seedling progeny of biotype R1 had a GR_{50} of 40 g AI/ha in comparison to 2.5 g AI/ha in unselected seedlings.

Acetolactate synthase (ALS) extraction and assay was carried out on phenotypes R1, seedling progeny of R1, r26, r52 and susceptible plant material. ALS I_{50} values (11 nM for chlorsulfuron) were similar in both resistant and susceptible phenotypes. These results suggest that the resistance mechanism is not due to a decreased sensitivity of the ALS enzyme.

Biotypes R1, r26 and r52 and a susceptible biotype were evaluated for cross-resistance. Patterns of cross-resistance were not common to the three chlosulfuron resistant biotypes. All biotypes showed a degree of cross-resistance to isoproturon and diclofop-methyl, with the exception of biotype R1 which was only cross-resistant to isoproturon. All biotypes were not cross-resistant to sethoxydim, imazapyr and chlorotoluron.

This work has shown that chlorsulfuron resistance may be selected from within a previously unexposed population of *L. perenne* and that the frequency of resistant phenotypes in the population studied here was between 5 - 250 x 10^{-6}. Phenotypic variation in resistance was noticeable after a single generation of selection suggesting that response to selection in successive generations will be gradual and controlled by several alleles. It is unlikely that resistance detected in this study is due to altered target site of herbicide action.

THE SIGNIFICANCE OF CROP DENSITY ON THE TOLERANCE OF IRRIGATED CROPS TO PENDIMETHALIN IN THE SUDAN

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ABSTRACT

The effect of crop density on crop tolerance to pendimethalin was tested in two field trials in the Sudan. Each of the crops sorghum, oats and pigeon pea showed increased mortality during establishment.with increasing density. The effects were most significant in sorghum, the most sensitive crop to pendimethalin.This response is contrary to the more often recorded effect of density where crop tolerance is increased by higher crop stands.

INTRODUCTION

This study consisted of two field experiments which were conducted at Faculty of Agriculture, University of Khartoum, Shambat, Khartoum North, Sudan. to study the effect of crop density on tolerance to pendimethalin.

MATERIALS AND METHODS

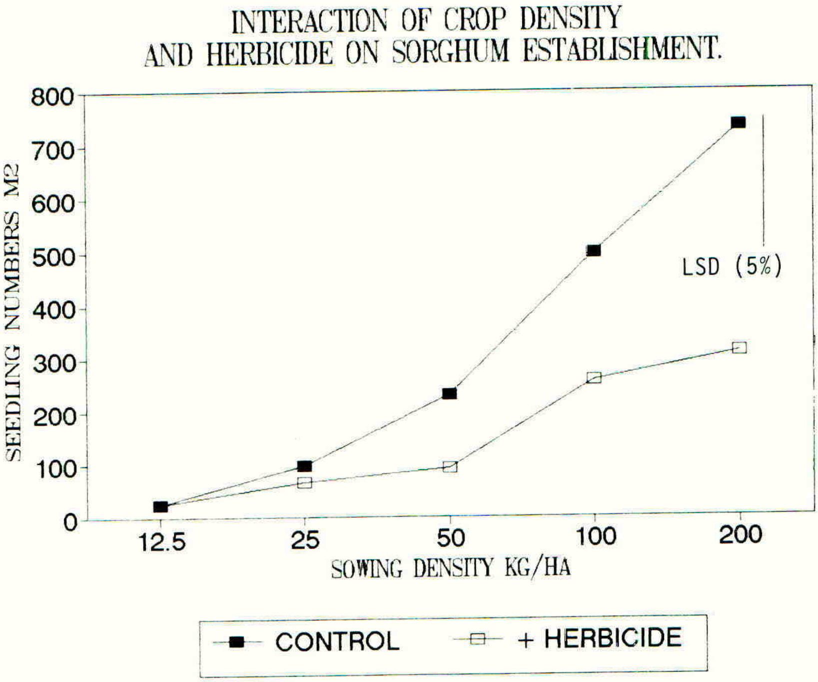
The materials and methods were the same for the two experiments which were conducted during the winters of 1988 and 1989. The experimental area was a heavy clay soil with individual plots of 2 x 2 metres. Flood irrigation was provided at 7 to 10 day intervals .and the plots were kept weed-free by frequent hand weeding of the weeds. The herbicide used was pendimethalin, formulated as an emulsifiable concentrate (Stomp from Cyanamid UK. Ltd.) applied at 6.0 l/ha. Application was made pre-emergence with a knapsack sprayer with a high pressure flat nozzle at an output of 760 l/ha.Sorghum (local cv. Tetron) was sown at densities 12.5, 25, 50, 100 and 200 kg seeds/ha. The experiment was a completely randomized block design with three replicates. At harvest, ten weeks from sowing, plant numbers, and fresh and dry weight from a 1.0 m^2 area were recorded. The data from each experiment were analysed separately and in combination using a weighted analysis of variance to compare between densities.

RESULTS AND DISCUSSION

Effects on Crop Establishment

Only the data for the sorghum, the most sensitive of the crops, are presented but similar effects although of lower statistical significance were recorded in oats and pigeon pea.

Both herbicide treatment, sorghum density and the interaction between density and herbicide had a highly significant ($P<0.001$) effects on crop stand/m^2. This indicated identical establishment at the lowest density and increased mortality as density increased (Fig. 1). Biomass production continued to reflect this interaction between density and herbicide due mainly to the effects on plant stand but also suggesting that the herbicide reduced plant size more as density increased. This is in conflict with the more normal interaction with herbicide and density as reported by Andersen (1981) where increasing crop or plant stand improves crop



tolerance as herbicide availability per plant is reduced. The most likely explanation of the current data, but one which requires experimental verification, is that the pendimethalin through its effects on root elongation was complementing intra-specific competition for moisture and causing increased mortality at the higher crop stands. S.el Tom (1991) has also recorded an increased ability of blackgrass plants at low density to overcome residual herbicide activity possibly due to greater plant vigour at low densities and this may also be a factor.

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