ENVIRONMENTAL FATE OF AZIMSULFURON, A NEW HERBICIDE FOR RICE

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ABSTRACT

Azimsulfuron is a new sulfonylurea herbicide used to control weeds in rice paddies. To support the registration of azimsulfuron in Japan and Europe, degradation, soil metabolism and mobility studies were conducted using study designs, conditions and soils appropriate for the use areas. Degradation and mobility of azimsulfuron were studied in soils from Japan, Italy, Spain and the US. The most significant degradation mechanisms for azimsulfuron appear to be metabolism in soil and indirect photolysis. Non-sterile soils under flooded and aerobic conditions gave faster rates of degradation than sterile soils, demonstrating the importance of microbial activity in the degradation. The formation of products unique to non-sterile test systems showed conclusively that azimsulfuron degrades by chemical and biological mechanisms. Photo-oxidation may occur in several different ways leading to rapid degradation of azimsulfuron. We will present a pathway for degradation of azimsulfuron and compare the rate of degradation and mobility data obtained with soils from each use area.

INTRODUCTION

Azimsulfuron is a new herbicide for post-emergence control of grass, sedge and broadleaf weeds in rice (Marquez *et al.*, 1995). Azimsulfuron is a sulfonylurea with structure shown in Figure 1. Like other sulfonylurea herbicides it is an acetolactate synthase inhibitor that is applied at low rates (Beyer *et al.*). Azimsulfuron has been tested extensively Japan, Korea, Italy, Spain and Portugal and has been shown to control key weeds at rates as low as 6 g ai/ha to 25 g ai/ha. The environmental fate of azimsulfuron has been studied to support registration in countries around the world.

PHYSICAL PROPERTIES

Azimsulfuron is a non-volatile solid with a melting point of 170°C. It is a weak acid with a pK_a of 3.6, and, as a result, its aqueous solubility and octanol/water partition coefficients are dependent on pH as shown in the table.

HYDROLYSIS

The hydrolysis of azimsulfuron was studied in sterile pH 5, 7 and 9 buffers incubated at 25°C in the dark. During the 30-day duration of the study, 15-22% of the azimsulfuron degraded through cleavage of the sulfonylurea bridge to give two principal products, tetrazole-pyrazole sulfonamide and pyrimidine amine (Figure 1). The hydrolysis half-lives were 89, 124 and 132 days, in order of increasing buffer pH.

Table of Physical/Chemical Properties

Melting Point (°C)	170
Aqueous Solubility (at 20°C) at pH 5	0.072 grams/Liter
at pH 7	1.050 grams/Liter
at pH 9	6.54 grams/Liter
Vapor Pressure (at 25°C)	3.0×10^{-11} mm Hg
Octanol/Water Partition Coefficient	
(at 25°C) pH 5	4.43
(at 25°C) pH 7	0.043
(at 25°C) pH 9	0.0084
Dissociation Constant (pK_a)	3.6

PHOTOLYSIS

Direct

The photolysis of azimsulfuron was studied in sterile pH 5, 7, and 9 buffered aqueous solutions exposed to simulated sunlight from a xenon arc lamp. The temperature was maintained at 25°C, and the solutions were irradiated continuously for 15 days.

Degradation was more rapid in the irradiated solutions than in the dark controls (see hydrolysis) with half-lives of 48, 71 and 83 days in the pH 5, 7 and 9 buffers, respectively. Correcting for hydrolysis, the half-lives for photolysis were 103, 164 and 225 days. The products were the same as those observed in the hydrolysis study.

Indirect

Degradation of azimsulfuron by reaction with photochemically produced oxidants was studied in natural water and in hydrogen peroxide solutions photolyzed to produce hydroxyl radicals (Draper and Crosby, 1984). Test solutions were irradiated with simulated sunlight For the natural water experiments, sterile and non-sterile solutions were buffered to pH 7 and irradiated continuously for 15 days. For the reactions with hydroxyl radicals, a competition kinetics method was used to determine the rate constant for reaction of azimsulfuron with hydroxyl radicals (Haag and Yao, 1992).

In the natural water experiments, the half-life for azimsulfuron, corrected for hydrolysis, was 13 days in both sterile and non-sterile solutions. The products included several unknowns, indicating a different degradation pathway from that observed in soil, and suggesting involvement of hydroxyl radicals or singlet oxygen in the degradation of azimsulfuron.

The rate constant for reaction of azimsulfuron with hydroxyl radicals was determined by photolyzing hydrogen peroxide solutions (0.01 - 0.08 M) containing acetophenone and azimsulfuron (10^{-5} M). After 5 min of irradiation, the reaction was quenched with methanol, and the solution was analyzed by HPLC. The relative rate of degradation was used to calculate the rate constant for azimsulfuron from the known rate constant for reaction of acetophenone with hydroxyl radicals ($5.9 \times 10^9 \text{sec}^{-1}$, (Buxton *et al.*, 1988)). The rate constant was found to be approximately $7 \times 10^9 \text{ sec}^{-1}$. Assuming a steady state hydroxyl radical concentration of 10^{-16} - 10^{-15} M in surface water (Zepp *et al.*, 1987) and no competition by $\cdot$OH scavengers, the half-life for azimsulfuron would be in the range of 2-13 days.

SOIL DEGRADATION

Flooded Soils

Degradation in flooded soils was studied in Tama silt loam and in three different Japanese paddy field soils collected from the Yamagata, Iwate and Ibaraki Prefectures (Ushiku soil). The Japanese soils were flooded to give a water depth of about 1 cm above the soil surface, and azimsulfuron, radiolabeled either in pyrazole or pyrimidine ring, was applied to the water layer at a rate corresponding to 0.06 mg/kg (dry soil basis). The soil and water layers were mixed well, and the test vessels were incubated at 25°C in the dark. The test systems were exposed to air either by connecting the test vessels to an air flow-through system or by allowing air to diffuse through a granular adsorbent which trapped CO_2. Volatile products were collected in scrubbers.

Azimsulfuron degraded rapidly under both non-sterile and sterile conditions, but there was a marked difference between the rate in non-sterile soil compared to sterile soil. The degradation followed first-order kinetics and gave half-lives in non-sterile soil in the range 24-26 days, while in sterile soil the half-lives were 78-90 days. The rate of degradation in sterile soil was consistent with the hydrolysis rate observed in pH 5 buffer. In Tama soil, azimsulfuron degraded very quickly with a DT_{50} estimated to be 11 days. The apparent rate of degradation decreased with time so that the DT_{80} was about 45 days (Figure 2).

Small amounts of $^{14}CO_2$ were evolved from non-sterile soil treated with [^{14}C-pyrimidine] azimsulfuron showing that the pyrimidine ring is cleaved by microbial reactions. The importance of microbial degradation was also shown by the difference in unextractable residues of non-sterile and sterile soils. In non-sterile soils the unextractable residue accounted for 42-51% of the applied radioactivity, whereas in sterile soils the unextractable residue accounted for only 5-9%.

The principal degradation pathway of azimsulfuron in soil is shown in Figure 1. JJ999 and KQ962 are formed by oxidative reactions which lead to pyrimidine ring cleavage. Both compounds can be hydrolyzed to A8342, which may form by chemical or microbially mediated hydrolysis. J290, produced by hydrolysis of azimsulfuron, and A8342 apparently further degraded with formation of bound residues.

Aerobic Soil Metabolism

Degradation in soils under aerobic conditions was studied in soils from the U. S., Japan and Italy. Radiolabeled azimsulfuron was applied to the soil at a rate corresponding to 0.06 mg/kg (dry soil basis). The test vessels were incubated at 25°C in the dark. Aerobic conditions were maintained by connecting the test vessels to an air flow-through system. Volatile products were collected in scrubbers.

The degradation of azimsulfuron was bi-phasic in all the soils except the soil from Novara, Italy in which degradation was first order. The DT_{50}s were 18-28 days, and were similar to the degradation rates observed in flooded soils.

The degradation pathway was similar to that observed in the flooded soil studies (Figure 2). $^{14}CO_2$ accounted for larger percentages of the applied radioactivity in the aerobic soil studies than in flooded soil studies.

MOBILITY IN SOIL

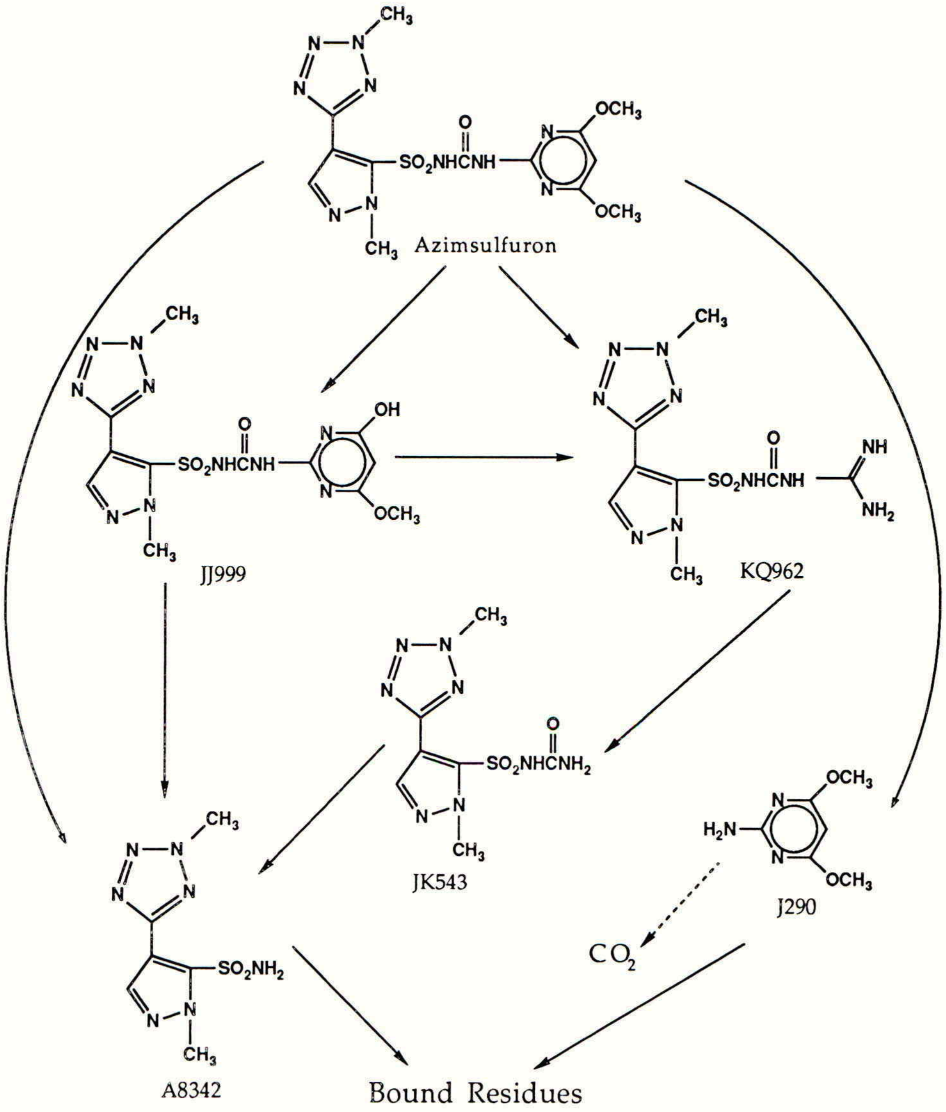
Soil adsorption coefficients were determined in eight soils with varying soil texture, organic matter and pH. K_{OC} was calculated for azimsulfuron in each soil with results ranging from 29-104. Soil TLC was used to assess potential mobility in five Japanese soils. On the basis of the Rf values, azimsulfuron was considered to have intermediate mobility (Helling and Turner, 1968).

DISCUSSION

The most significant degradation mechanisms for azimsulfuron appear to be indirect photolysis and metabolism in soil. The rate of degradation observed in the natural water photolysis study (13 days) was considerably faster than the rate of direct photolysis (164 days). In the natural water photolysis study azimsulfuron was degraded through reaction with naturally produced oxidizing reagents. The degradation of azimsulfuron is considered an indirect photolysis reaction since the oxidizing reagents are produced by the action of sunlight on normal constituents of paddy water rather than through the direct effect of light on azimsulfuron itself. The results suggest rapid degradation of azimsulfuron in rice paddies when water is at typical depths of 5-10 cm.

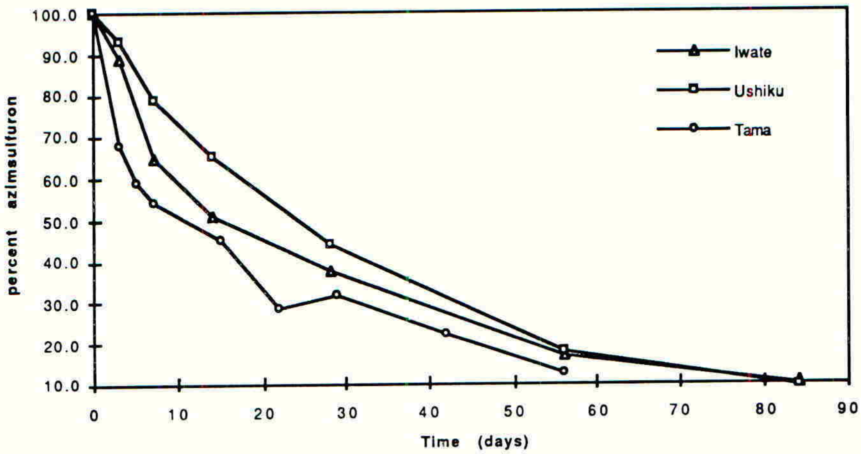
Azimsulfuron is degraded by microorganisms and by chemical reactions. The increased rate of degradation compared to hydrolysis and the formation of the O-demethyl product indicate that microbial metabolism is a significant factor in the dissipation of azimsulfuron. The microbial degradation occurs most rapidly immediately after application when a large fraction of the azimsulfuron is in the soil water (Figure 2). Once azimsulfuron is sorbed onto soil particles it will not

Figure 1. Degradation Pathway for Azimsulfuron in Soil



be available for microbial degradation, and chemical degradation is the primary mode of soil dissipation (Duffy *et al.*, 1993). The rate of chemical degradation is dependent on soil pH as shown by the influence of pH on the aqueous hydrolysis rates. Assuming similar rates of microbial degradation, azimsulfuron will degrade more rapidly in acidic soils than in neutral or basic soils.

Figure 2. Degradation of Azimsulfuron in non-sterile flooded paddy soils.



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REFERENCES

Beyer, E. M.; Duffy, M. J.; Hay, J. V. and Schlueter, D. D.; *Herbicides: Chemistry, Degradation, and Mode of Action,* eds. Kearny, P. C. and Kaufmann, D. D., Vol. 3, Marcel Dekker. Inc.; New York, and Basel, pp. 117-185, 1988.

Buxton, G. V.; Greenstock, W. P. H., and Ross, A. B.; *J. Phys. Chem. Ref. Data*, **1988**, 17, 513.

Draper, W. M. and Crosby, D. G.; *J. Agric. Food Chem*, **1984,** 32, 231-237.

Duffy, M. J.; Carski, T. H. and Hanafey, M. K.; *IX Simposium Pesticide Chemistry, Mobility and Degradation of Xenobiotics*; eds. A.A.M. Del Re et al., pp. 295-308, **1993**.

Haag, R. W.; and Yao, C. C. D.; *Environ. Sci. Technol.*, **1992**, 26, 1005.

Helling, C. S. and Turner, B. C. ; *Science*, **1968**, 162, 562.

Marquez, T.; Joshi, M. M.; Fader, T. P.; Massasso, W.; The Brighton Conference - Weeds 1995; Nov. 20-23, 1995

Zepp, R. G.; Hoigné, J.; Bader, H.; *Environ. Sci. Technol.*, **1987**, 21, 443.

EFFECTS OF LOW DOSES OF HERBICIDES, TEMPERATURE AND SIMULATED HARROWING ON THE SURVIVAL OF THREE WEED SPECIES

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ABSTRACT

Galium aparine, *Papaver rhoeas* and *Veronica persica* plants were sprayed at the 2-4 leaf stage with 5, 15 and 25% of the recommended field doses of mecoprop-P or tribenuron-methyl. Plants were maintained in controlled environment cabinets at different temperatures: 22/12, 15/7 and 10/5 °C light / dark respectively. Seven days after spraying, sets of plants were buried to 0.5 cm, 1.0 cm and 2.0 cm to simulate the burying effects of harrowing.

When plants were treated with mecoprop-P, duration of weed control increased as temperature decreased. However, in general, it did not affect the final fresh weights of the weeds. Weed control was achieved by burying alone and by herbicide alone on *G. aparine*. Best control of *V. persica* was achieved using at least 5% of the recommended field dose of mecoprop-P and burying to 0.5 cm. *P. rhoeas* was not affected by tribenuron-methyl at the concentrations used.

INTRODUCTION

Crop production has been vastly improved in terms of crop quality and quantity since the widespread availability of agrochemicals. However, during the past few decades there have been growing concerns over adverse effects of pesticides on wildlife, ground-water pollution and the presence of pesticides in human food substances. Thus, many European countries are encouraging reduced pesticide usage.

Alternatives to conventional intensive farming practices are being developed. Several approaches involve integrating reduced pesticide doses and non-chemical control methods, as in the LIFE (Less Intensive Farming and Environment) and TALISMAN (Towards A Lower Input System Minimising Agrochemicals and Nitrogen) research projects (Jordan & Hutcheon, 1990). When using reduced herbicide doses, the weed spectrum and weed growth stage must be considered (Kudsk, 1989). It has been shown that environmental factors, such as light intensity and temperature, may also affect herbicide activity and metabolism in plants (Cole,1983, Gerber *et al.*,1983, Kudsk, 1989). Sub-lethal doses can also be used to weaken or stunt plants pre-disposing them to further control measures, such as mechanical control (Caseley *et al.*, 1993).

Harrowing can be an effective method of weed control, causing damage or uprooting plants or else covering them with soil. Results are often variable since there are several factors to consider, such as weed size and root anchoring systems, the severity of each pass of the harrow, the number of passes made and the weather conditions after harrowing. The objectives of the present work were to use low doses of autumn- or spring- applied herbicides to pre-dispose weed species to simulated mechanical damage. The treated plants were subjected to various simulated harrowing intensities under a range of temperature regimes.

METHODS

Galium aparine and *Veronica persica* plants were grown in 9 cm pots of a sandy loam soil, under normal glasshouse conditions, until they reached the two whorl or leaf stage, when they were transferred to controlled environment cabinets set at 22/12°, 15/7° and 10/5 °C light/dark, respectively. Cabinets were maintained with a 16 hour photoperiod and 60-70% humidity. Plants were acclimatised to these conditions for two days. Sets of plants from each cabinet were then sprayed in a track-sprayer with 0, 69 or 207 g mecoprop-P/ha (0, 5 and 15% recommended field rate of 'Duplosan', respectively), at an application rate of 200 l/ha and 2 bar pressure. All plants were then returned to the cabinets. Seven days after spraying, cultivation was simulated by burying plants from each herbicide treatment under additional soil to a depth of 0, 0.5, 1 and 2 cm. Plants were observed each week to determine when regrowth commenced. Once the untreated plants had developed eight whorls (*G. aparine*) or five-six pairs of leaves (*V. persica*), fresh weights of shoots above soil level were recorded.

In a second experiment, *G. aparine* and *Papaver rhoeas* were grown in the same manner as described above. After acclimatising in the controlled environment cabinets, plants were sprayed with 0, 0.75, 2.25 or 3.75 g tribenuron-methyl/ha (0, 5, 15 or 25%, respectively, of the recommended field rate of 'Quantum'), then returned to the cabinets. Eight days after spraying, plants were buried to 0, 1 or 2 cm for each treatment. Plant growth rate was assessed by measuring the length of the main stem (*G. aparine*) or plant diameter (*P. rhoeas*) at regular intervals. Shoot fresh weights were recorded when the untreated plants had developed eight whorls (*G. aparine*) or were approximately 20 cm in diameter (*P. rhoeas*).

In each experiment, weed species were arranged in a randomised block design within each temperature regime. There were four replicates of each species. Analyses of variance using ln transformations were carried out on all fresh weight data.

RESULTS

Mecoprop-P

The duration of weed control varied with weed species and temperature (Table 1). In general, the interval between spraying and commencement of plant regrowth increased as herbicide dose increased and as temperature decreased. *G. aparine* plants in the 15/7° regime weighed more than those in the other regimes (Table 2), suggesting that this regime was closest to the optimum growing conditions for this weed.

Table 1: Duration of suppression (days) of *G. aparine* and *V. persica* after treatment with mecoprop-P at 0, 5% or 15% of the recommended rate under various treatment regimes (means across all burying regimes).

Temp. regime (°C)	*G. aparine*			Time to harvest (days)	*V. persica*			Time to harvest (days)
	0	5%	15%		0	5%	15%	
22/12	-	14	20*	20	-	21	21*	21
15/7	-	14	27	27	-	14	27*	27
10/5	-	28	35	43	-	43	43	37

* = no regrowth at harvest

Table 2: Effects of temperature on final fresh weights (g) of *G. aparine* at eight whorls.

	Temperature regime (°C)		
	22/12	15/7	10/5
Fresh weight	-0.749 (0.423)	0.181 (1.149)	-0.215 (0.757)
LSD ($p=0.05$) = 0.476			

Note: Means and LSD are presented on a ln scale. Back-transformed means are shown in parentheses.

G. aparine was affected by an interaction between mecoprop-P and burying depth. This was due to minor changes in the size of effect rather than an overall pattern. The individual effects of burial depth and herbicide dose were much more significant ($p<0.001$) (Tables 3 and 4). Fresh weights declined significantly with each increase in herbicide dose and with each increase in burial depth.

Table 3: Effect of burial depth on the final fresh weights (g) of *G. aparine*, at the eight whorl stage.

	Burial depth (cm)			
	0	0.5	1	2
Fresh weight	1.388 (3.959)	0.395 (1.435)	-0.908 (0.353)	-1.919 (0.097)
LSD ($p=0.05$) = 0.405				

Note: Means and LSD are presented on a ln scale. Back-transformed means are shown in parentheses.

Table 4: Effect of mecoprop-P on the final fresh weights (g) of *G. aparine*, at the eight whorl stage.

	% of recommended rate of mecoprop-P		
	0	5	15
Fresh weight	0.927 (2.476)	0.023 (0.973)	-1.732 (0.127)
	LSD (P=0.05) = 0.351		

Note: Means and LSD are presented on a ln scale. Back-transformed means are shown in parentheses.

As with *G. aparine*, the duration of growth suppression of *V. persica* increased as temperature decreased (Table 1). At the 15/7° regime, the plants appeared to grow much more quickly than plants in the 22/12° regime. However, plants were only assessed once each week, thus the 22/12° regime may have been controlled for any time between 14 and 21 days. Control of *V. persica* was affected by an interaction between dose of mecoprop-P applied and burial depth (Table 5). The fresh weights of unsprayed plants decreased with increasing burial depth. However, after spraying, control was equally good at all burial depths. The effect of applying 5% of the recommended rate of mecoprop-P alone did not significantly reduce fresh weight compared to not spraying, but 15% of the recommended rate of mecoprop-P did reduce the fresh weights.

Table 5: Combined effects of mecoprop-P and burial depths on the final fresh weights (g) of *V. persica*, at the five to six pairs of leaves stage.

	Depth of burying (cm)			
	0	0.5	1	2
0	2.462 (11.678)	1.659 (5.205)	-0.120 (0.837)	-1.698 (0.133)
5	1.871 (6.444)	-2.450 (0.036)	-2.996	-2.996
15	0.646 (1.858)	-2.996	-2.930 (0.003)	-2.996
	LSD (p=0.05) = 0.613			

Note: Means and LSD are presented on a ln scale. Back-transformed means are shown in parentheses.

Tribenuron-methyl.

The growth rates of both species varied greatly, hence it was not possible to distinguish growth repression due to this herbicide from other factors. The concentration of tribenuron-methyl applied affected the control of *G. aparine* (Table 6). As herbicide dose increased, fresh weights decreased. Burial depth also affected the fresh weights of *G. aparine* (Table 7). As burial depth increased, fresh weight decreased.

Table 6: Effects of burial depth on final fresh weights (g) of *G. aparine* and *V. persica* (means across all herbicide doses).

Species	Depth of burial (cm)			LSD
	0	1	2	(p=0.05)
G. aparine	2.012 (7.425)	0.207 (1.180)	-1.058 (0.297)	0.307
P. rhoeas	1.88 (6.477)	-0.62 (0.486)	-1.78 (0.118)	0.520

Note: Means and LSD are presented on a ln scale. Back-transformed means are shown in parentheses.

Table 7: Effects of tribenuron-methyl on fresh weights (g) of *G. aparine* at the eight whorl stage.

% recommended rate of tribenuron-methyl			
0	5	15	25
0.744 (2.055)	0.568 (1.715)	0.280 (1.273)	-0.045 (0.906)
LSD (p=0.05) = 0.354			

Note: Means and LSD are presented on a ln scale. Back-transformed means are shown in parentheses.

Tribenuron-methyl was not effective against *P. rhoeas* at the doses used. However, depth of burial significantly affected fresh weights of this species (Table 6). As burial depth increased, fresh weight decreased.

DISCUSSION

P. rhoeas was not sensitive to tribenuron-methyl at the concentrations applied. This emphasises the importance of taking into account the relative tolerances of the different species in a mixed weed flora when devising a control strategy.

Temperature had a marked effect on the duration of weed growth suppression. Leaf curl symptoms of mecoprop-P were visible within hours of spraying. These effects lasted longer in the lowest temperature regime than in the warmer environments. This may well be due to an increased plant metabolic rate in warmer conditions, enabling the herbicide to be degraded more quickly. Although temperature affected duration of control, in many instances it did not affect final plant weights. In all cases, the stunting effects of the herbicide suppressed plant growth until at least one week after burial. Hence, by the time the effects of the herbicide had worn off and plants were able to regrow they had been deprived of light for at least one week. This probably reduced their potential to regrow and to reach the soil surface.

In all cases weed control increased with each depth of burying. In the field, it is unlikely that weeds would be buried to 2 cm by the spring tine harrow without accompanying severe crop damage. Burial to 0.5 or 1 cm would thus seem more realistic. Control of *G. aparine* increased as the concentration of each herbicide increased, however there were no interactions between spraying and burying. Therefore, unlike Caseley *et al.* (1993), these experiments suggest that there is no added benefit of pre-disposing *G. aparine* to sub-lethal herbicide doses prior to burying. Control of *V. persica* showed interactions between burying depth and dose. The best weed control was achieved using at least 5% of the recommended dose of mecoprop-P and burying to 0.5 cm. These results were obtained with plants buried seven days after spraying. Caseley *et al.* (1993) showed that cultivation one day after spraying gave better control than cultivation six days after spraying. The results reported have confirmed the effectiveness of reduced herbicide doses applied before simulated cultivations on one species only. Better weed control may be achieved on *V. persica* with a shorter spray-harrow interval.

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REFERENCES.

Caseley, J C; Wilson, B J; Watson E; Arnold G (1993) Enhancement of mechanical weed control by sub-lethal doses of herbicide. *Proceedings of European Weed Research Society*, pp. 357-364.

Cole, D J (1983) The effects of environmental factors on the metabolism of herbicides in plants. *Aspects of Applied Biology*. **4**, pp. 245-252.

Gerber, H R; Nyffeler, A; Green, D H (1983) The influence of rainfall, temperature, humidity and light on soil- and foliage-applied herbicides. *Aspects of Applied Biology*. **4**, pp. 1-14.

Jordan, V W L; Hutcheon, J (1990) Approaches to the development of low input farming systems. BCPC Monograph No. 45, pp. 9-18.

Kudsk, P (1989) Experiences with reduced herbicide doses in Denmark and the development of the concept of factor-adjusted doses. *Proceedings of Brighton Crop Protection Conference - Weeds*, pp. 545-554.

A MONIC ACID DERIVATIVE : EVALUATION AS A CEREAL HERBICIDE

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ABSTRACT

The herbicidal properties of derivatives of pseudomonic acid were first reported in 1994. These compounds were derived from natural products produced by the bacterium, *Pseudomonas fluorescens*. Lead compounds from this series have exhibited useful activity on broad leaved weed species, including *Fallopia convolvulus* and *Chenopodium album*, and activity on grasses such as *Setaria viridis*, which are important weeds in cereals. One of the more promising analogues, a monic acid derivative, is potent, giving good field control of key weed species at rates of 25-50 g/ha. Thus, the group holds promise for the development of novel cereal herbicides.

INTRODUCTION

The total value of the cereal herbicide market in 1994 was $2.15 billion (Wood Mackenzie, 1995), and 75% of these sales were to farmers in North America and Western Europe. The majority of herbicides used in cereals are for the control of grass weeds or broadleaved weeds, with only a few compounds active on monocots and dicots, yet selective to wheat and barley. However, a novel group of molecules derived from pseudomonic acid are of potential value as cereal herbicides, as they provide selective control of broadleaved weeds and some key grass weeds. These novel herbicides may overcome some of the weed resistance problems occurring in the field and offer alternatives to herbicides such as IPU which are facing restrictions in some markets. This paper details the synthesis of a promising analogue and the evaluation of its herbicidal properties in cereals.

THE CEREAL HERBICIDE MARKET

Small grain cereals, particularly winter and spring wheats, are one of the major world crops, with almost 400 million hectares planted in 1994 and a total yield of some 829 million tonnes (Wood Mackenzie, 1995). The world cereal herbicide market is correspondingly large, with some $2.15 billion spent last year on grass and broad leaved weed control. North America, Western Europe, the CIS and India are the major producers, accounting for almost 60% of global production (Fig 1).

Although Western Europe only accounts for 7.7% of the planted area, it is the leading producer with 17% of global production. Not suprisingly then, Western Europe dominates the cereal herbicide market, with some 43.3% of global sales, while North America accounts for a further 31.6% (Fig 2).

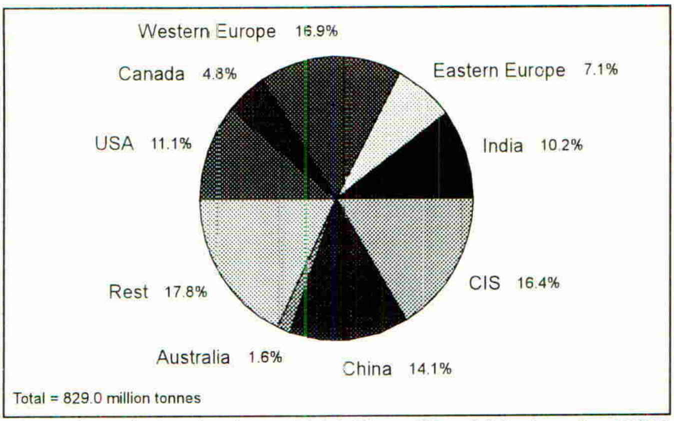

Fig 1. Cereals Production - 1994 (from Wood Mackenzie, 1995)

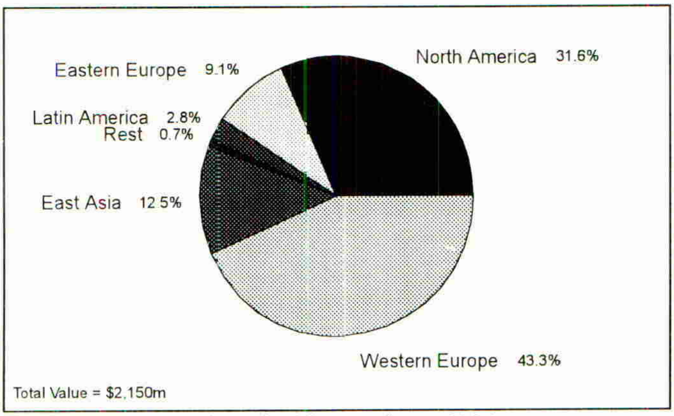

Fig 2. World Cereal Herbicides Market - 1994
(From Wood Mackenzie, 1995)

Research for novel cereal herbicides naturally focuses on selectivity in winter cereals and activity on West European weeds, such as wild oats (*Avena fatua*), blackgrass (*Alopecurus myosuroides*), cleavers (*Galium aparine)*, chickweed (*Stellaria media*), pansy (*Viola arvensis*) and mayweeds (*Matricaria* spp.), in addition to key North American species such as green foxtail, *(Setaria viridis*), lambsquarters (*Chenopodium album*) and buckwheat (*Fallopia* (*Polygonum) convolvulus*).

Although there are many cereal herbicides available to growers, there continues to be a demand within the industry for novel materials which are highly potent and of low environmental impact. In recent years the industry has seen a move towards resolved materials (eg mecoprop-P) as a means of reducing chemical inputs, and of restricting annual applications of compounds which move into groundwater (eg isoproturon). New herbicidal toxophores are also required to combat the threat of insensitive weeds which have evolved resistance to certain classes of herbicides, such as the ACCase and ALS inhibitors (Devine *et al.*, 1991, Tardif & Powles, 1993).

CHEMISTRY OF PSEUDOMONIC ACIDS

The pseudomonic acids are a family of natural products produced by the bacterium, *Pseudomonas fluorescens*, and the herbicidal properties of derivatives of these acids were first reported by Barton *et al* in 1994. The characteristic structural features of pseudomonic acids are the possession of a di- or tri-hydroxylated tetrahydropyran ring, an acrylic ester, and a hydroxylated side chain containing either an epoxide or double bond. There are a number of pseudomonic acids, but pseudomonic acid A is always the major component produced.

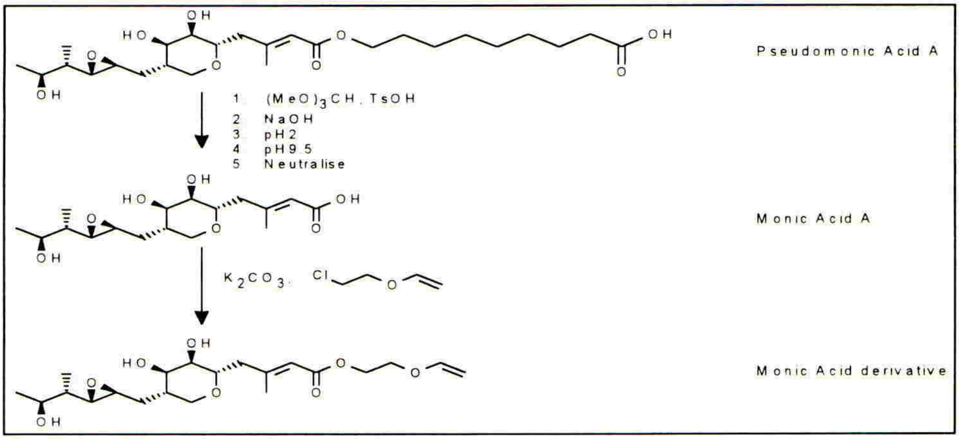

Fig 3. Synthesis of a Monic Acid derivative

The ester moiety of pseudomonic acid A can be cleaved hydrolytically to monic acid A and this can subsequently be converted to further derivatives as shown in Figure 3. Many analogues have been synthesised to perform structure/activity relationship studies. One of the more promising analogues is the monic acid derivative shown in Figure 3 and the biological properties of this molecule are described below.

GLASSHOUSE STUDIES

A series of glasshouse tests was conducted with the monic acid derivative in 1993 and 1994, following initial screens showing high levels of potency and selectivity to winter wheat.

Cereals and weeds were grown in 3 inch pots and treated at the 2 to 3 leaf stage with a range of rates of the monic acid derivative (in mixture with either a non-ionic or oil-based adjuvant, at an application volume of 200 l/ha). The plants were maintained in the glasshouse for 13 to 28 days at approximately 24/19 °C (day/night) and a 14 hour photoperiod, under metal halide lamps, prior to visual assessment of herbicidal crop damage and weed control.

Table 1 presents typical glasshouse data from these replicated tests, where the monic acid derivative was applied, post-emergence, to a wide range of cereal weeds and crop varieties.

Table 1: Crop Injury and Weed Control (% Visual Damage), at 13-28 Days after Post-Emergence Treatment

Species	Test 1 32g/ha	Test 2 64g/ha	Test 3 128g/ha
Crops			
Winter Wheat	1	2	4
Spring Wheat	2	5	3
Winter Barley	-	2	0
Spring Barley	-	7	0
Broad Leaved Weeds			
Galium aparine	100	-	100
Matricaria perforata	-	100	100
Stellaria media	-	100	100
Viola arvensis	-	100	100
Polygonum aviculare	-	87	100
Fallopia convolvulus	90	-	100
Lamium purpureum	100	-	-
Chenopodium album	100	-	-
Sinapis arvensis	100	-	-
Solanum nigrum	95	-	-
Grass Weeds			
Avena fatua	2	5	-
Alopecurus myosuroides	0	3	-
Lolium multiflorum	12	-	-
Bromus sterilis	5	-	-
Setaria viridis	100	100	99

NB: Adjuvants used were as follows: Test 1, 0.5% Non-Ionic; Test 2, 0.1% Non-Ionic; Test 3, Adjuvant Oil. Data are means of 3 or 4 replicates per treatment.

It is evident that the monic acid derivative is an extremely potent herbicide, being active on a wide range of broad leaved weeds, including cleavers, mayweeds, pansy, knotgrass and chickweed and on grasses such as green foxtail. Some variation was seen with this compound in terms of both the rates required for weed control and the level of cereal selectivity. In general, however, excellent control of broad leaved weeds was achieved with 32 to 64 g/ha, with adequate levels of crop safety, even at overlap rates, and of green foxtail at 32g/ha.

FIELD RESULTS

A series of trials was conducted during 1994 in the major cereal growing regions of France and the UK in winter wheat and barley on the key European broad leaved weed targets. Applications were made in the spring (March to May) to the weeds at a range of growth stages under a variety of environmental conditions.; in all cases, mecoprop-P was included as the commercial standard at its recommended rate (1200 g/ha) and the monic acid derivative was mixed with an oil adjuvant at a loading of 0.5% vol/vol. A summary of the results is shown in Figure 4.

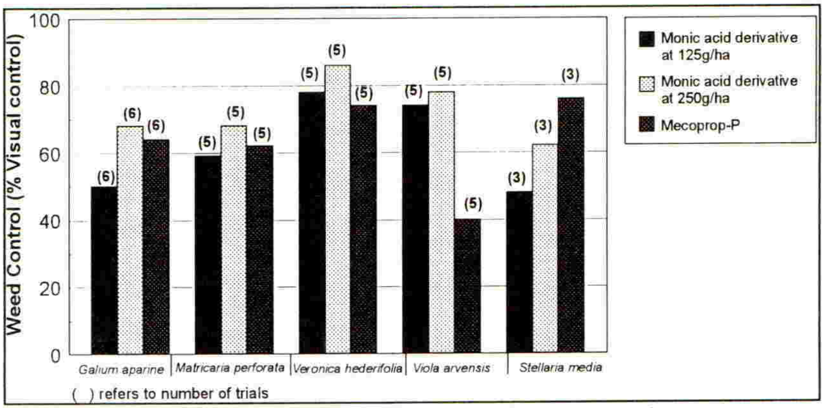

Figure 4. European Field Results (35-48 days after treatment)

The monic acid derivative was generally safe to winter cereals up to, and including, rates of 250 g/ha. Crop phytotoxicity symptoms, when present, were expressed as a slight chlorotic spotting of the leaves present at the application time. In two of the trials, which contained both wheat and barley, unacceptable injury (18-20%) was observed on wheat but not barley, suggesting that the latter is less sensitive than winter wheat.

The level of weed control achieved with the monic acid derivative and mecoprop-P varied considerably from trial to trial in Europe. High levels of control were seen when the monic acid derivative was applied to relatively small weeds under warm bright conditions. Control of *Viola arvensis* and *Veronica hederifolia* at 125 g/ha was superior to that seen with mecoprop-P, with 250 g/ha required to match the standard on both *Galium aparine* and *Matricaria perforata*; however, even at this rate activity on *Stellaria media* was poor.

Canadian trials were conducted in Saskatchewan, Manitoba and Alberta in the spring of 1994. Applications were made in spring wheat and barley to young weeds, typically at the 2 to 4 leaf stage, using Laser™ (a commercial mixture of fenoxaprop, thifensulfuron and MCPA) as the standard. All applications were made with an oil adjuvant at 0.5% vol/vol. Figure 5 summarises the results on the key grass and broad leaved weeds.

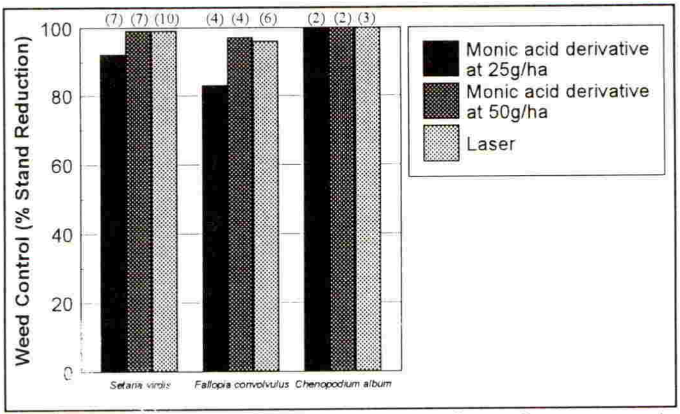

Figure 5. Canadian Field Results (24-40 days after treatment)

Once again, some initial chlorosis was observed on the cereals following applications of the monic acid derivative, but this injury was transient in nature, the crops having recovered fully within 8 to 14 days of treatment. Typical levels of damage seen on spring wheat was ca. 11% at 50 g/ha of the monic acid derivative, with spring barley being more sensitive giving 23% injury. Laser^{TM} is not registered in barley because it is too damaging, but was safe to spring wheat in all of the trials, causing less than 15% injury. Low rates of the monic acid derivative (25 g/ha) were effective in controlling *Setaria viridis* and *Chenopodium album* while 50 g/ha was required to control the major Canadian broad leaved weed *Fallopia convolvulus*. The level of weed control achieved with the monic acid derivative at 50 g/ha always matched that seen with the commercial standard Laser^{TM}.

TOXICOLOGICAL/ENVIRONMENTAL PROPERTIES

The monic acid derivative exhibits excellent toxicological and environmental properties. In terms of oral, dermal and Ames tests the compound is very safe, while in soil the compound degrades very rapidly and has a half-life of <0.5 days.

CONCLUSIONS

Activity of the monic acid derivative, was found to vary considerably in the field, depending upon weed species, growth stage and environmental conditions. The compound did not perform as well in European trials as might have been predicted from glasshouse results, although at rates of 250 g/ha it gave similar levels of weed control to the commercial standard mecoprop-P. Canadian results were much more promising, with high levels of grass and broad leaved weed control being achieved at rates of 25 to 50 g/ha, matching the commercial standard Laser^{TM}.

The toxicological and soil properties of the monic acid derivative indicate that this compound should have a very low environmental impact. These factors, coupled with the high levels of potency, cereal safety and the novel mode of action of this toxophore, suggest that monic acid derivatives offer considerable potential as novel cereal herbicides.

ACKNOWLEDGEMENTS

Thanks are due to the many chemists, biologists and field staff in Zeneca Agrochemicals who have all contributed in the discovery and evaluation of this new herbicide toxophore.

REFERENCES

Barton J. E. D., Clinch, K., Clough, J.M., Ormrod, J.C. & Rice, M. J. (1994). Herbicidal Activity of Derivatives of Pseudomonic Acid. 8th International Congress of Pesticide Chemistry, Options 2000.

Devine, M. D., Marles, S.M.S & Hall, L M (1991). Inhibition of Acetolactate Synthase in Susceptible and Resistant Biotypes of *Stellaria media*. Pesticide Science **31**, 273-280

Tardif, F. J. & Powles, S. B. (1993). Target site-based resistance to herbicides inhibiting Acetyl-CoA carboxylase. 1993 British Crop Protection Conference - Weeds **2**, 533-540

Wood Mackenzie (1995), Agrochemical Service, June 1995.

F8426 - A NEW, LOW RATE HERBICIDE FOR THE POSTEMERGENCE SELECTIVE CONTROL OF BROADLEAF WEEDS IN MAIZE

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ABSTRACT

F8426 is a new, selective herbicide for postemergence broadleaf weed control in maize. F8426 was discovered and is under development by FMC Corporation. F8426 is an inhibitor of protoporphyrinogen oxidase which results in rapid desiccation of sensitive broadleaf weed species. Results from U.S. and European testing during the past two years indicate that *Ipomoea* spp., *Abutilon theophrasti, Chenopodium album, Amaranthus* spp. and *Solanum nigrum* are controlled at rates as low as 9-17 g ai/ha. Other major broadleaf weeds in the U.S. such as *Xanthium strumarium* and *Helianthus annuus* are controlled at rates ranging from 17-35 g ai/ha. It has been shown that the use of adjuvants improves weed control.Optimum application timing is at the 3-5 leaf stage of maize. Although some crop injury has been observed at the highest rates with nonionic surfactant and crop oil concentrate, this injury is quickly outgrown, and results indicate no negative impact on yield. Testing in the U.S. and Europe in combination with other grass and broadleaf herbicides is continuing.

INTRODUCTION

There continues to be a strong demand for postemergence herbicides that will control broadleaf weeds in maize. In addition, there is a need to develop unique chemistry that will provide control of resistant weed populations such as those resistant to ALS inhibitors. F8426 controls weeds by the mechanism of membrane disruption. Activity is observed within hours. The high level of sensitivity observed with several broadleaf weed species and the low to moderate levels of maize injury; as well as, control of ALS resistant weed species have all been major factors in the development of this chemistry.

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MATERIALS AND METHODS

Small plot field trials were carried out in the U.S. and France in 1993 and 1994 by FMC researchers and private researchers. These trials were randomized complete block design with three to four replicates. Standard plot size was 3 m x 9 m. Maize injury was recorded at 7, 15 and 30 days after treatment. Weed control was recorded at 30 and 60 days after treatment. Adjuvants used in U.S. trials were nonionic surfactant at a rate of 0.25% v/v and crop oil concentrate at a rate of 1.0% v/v.

RESULTS

Maize injury (4 leaf)

Table 1. Maize tolerance to F8426 without adjuvant (U.S. trials 1993-4)

F8426 (g a.i./ha)	% Necrosis 7 DAT	% Necrosis 15 DAT
9	4 (18)	2 (17)
17	6 (18)	3 (18)
35	8 (15)	5 (15)
71	13 (15)	6 (15)

Number of trials are in parentheses

Table 2. Maize tolerance to F8426 with nonionic surfactant (U.S. trials 1993-94)

F8426 (g a.i./ha)	% Necrosis 7 DAT	% Necrosis 15 DAT
9 + NIS 0.25 % v/v	9 (22)	5 (21)
17 + NIS 0.25 % v/v	12 (22)	6 (21)
35 + NIS 0.25 % v/v	17 (19)	10 (18)
71 + NIS 0.25 % v/v	21 (18)	11 (17)

Number of trials are in parentheses

Table 3. Maize tolerance to F8426 with crop oil concentrate (U.S. trials 1993-4)

F8426 (g a.i./ha)	% Necrosis 7 DAT	% Necrosis 15 DAT
9 + COC 1.0 % v/v	10 (22)	6 (25)
17 + COC 1.0 % v/v	13 (23)	8 (25)
35 + COC 1.0 % v/v	19 (16)	12 (19)
71 + COC 1.0 % v/v	28 (15)	13 (14)

Number of trials are in parentheses

Maize necrosis was substantially reduced by 15 DAT compared to 7 DAT (Tables 1-3 . When F8426 was combined with nonionic surfactant, maize injury increased (Table 2) compared to F8426 alone (Table 1). The 35 g a.i./ha rate of F8426 + NIS exhibited maize injury similar to the 71 g a.i./ha rate of F8426 without NIS. The addition of crop oil concentrate further increased maize necrosis (Table 3) compared to F8426 + NIS (Table 2). Early maize necrosis was much more apparent from the higher rates of F8426 + NIS and F8426 + COC.

Maize injury (growth stage)

Figure 1. Maize growth stage injury from F8426 (U.S. trials 1993-4)

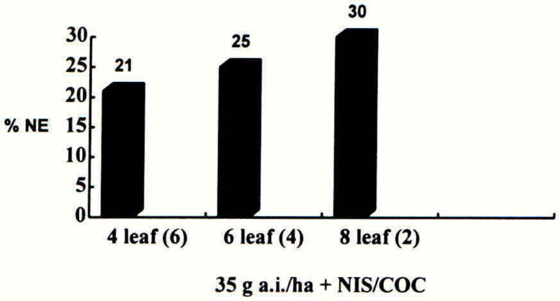
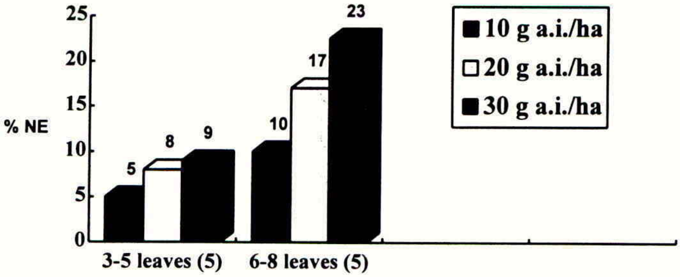


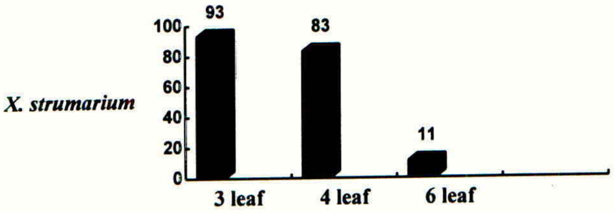
Figure 2. Maize growth stage injury from F8426 (France 1993)



More maize necrosis was observed at 6-8 leaf maize compared to 3-5 leaf maize (Figures 1 and 2). Maize in the 3-5 leaf stage quickly outgrows necrosis; whereas, maize in the 6-8 leaf stage has much slower recovery from leaf necrosis.

Weed control (growth stage)

Figure 3. Effect of broadleaf weed growth stage on % control with F8426 (U.S. trial 1994)



17 g a.i./ha + COC 1.0 % v/v

Proper timing of F8426 is critical for adequate weed control. Generally, broadleaf weeds should be treated early for best results. An example of this is shown in Figure 3. *Xanthium strumarium* control was reduced when F8426 was applied at 4 leaf compared to 3 leaf, and control was much less when application was made at 6 leaf. These results suggest that weed growth stage and application timing are critical factors, especially with broadleaf weeds that tend to be less sensitive to F8426.

Weed control (4 leaf)

Table 4. Broadleaf weed control with F8426-NIS vs. COC (U.S. trials 1993-4)

F8426 (g a.i./ha)	*X. strumarium*	*Ipomoea* spp.	*A. theophrasti*	*C. album*
9 + NIS 0.25 %	43 (6)	89 (5)	97 (6)	85 (5)
9 + COC 1.0 %	69 (7)	94 (4)	93 (6)	85 (7)
17+ NIS 0.25%	61 (6)	96 (5)	99 (6)	92 (5)
17+COC 1.0 %	79 (5)	95 (5)	97 (6)	91 (7)
35+ NIS 0.25%	79 (5)	95 (5)	98 (6)	97 (5)
35+COC 1.0%	95 (6)	97 (6)	99 (5)	95 (6)

Number of trials are in parentheses

Table 5. Broadleaf weed control with F8426-NIS vs. COC (U.S. trials 1993-4)

F8426 (g a.i./ha)	*H. annuus*	*Amaranthus* spp.	*D. stramonium*	*A. artemisiifolia*
9 + NIS 0.25 %	46 (4)	84 (7)	76 (1)	3 (2)
9 + COC 1.0 %	54 (4)	86 (9)	80 (1)	2 (5)
17+ NIS 0.25%	64 (4)	91 (7)	75 (1)	17 (5)
17+COC 1.0 %	71 (4)	93 (9)	87 (1)	12 (2)
35+ NIS 0.25%	69 (2)	95 (6)	95 (1)	10 (2)
35+COC 1.0%	94 (1)	97 (7)	99 (1)	14 (2)

Number of trials are in parentheses

Results indicate that *Xanthium strumarium* and *Ipomoea* spp. control with F8426 was better with COC compared to NIS (Table 4). Effective *Xanthium strumarium* control was achieved with the 35 g a.i./ha rate of F8426 + COC. All rates of F8426 + COC gave effective *Ipomoea* spp. control; whereas, effective control with F8426 + NIS was obtained at the 17 g a.i./ha rate and higher (Table 4). *Abutilon theophrasti* is highly sensitive to F8426 as shown in the results in Table 4. All rates of F8426 regardless of adjuvant type gave effective control. It appears that F8426 at 35 g a.i./ha + COC is needed to control *Xanthium strumarium* (Table 4). *Helianthus annuus* control was similar to control of *Xanthium strumarium* (Table 5); although, data from U.S. trials for *Helianthus annuus* control was limited. Control of *Amaranthus* spp. is similar to control of *Chenopodium album* (Table 5). The 17 g a.i./ha rate of F8426 is needed for control of both of these weed species. U.S. data are very limited for control of *Datura stramonium* (Table 5); however, the data suggest that it takes the 35 g a.i./ha rate + adjuvant to control this weed species. Control of *Ambrosia artemisiifolia* was not achieved with any rate of F8426 (Table 5).

Table 6. Broadleaf weed control with F8426 (NW France 1994)

F8426 (g a.i./ha)	*Chenopodium album*	*Solanum nigrum*
12	94 (7)	99 (7)
24	98 (7)	100 (7)

Number of trials are in parentheses

Table 7. Broadleaf weed control with F8426 (SW France 1994)

F8426 (g a.i./ha)	*Amaranthus retroflexus*	*Solanum nigrum*
10	87 (5)	98 (5)
15	96 (5)	99 (5)
20	100 (5)	100 (5)

Number of trials are in parentheses

Weed control results from France in 1994 show that F8426 at 10-12 g a.i./ha effectively controls *Solanum nigrum* (Tables 6 and 7). Control of *Chenopodium album* with F8426 was achieved between 12-24 g a.i./ha, stronlgly depending on the weed size (Table 6). Control of *Amaranthus retroflexus* with F8426 was achieved at the 15 g a.i./ha rate (Table 7). Results from France on broadleaf weed control are similar to those from the U.S.

CONCLUSIONS

The mode of action of F8426 offers an alternative to ALS inhibitor type of chemistry for postemergence control of a variety of broadleaf weeds in maize. It has been documented that F8426 controls SU resistant *Kochia scoparia* in cereal grains. Maize necrosis as a result of F8426 application is low to moderate with the higher rates of F8426 + NIS or F8426 + COC being of concern. F8426 effectively controls *Amaranthus* spp., *Chenopodium album*, *Solanum nigrum* and *Abutilon theophrasti* at rates of 9-17 g a.i./ha. Higher rates are needed for control of *Xanthium strumarium*, *Helianthus annuus* and *Datura stramonium*. Field research with herbicide combinations for enhanced broadleaf weed control is in progress. Also, research is underway to study the effect of grass herbicide combinations. F8426 offers the potential of broad spectrum weed control in maize, and the opportunity to utilize a different class of chemistry for control of weeds progressively becoming resistant to presently used herbicide types.

ACKNOWLEGEMENTS

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REFERENCES

Matringe, M; Camadro, J M; Labbe, P; Scalla, R (1989) Protoporphyrinogen oxidase as a molecular target for diphenyl ether herbicides. *Biochemical Journal*, **60**, 231-235.

Poss, K M (1992) U.S. Patent 5, 125, 958

Witkowski, D A; Halling, B P (1989) Inhibition of plant protoporphyrinogen oxidase by the herbicide acifluorfen-methyl. *Plant Physiology*, **90**, 1239-1242.

Van Saun, W A; Bahr, J T; Bourdouxhe, L A; Gargantiel, F J; Hotzman, F W; Shires, S W; Sladen, N A; Tutt, S F; Wilson, K R (1993) F8426 - a new, rapidly acting, low rate herbicide for the postemergence selective control of broad-leaved weeds in cereals. *Brighton Crop Protection Conference Procedings*, **2-1**, 19-22.

POTENTIAL FOR WEED CONTROL BY SUPPRESSIVE CEREAL CULTIVARS

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ABSTRACT

An experiment was established in Autumn 1994 to study the weed suppression characteristics of different cereal species and cultivars. Two cultivars each of barley, oats and wheat were studied using oilseed rape as a model weed species. Significant differences were found in the suppressive abilities of the different species. By late July, weed biomass and weed seed production were significantly lower when in competition with oats. Wheat was the least suppressive of the three species.

INTRODUCTION

Weeds are major constraints in developing profitable, less intensive crop management systems, where the aim is to manage weeds at population levels below those that cause economic losses in crop yields (Jordan & Hutcheon, 1993). An understanding of weed-crop competition and weed population dynamics is essential in this management strategy because, with reduced use of herbicides, the capacity of the crop to compete with weeds is particularly important.

Previous work at Long Ashton (Wilson & Wright, 1990) has already identified the relative competitive abilities of a range of important weed species. Recent work has highlighted the need to quantify the competitive abilities of crops and cultivars (Richards & Whytock, 1993) and the importance of physiological and phenological factors in relative competitive ability (Grundy *et al.*, 1993).

In the work reported here, two cultivars each of winter barley, winter oats and winter wheat were grown either in monoculture or in the presence of winter oilseed rape as a model weed, in order to determine differences in their competitive abilities.

MATERIALS AND METHODS

The experiment was set up in two raised beds of silty clay loam contained within concrete block walls measuring 5 m across, 25 m long and 30 cm deep. The experiment consisted of three replicates of a split-plot randomised block design. Each replicate consisted of six cultivars (two of each crop species; Table 1) as main plots, split into two sub-plots, with and without weed. Fertiliser was applied prior to planting and then again in March. Standard fungicides and pesticides were applied as necessary. Plots were watered twice daily by overhead irrigation.

The crops and weed (rape) were sown by hand on 11 October 1994, each plot consisted of 12 crop rows 4 m long sown at 300 seeds m^{-2}. The rape was broadcast onto one half of each plot (sub-plot) at 60 seeds m^{-2}. Following crop and weed emergence in late October, a 0.5 m^2 area on each sub-plot was marked for later yield assessment; all crop and sown weed plants were counted in this area during November. Weeds, other than rape, were removed by hand from all assessment areas. At intervals throughout the growing season, crop and weed plants were removed from 0.1 m^2 areas from each sub-plot; plant numbers and tillers were counted, the plants washed, oven-dried and weighed. Light quality and PAR (photosynthetically-active radiation) were measured at intervals prior to canopy closure using a Sunfleck Ceptometer (Delta-T Devices Ltd, Cambridge, UK) and a portable Spectroradiometer (Li-1800, Li-Cor inc, Lincoln, USA). The harvest areas were also visually assessed for percentage ground cover and plant heights measured. Weed plants from the harvest areas were removed just prior to seed shedding in early July for assessment of seed production. The plants were counted, weighed and seed numbers were estimated. The crop was harvested in late July, each 0.5 m^2 being cut at ground level. Crop stem numbers were counted, the crop sheaf weighed, threshed and fresh and dry weights of grain obtained.

RESULTS

The ranking order of the relative ground cover of the three crop species changed between the autumn and spring assessments (Table 1). In November, ground cover of oats was significantly lower than that of both barley and wheat. However, by March this ranking order had changed so that ground cover was barley > oats > wheat, oats having increased relatively more than the other two species with very little increase in the cover of wheat. This corresponds well with the measurements of PAR within the various canopies in March where the lowest light levels were found in the barley plots and highest in the wheat.

Table 1. Ground cover (%) of the crop and PAR measurements

Crop species	Cultivar	% Ground cover in November	% Ground cover in March	PAR in March (μmol m^2 s^{-1})
Barley	Puffin	30	68	273
	Maris Otter	34	63	277
	Mean	**32**	**65**	**275**
Oats	Kynon	15	49	333
	Solva	20	53	298
	Mean	**18**	**51**	**315**
Wheat	Fresco	33	39	360
	Maris Huntsman	41	46	353
	Mean	**37**	**43**	**356**
s.e.d. (d.f.=10)		1.12	3.75	25.8
		0.79	**2.65**	**18.3**

Changes in weed biomass during the spring and summer are shown in Table 2. Early biomass measurements (March) showed significant differences between the species, with the lowest weed biomass in barley and highest in wheat. However, by May there was no significant difference between the species. In July, differences between the species were once again significant but with the lowest weed biomass from the oat plots. Weed biomass in the wheat plots remained the highest of the three species.

Table 2. Effect of crop species and cultivar on $\log_e$ weed biomass (g/m^2)

Crop/weed species	Cultivar	Date 6/3	 27/3	 17/5	 10/7
Barley	Puffin	1.92	3.02	4.75	5.84
	Maris Otter	2.84	2.83	6.01	6.20
	Mean	**2.38**	**2.93**	**5.38**	**6.02**
Oats	Kynon	3.17	3.63	5.96	5.70
	Solva	2.74	3.67	5.43	5.46
	Mean	**2.95**	**3.65**	**5.70**	**5.58**
Wheat	Fresco	3.16	4.23	5.97	6.25
	Maris Huntsman	3.44	4.35	5.77	6.41
	Mean	**3.30**	**4.29**	**5.87**	**6.33**
Rape alone		-	-	-	6.93
s.e.d.	Across cvs	0.251	0.242	0.233	0.233
	Across crops	**0.356**	**0.342**	**0.330**	**0.165**
	+rape	**-**	**-**	**-**	**0.202**
d.f.		10	10	10	12

When weed biomass in July was compared with that from the plots where rape was grown in monoculture, significant reductions of 74%, 60% and 45% were recorded for oats, barley and wheat, respectively.

Barley cultivars were significantly taller than the oats in April when their suppression of weed biomass was greatest (Table 3). The oats continued to increase in height from late May until July, whilst both barley and wheat had reached their maximum heights by early June. Crop plants were found to be consistently taller when grown together with the weed plants than those grown in monoculture.

Table 3. Crop heights (mm)

Crop species	Cultivar	Date			
		19/4	17/5	19/6	31/7
Barley	Puffin	522	1113	1080	922
	M.Otter	515	1097	1260	1028
	Mean	**518**	**1105**	**1170**	**975**
Oats	Kynon	473	1113	1053	1733
	Solva	448	1053	1365	1698
	Mean	**460**	**1083**	**1383**	**1716**
Wheat	Fresco	443	732	915	903
	M.Huntsman	478	948	1230	1218
	Mean	**460**	**840**	**1073**	**1061**
s.e.d. (d.f.=10)		18.5	57.7	75.4	46.7
		13.1	**40.8**	**53.3**	**33.0**
Mean of crops	-Rape	465	983	1185	1226
	+Rape	494	1036	1232	1275
s.e.d. (d.f.=10)		6.8	11.4	19.9	9.4

Table 4 shows final crop yields and weed seed production data. The oats were least affected by the presence of the weed with yields being reduced by only 11%, whilst barley and wheat were reduced by 18% and 32%, respectively. However, this does mask a difference in the suppressiveness of the two oat cultivars with Kynon contributing most to this mean yield loss value.

The weed seed production data follow a similar pattern to that observed in the biomass assessments. Oats reduced weed seed production by 77%, with barley and wheat suppressing seed numbers by 58% and 44%, respectively, as compared to the crop-free plots.

Table 4. Final crop yields and weed seed production

Crop/weed species	Cultivar	Crop yield (t ha^{-1})		Weed seed production (sq rt number m^{-2})
		-Rape	+Rape	
Barley	Puffin	9.50	7.79	119.4
	M.Otter	9.29	7.55	162.0
	Mean	**9.40**	**7.67**	**140.7**
Oats	Kynon	9.33	7.39	116.2
	Solva	9.63	9.41	90.1
	Mean	**9.48**	**8.40**	**103.1**
Wheat	Fresco	8.02	6.22	147.4
	M.Huntsman	10.13	6.07	177.3
	Mean	**9.07**	**6.14**	**162.4**
Weed alone		-	-	**217.3**
s.e.d.	Across cvs	0.711*		25.53
	Across crops	**0.503***		**18.05**
	+rape	-		**22.11**
d.f.		10		12

* Comparing plus and minus rape only

DISCUSSION

There were clear differences in the weed-suppressive characteristics of the crop species studied. Oats were the most suppressive, reducing weed biomass by 74% and weed seed production by 77%. Crop yield reductions due to the presence of the weed were also lowest for the oats. However, this was mainly due to the very small yield-loss of Solva which also showed greater suppression of weed biomass and seed production than Kynon. Oats were the only crop species that were taller than the weed by the time of weed seed development.

When ground cover values were followed from crop emergence to late tillering, the relative ranking order of the species changed. This could be related to the early growth habits of the species, with oats having a very upright habit initially and wheat very prostrate. When tillering began, the barley cultivars, although having a slightly more erect habit than the wheat, produced tillers more rapidly. This resulted in increased ground cover. The oat cultivars although producing few tillers, increased ground cover by leaf expansion, whereas wheat, although producing more tillers than oats, had little early leaf expansion. This resulted in low ground cover relative to the other species.

The ranking order of the crop species which had the greatest suppressive effect on weed biomass also changed between spring and early summer. Barley was significantly more suppressive than the other two species up to April. During May, a transition occurred during which time, differences in weed biomass between species became non-significant. From the end of May up to harvest in late July, oats were significantly more suppressive of the weed than either barley or wheat. Wheat was the least suppressive species during this whole period. The improvement in oat weed suppression over barley could be related to the point at which stem extension in oats increased rapidly, resulting in a much taller canopy at anthesis compared with barley.

There were few significant differences in competitiveness between cultivars. Each pair of cultivars had similar straw length, except for wheat in May and June, where Maris Huntsman was significantly taller than Fresco. Christensen (1993) has advocated straw-length as a predictor of competitiveness in spring barley cultivars. Christensen also suggested that light interception measurements had the potential to be important indicators of competitive ability. Our findings suggest that differences in light penetration into the canopy are more important than straw-length alone, as exemplified by the observation that the shorter, more leafy barley appeared to be more suppressive than the taller barley cultivar, which had a more open canopy. Our measurements also show a link between early ground cover and PAR.

Our preliminary study has provided indications that some potential for weed suppression by crop canopy manipulation is possible. However, more work will be needed to determine the physiological basis for the ability of a range of crop cultivars to suppress weed species with different growth characteristics and competitive abilities.

ACKNOWLEDGEMENTS

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REFERENCES

Christensen, S (1993) Weed suppression in cereal varieties. *Statens Planteavlsforsog Rapport Nr. 1 (PhD Dissertation)*. Danish Institute of Plant and Soil Science. 104pp.

Grundy, A C; Froud-Williams, R J; Boatman N D (1993) The use of cultivar, crop seed rate and nitrogen level for the suppression of weeds in winter wheat. *Proceedings Brighton Crop Protection Conference - Weeds*, 997-1002.

Jordan, V W L; Hutcheon, J A (1993) Less-intensive integrated farming systems for arable crop production and environmental protection. *Proceedings of The Fertiliser Society*, **346**, pp. 1-32.

Richards, R C; Whytock G P (1993) Varietal competitiveness with weeds. *Aspects of Applied Biology*, **34**, Physiology of varieties, 354-354.

Wilson, B J; Wright, K J (1990) Predicting the growth and competitive effects of annual weeds in wheat. *Weed Research*, **30**, 201-211.

ADJUVANT EFFECTS ON SULPHOSATE AND GLYPHOSATE FOR CONTROL OF RED-RICE IN RICE

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ABSTRACT

The minimum tillage system for rice was implemented in Brazil in 1985 and later, the introduction of the no-till system for rice, expanded the cultivated area in the irrigated plain to approximately 25-30%. Generally, after the soil is prepared (minimum tillage) or before planting (no-till), herbicides are applied at the pre-planting stage when red-rice reaches approximately 25-30 cm in height. This study evaluated the efficacy of glyphosate and sulphosate (recommended dose generally 3.5 l/ha) at 3.5, 3.0 and 2.5 l/ha with the addition of three types of adjuvants (siliconized and common). The results obtained at 7, 14 and 28 days after treatment showed that the addition of siliconized adjuvants at 0.5% (v/v) (poliglicol) associated with the use of low volume nozzles (TeeJet DG 110.015), gave good weed control with herbicides (glyphosate or sulphosate) applied at 2.5 l/ha, at efficacy levels equivalent to those obtained with a dose of 3.5 l/ha.

INTRODUCTION

In the cultivation of irrigated rice, mainly in Rio Grande do Sul (where approximately 750,000-800,000 ha of the plains are planted) as well as in Santa Catarina, Paraná and São Paulo States, red-rice did not represent a problem until the late 1960s and early 1970s. By this time, the Philippine variety type IR was introduced; its main characteristic was that it was high yielding in a longer growing cycle than the traditional varieties eg Lebonet, Blua bela, etc. Because of the higher yields obtained with this new variety, it was rapidly adopted by farmers. When the new variety was grown for several years with the traditional cultivation, red-rice finished its growing cycle earlier and, because of its dehiscent panicles, each year it formed a great seed bank of germplasm in the soil. The consequence was that in Rio Grande do Sul, 30% of the area became heavily infested and 65% of the area, corresponding to more than 500,000 ha, became lightly infested.

According to Noldin (1981), red-rice is generally classified as *Oryza sativa* and is, therefore, of the same species as cultivated rice, although some consider it a variety of that species. It is also classified as a species of wild rice *Oryza rufipogon*. Red-rice forms vigorous stumps in which stalks reach 100 to 150 cm in height. The panicles are long and sometimes open, presenting a high degree of shattering and only a gentle movement is sufficient for the mature spikelet to fall. Maturation is not uniform. Damage to the crop results from both competition and contamination by harvested grains, causing problems for industrial processing; final product depreciation is due to the physical and qualitative differences between the grains, especially in the case of the modern fine-grained cultivars.

Guimarães (1970, pers. comm) concluded that in the Vale do Paraiba, red-rice seeds remained viable in soil for up to 20 years. Red-rice is of the same kind and species as *O. sativa* L. and consequently, the herbicides that are selective for one species are also selective for the other.

The no-till system was introduced in Brazil in the early 1970s in Paraná State, mainly for the soya bean crop. The advantages of the no-till system, compared with the conventional system, are fuel savings, preservation of the biological balance in the soil/plant system and mainly erosion control (Muzilli, 1981).

Based on the experiences of the no-till system for soya bean, there was an effort to implement this system for rice. Due to several reasons, but mainly because of the pasture-rice rotation, the system was not viable initially (Lovato, 1982).

From 1980 to 1986, Campos *et al.* (1986) proposed a minimum tillage system for rice, in an attempt to combine the advantages of the no-till system with the reduced operations for preparation and elimination of red-rice. It was based on the principle that the initial soil cultivation exposed viable seeds which, after irrigation, germinated. After 30-40 days, glyphosate was applied pre-planting. As the soil was not inverted, an excellent control of rice was possible. This system was such a success that during the "X Seminário de Plantio Direto de Arroz" (held in Rio Grande do Sul, July 1994), it was estimated that 250,000-300,000 ha of the area was cultivated through no-till and minimum tillage.

The objective of this work was to evaluate the efficacy of sulphosate, applied alone and in mixture with different adjuvants, compared with glyphosate (both at reduced rate) for red-rice control at pre-planting application.

MATERIALS AND METHODS

A field study was conducted in a systemised irrigated plain, where rice has been cultivated for more than 30 years, in an area of hydromorphic soil (9.3% of organic matter, pH 4.5 and Cation Exchange Capacity of 18.3) in São Paulo State. The no-till system had been used in the area for two years. The experimental design was a randomised block with 26 treatments and 3 replicates; plots measured 4.0 x 10.0 m. The treatments and doses were sulphosate ('Zaap') and glyphosate ('Roundup') at 1.20, 1.44 and 1.68 kg a.i./ha applied alone or in association with three different adjuvants at 0.5% v/v (Poliglicol, 'Mojante'; L-77, 'Silwet'; Amina-graxa, 'Frigate') and also the standard treatment (glyphosate + adjuvant, 'Ativatec') and one control. The area was irrigated 30-40 days before application to promote red-rice germination. Treatments were made at post-emergence of red-rice and pre-planting of irrigated rice. At the time of application, the weed population was 90% red-rice which was 50 cm tall and at the sprouting stage. Applications were made on 11 November 1994, through a CO^2 sprayer at an operating pressure of 2.78 bar, equipped with 4 nozzles XR 110,015 spaced at 0.50 cm (effective width 2.0 m) at a rate of 125 l/ha.

Efficacy evaluations were made by visual inspection at 7, 14 and 28 days after treatment (DAT) (0% = non-control, 100% = total death); the height of red-rice was also observed. After planting (16 DAT) and germination, the stand and height of rice were also measured.

RESULTS AND DISCUSSION

The results are summarised in Table 1 and are shown as the average for the three replicates in relation to red-rice control. Results showed that at 7 DAT, the addition of Poliglicol and L-77 permitted a higher efficacy of tested herbicides, particularly at lower doses. At 14 DAT, it was observed that the treatments resulted in a high efficacy, higher than 90%, even for those applied at reduced doses with or without adjuvants. At 28 DAT, the levels of control were maintained, in general, apart from the lowest dose of sulphosate and glyphosate without adjuvants.

Table 1. Percentage of red-rice control at 7,14, and 28 days after post-emergent treatment (DAT) of the herbicides in irrigated rice (no-till) - Bariri, São Paulo - 1994/95.

No	Treatment	Doses (l/ha)	% control 7		14		28	
			(%)		(%)		(%)	
1	sulphosate + poliglicol	2.5 + 0.5	80.0	CDE	94.3	ABC	94.3	ABC
2	sulphosate + poliglicol	3.0 + 0.5	85.0	ABC	100.0	A	95.0	AB
3	sulphosate + poliglicol	3.5 + 0.5	86.7	AB	100.0	A	99.3	A
4	glyphosate* + poliglicol	1.85 + 0.5	83.3	BC	99.3	AB	93.3	ABC
5	glyphosate* + poliglicol	2.22 + 0.5	85.0	ABC	100.0	A	96.7	AB
6	glyphosate* + poliglicol	2.59 + 0.5	86.7	AB	100.0	A	96.7	AB
7	sulphosate + L-77	2.5 + 0.5	76.7	DEF	94.3	ABC	91.7	ABC
8	sulphosate + L-77	3.0 + 0.5	80.0	CDE	98.0	AB	96.7	AB
9	sulphosate + L-77	3.5 + 0.5	85.7	AB	99.3	AB	99.3	A
10	glyphosate + L-77	2.5 + 0.5	81.7	BCD	93.3	BC	92.3	ABC
11	glyphosate + L-77	3.0 + 0.5	85.0	ABC	98.3	AB	97.7	AB
12	glyphosate + L-77	3.5 + 0.5	90.0	A	94.3	AB	98.3	A
13	sulphosate + amina-graza	2.5 + 0.5	75.0	EFG	99.3	ABC	91.0	ABC
14	sulphosate + amina-graza	3.0 + 0.5	80.0	CDE	100.0	AB	98.0	AB
15	sulphosate + amina-graza	3.5 + 0.5	81.7	BCD	93.3	A	100.0	A
16	glyphosate + amina-graza	2.5 + 0.5	71.6	FG	97.7	BC	91.7	ABC
17	glyphosate + amina-graza	3.0 + 0.5	80.0	CDE	99.3	AB	97.3	AB
18	glyphosate + amina-graza	3.5 + 0.5	80.0	CDE	93.3	AB	100.0	A
19	sulphosate	2.5	70.0	G	97.0	BC	83.3	C
20	sulphosate	3.0	80.0	CDE	99.3	AB	93.3	ABC
21	sulphosate	3.5	85.0	ABC	99.3	AB	98.3	A
22	glyphosate	2.5	70.0	G	93.3	BC	86.7	BC
23	glyphosate	3.0	73.3	FG	96.0	ABC	93.3	ABC
24	glyphosate	3.5	85.0	ABC	100.0	A	100.0	A
25	glyphosate + Ativatex	3.0 + 0.5	75.0	EFG	90.0	C	98.3	A
26	Control		0.00	H	0.0	D	0.0	D
Treatments (F)			319.41**		256.76**		85.16**	
C.V. (%)			2.09		2.23		3.92	
D.M.S. Tukey 5%			5.126		6.598		11.383	

* applied as 'Rodeo', a glyphosate formulation without adjuvant

Measurements on the height of red-rice or on the cover it formed after it was killed were made as a supplement to the visual evaluations and showed that, at 28 DAT, highest was for glyphosate + L-77 (20.7 cm) and the lowest was for sulphosate (10.3 cm). For the control, the height was 60.3 cm. After planting (16 DAT) and 12 days after planting (28 DAT), it was observed that none of the treatments resulted in any phytotoxic symptoms on the crop and also that the stand did not significantly differ in relation to the treatments.

Although doses as low as 2.5 l/ha herbicide were tested compared with the recommended dose of 3.5 l/ha (Campos *et al.,* 1986), with the objective of reducing the dose and observing the efficacy of tested adjuvants, all treatments gave good results (except the lowest dose of the two pure herbicides) possibly as a function of the type of nozzle used, that provided a good coverage and had an adequate drop size.

The results show that is possible to get good control of red-rice by reducing the dose of the product, provided that low volume nozzles and adjuvants are used to maximize herbicide efficacy.

Under the conditions of the experiment, it was observed, that red-rice died-off readily and that it was easier to maintain control for a longer period of time.

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REFERENCES

Anon. (1992) Drop size versus accumulated volume percentage for DG TeeJet Drift Guard 110 series nozzles. *Data Sheet n° 12135-141M.* S. Systems Co. Wheaton.

Campos, J A D; Foloni, L L; Belmar, C F (1986) Control of red-rice (*Oryza sativa* L.) In: *Brazil. Twenty-Sixth Meeting.* Weed Science Society of America, Houston, Texas, USA (Abstract).

Lovato, L A (1982) Plantio direto em arroz irrigado. *Lavoura arrozeira.* Porto Alegre. 35 (334), 7-8.

Muzilli, O (1981) Principios e perspectivas de expansão. In: *Plantio direto no estado do Paraná.* Circular IAPAR n° 23. Londrina, PR. pp. 11-16.

Noldin, J A (1981) Plantas daninhas. In: *Manual de produção de arroz irrigado.* Coord. Ramos, M Florianópolis - EMASC - ACARESC. Boletim n° 270, pp. 147-158

RESISTANCE OF BOTANIC TAXONS OF POACEA (GRAMINEA L.) TO HERBICIDES FROM DIFFERENT CHEMICAL GROUPS

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ABCTRACT

Long-term researches (1966-1990) have confirmed distinctions in resistance of 65 botanic taxons of Graminea (genera, species, varieties) of spring wheat, barley, and oats to 29 herbicides from different chemical groups. Susceptibility of wild oat specimens grown in various regions to herbicides has also been different. The experimental data obtained in vegetative and field trials confirm the need to use herbicides with due regard for the response of some botanic taxons to them. The reasons causing the differences in resistence of botanic taxons of Graminea to herbicides have been revealed. Annual application of the same product for many years negatively affects the yield of low resistant varieties of wheat and barley. The rotation is necessary in herbicide application.

INTRODUCTION

Herbicides are widely used in cereals, but insufficient attention is paid to the resistence of cultivated plants to them. Firstly, the efficacy of herbicides upon weed plants is taken into consideration. Early in the 1960's papers were published which confirmed different responses of cereal species and varieties to herbicides (Price & Klingman, 1958; Monstvilaite, 1961, et al.). Our work was designed to study the response of cereal species and varieties being cultivated in Russia to different herbicides as well as elucidating the possible reasons of different resistence in cultivated crops to herbicides.

MATERIALS AND METHODS

Response of crops of Poacea to herbicides from different chemical groups was determined under conditions of greenhouse and small-plot field trials in the Leningrad region 65 botanic taxons, (genera, species, varieties) of spring wheat, barley and oat of different ecotypes varying in morphology, anatomy and biochemical characteristics as well as genetic origin were studied. The samples of wild oat plant from different regions of cultivation were also used. Crop response to 29 herbicides from various chemical groups (e.g. 2,4-D, mecoprop, dichlorprop, triazine, phenylurea, sulphonylurea, dicamba, carbamates, thiocarbamates, ioxynil, bromoxynil, picloram etc.) which vary in their mode of action on plants was studied. Herbicides were applied at recommended and double dosage rates at optimum times (2–3 leaf and tillering stages for cereals). Untreated check was weeded by hand. We assessed the resistance level in cereals to herbicides by changes in biomass of overground organs and roots after treatment (3, 7, 15 and 30 days) as well as by amount and structure of yield. Seed characteristics (such as quality, viability and biochemical composition) were determined. Water relations of roots and level of carbohydrate and nitrogen metabolism were studied in some trials. Response of regional varieties of spring wheat and barley to herbicides was studied in commercial trials in different soil and climatic regions (Ural, Siberia, Central Chernozem Zone and Kazakhstan). In farms hand weeding was not used for untreated control.

RESULTS AND DISCUSSION

Differences in response of wheat species to herbicides already developed in early time of countings after treatment by action on plant biomass and these differences often persisted to the harvest.

Table 1. The effect of herbicides on biomass (%) of plant species of Triticum L.

Species	2.4-D	Mecoprop	Barban
T.monococcum L.	97	94	70
T.timopheevii Zhuk.	110	69	82
T.persicum Vav.ex Zhuk.	96	81	73
T.dicoccum Schuebl.	67	58	69
T.durum Desf.	87	80	73
T.compactum Host.	89	88	76
T.aestivum L.	89	78	83

Note: Biomass is the average of four annual countings 3, 7, 15 and 21 days after treatment.

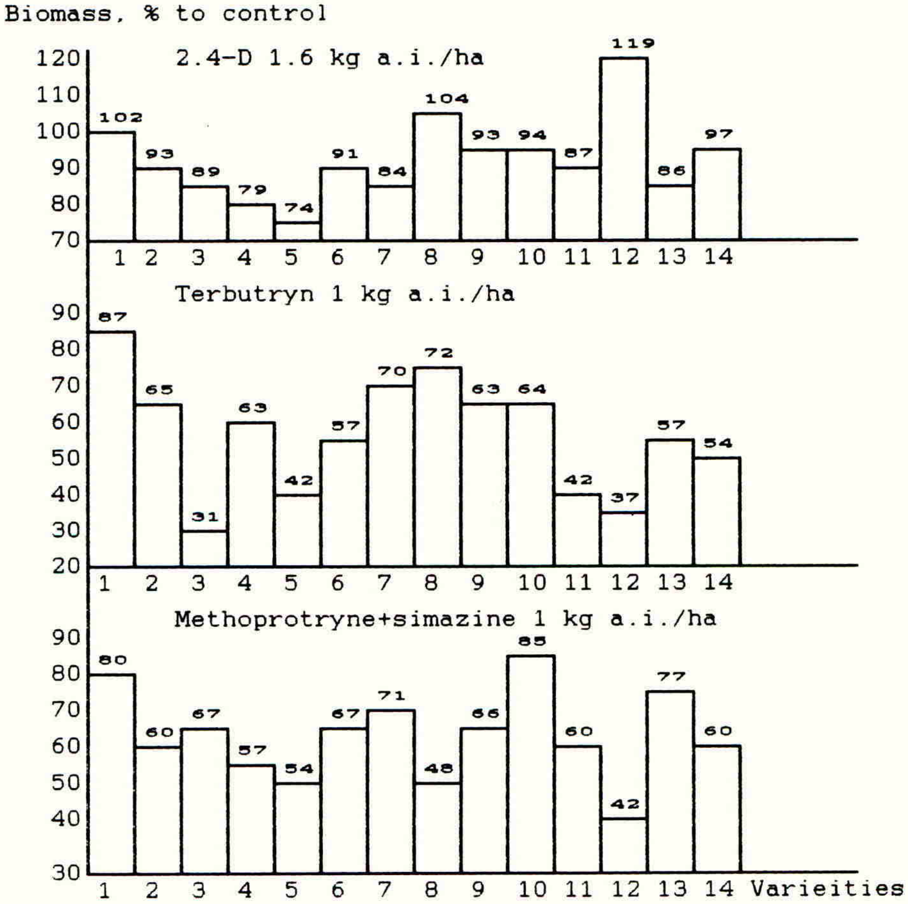
Table 2. The effect of herbicides on height of stem (%) of plant species of Triticum L.

Species	2.4-D	Mecoprop	Barban
T.monococcum L.	104	74	79
T.timopheevii Zhuk.	100	90	91
T.persicum Vav.ex Zhuk.	86	81	79
T.dicoccum Schuebl.	84	57	96
T.durum Desf.	103	90	94
T.compactum Host.	95	87	76
T.aestivum L.	90	84	102

Note: The height of stems was measured at harvest.

The level of changing the biomass and height of crops is different and depends on varietal resistance to particular herbicides. The products based on triazines (Igran=terbutryn and Gesaran=methoprotryne+simazine) have a stronger effect on vegetative organs of _T. aestivum_ and _T. durum_ than 2.4-D.

Diagram 1. The effect of 2.4-D, terbutryn and methoprotryne plus simazine on biomass of wheat varieties of _T.aestivum_ and _T.durum._



Varieties: **T.aestivum**
1.Garnet 2.Milturum 321 3.Turchikum 1 4.Khulugo
5.Amurskaya 74 6.Otechestvennaya 7.Minskaya
9.Saratovskaya 29 9.Diamant 10.Zarya
T.durum
11.Chakinskaya 226 12.Raketa
13.Novopodolskaya 14.Melyanopus 26

Resistance of varieties depends on time of herbicide application. The stage of forming the generative organs affects the plant resistance level to some herbicides. Resistant varieties overcome the toxic effect of herbicides by the end of the vegetative period and the height of plants tested is similar to untreated control. The amount of yield serves as a final criterion for resistance level of botanic taxons of Poacea to certain herbicides. With due regard for this index the data on resistance to herbicides of growth type for varieties T.aestivum, T.durum, Hordeum and Avena sativa in % of the total amount of varieties used in trials are summarized below. On the whole wheat is the most resistant to 2.4-D and mecoprop, then barley and oat is the least resistant crop.

Table 3. The comparison of cereal crop resistance to herbicides of growth type.

Crop	Herbicide	Dose kg a.i./ha	Varieties due to resistant groups		
			I	II	III
Spring wheat	2.4-D	0.8	56	33	11
		1.6	42	42	16
	Mecoprop	3.0	75	–	25
		6.0	58	8	34
Spring barley	2.4-D	0.8	53	24	23
		1.6	53	18	29
	Mecoprop	3.0	47	24	29
		6.0	24	18	58
Spring oats	2.4-D	0.8	31	38	31
		1.6	31	15	54
	Mecoprop	3.0	54	8	38
		6.0	15	8	77

I - Yield increase by 10% and more
II - Yield is similar with weeded untreated control
III - Yield reduction by more than 10%

There are, however, varieties varying in their resistance to different herbicides within each genus and species. When the same herbicide is annually used for many years a negative effect on low-resistant varieties increases therefore rotation of herbicides is necessary. Wheat and barley varieties of the intensive type may reduce the seed yield even when optimum dosage rates of herbicides are used.

Chart of herbicide application on cereals with due regard of species and variety response to products.

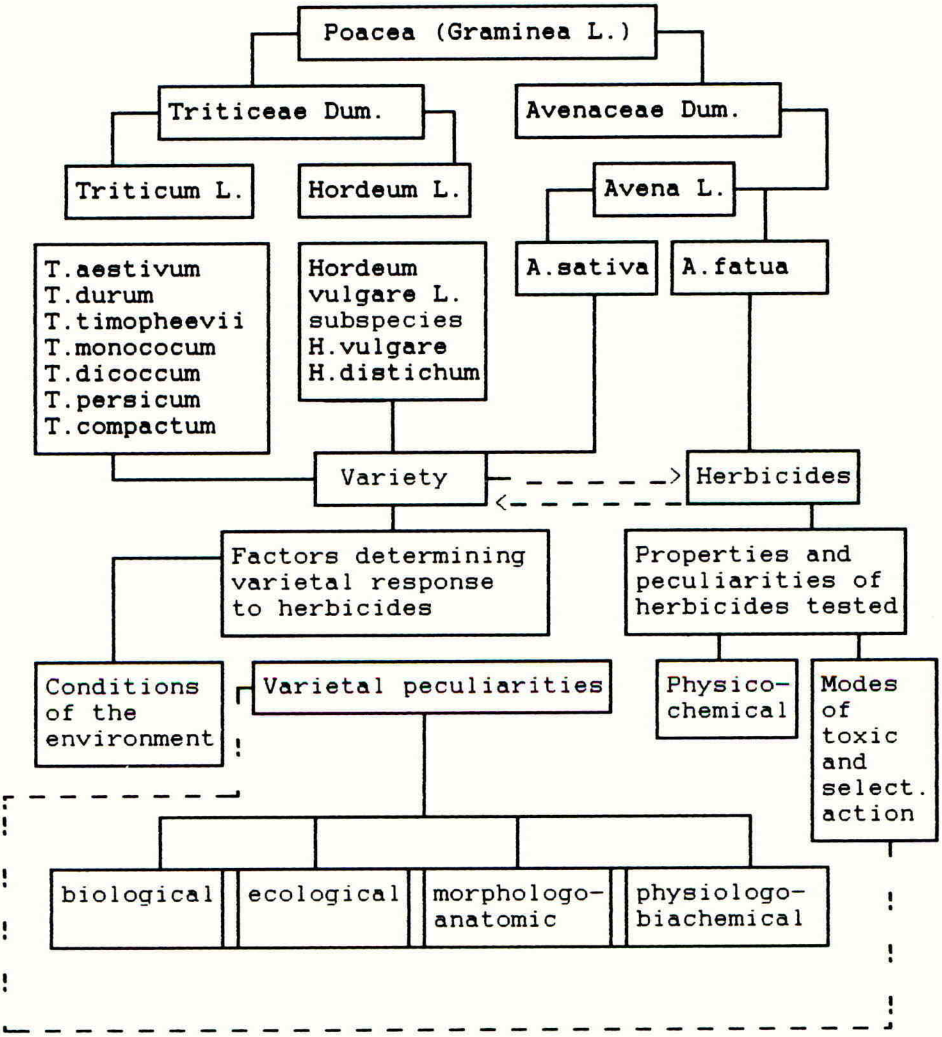


Table 4. The effect of 2.4-D (0.8 kg a.i./ha) and MCPA (1.5 kg a.i./ha) on barley varieties of the intensive type.

Variety	Treatment	Yield, %	Albumin, % of absolute dry mass	Height of plant %
Luch	Untreated	100.0	13.6	100.0
	2.4-D	70.7	13.5	88.7
	MCPA	99.9	14.2	98.6
Elgina	Untreated	100.0	13.3	100.0
	2.4-D	95.3	13.2	100.0
	MCPA	103.1	14.0	104.0
Nadya	Untreated	100.0	13.3	100.0
	2.4-D	87.4	13.1	93.8
	MCPA	86.4	12.5	103.1
Omsky 13709	Untreated	100.0	16.6	100.0
	2.4-D	95.4	16.5	106.3
	MCPA	127.3	16.9	102.1

For rational application of herbicides on cereals it is necessary to take into account resistance of Poacea species and varieties. The chart of herbicide application on cereals for many years is shown (see p. 5).

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REFERENCES

Monstvilaite Ya.I. (1961) The effect of systemic application of 2.4-D on yield of spring cereals. In: The use of herbicides plant growth promoters. AN BSSR, Minsk, pp.39-41.

Petunova A.A. (1988) Response of species and varieties of wheat and barley to herbicides. Author`s abstract of thesis. Omsk, 31 pp.

Petunova A.A. & Trofimovskaya A.Ya. (1978) Resistance of cereals and wild oat to wild oat herbicides. In: Vestnik selskokhozyaistvennoi nauki. (3), pp. 30-33.

Price C.D. & Klingman G.C. (1958) Wheat and oat varietal responses to application of alkanolamine salt of 2.4-D. In: Agronomical Journal. **50** (4), pp.200-204.

INTERACTION OF TRIBENURON AND GRAMINICIDES IN WHEAT

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ABSTRACT

The interaction of tribenuron and four graminicides including tralkoxydim, diclofop-methyl, fenoxaprop-p and clodinafop-propargil (CGA 184927) was studied under controlled environment and field condition in wheat.Indicator plants were wild oat *(Avena ludoviciana)* and charlock *(Sinapis arvensis).* In both experiments no interaction occurred with tank-mixed application of tribenuron at 15 g/ha and fenoxaprop-p at 75 g/ha or clodinafop-propargil at 80 g/ha for controlling wild oat. The efficacy of diclofop-methyl at 900 g/ha and tralkoxydim at 300 g/ha, in controlling wild oat, reduced when combined with tribenuron. Tribenuron alone or in combination with the graminicides, controlled charlock, completely. Tank-mixed application of tribenuron plus fenoxaprop-p or clodinafop-propargil, as well as individual application of them with one week interval, gave significantly higher grain yield, compared to the other treatments.

INTRODUCTION

Wild oat *(Avena ludoviciana)* and charlock *(Sinapis arvensis)* are most prevalent weeds in wheat field of the Gorgan area, northern Iran.

The response of a weed species to a particular herbicide can be altered when mixed with another herbicide,and the response can be additive, synergistic or antagonistic (Hatzios and Penner, 1985). Antagonistic interaction, reflected in reduced grass weed control , have been observed when grass herbicides are used in tank-mixed combination with certain broadleaf herbicides (O'Sullivan et al., 1977; Wharton and Shaw, 1987).

Fenoxaprop efficacy on johnsongrass *(Sorghum halepens)* reduced by adding 2,4-D (Muller et al., 1989); and adding 2,4-D or MCPA to diclofop-methyl produced an antagonistic response for *A. fatua* control. Jensen and Caseley (1990) reported that the control of *A. fatua* with tralkoxydim was significantly reduced, when the herbicide was tank-mixed with either 2,4-D amin or bentazon.

Tribenuron belongs to the sulfonyl ureas, which represent a new group of chemicals.This compound control annual broadleaf weeds in cereal (Humburg et al., 1989). There is not enough information about interaction of tribenuron and new graminicides. The following study was conducted to determine the interaction of tribenuron and selected graminicides in wheat.

MATERIALS AND METHODS

Field experiment: Feild experiment was conducted in 1992 at the Agricultural Research Center of Gorgan,northern Iran.

Herbicide treatments included of tank-mixed application of graminicides plus tribenuron and use of them individually. In the later case , tribenuron was applied one week after the graminicides application. Graminicides were clodinafop-propargil at 80 g/ha, fenoxaprop-p at 75 g/ha,diclofop-methyl at 900 g/ha and tralkoxydim at 300 g/ha. Tribenuron was applied at 15 g/ha. Weedy check and use of tribenuron,alone,were also included in the experiment.

Herbicide treatments were applied when wheat and wild oat were respectively at growth stage of 29 and 26, based on Zadoks decimal (Zadoks et al., 1974). At this time , charlock was at 4-6 leaf stage.

Herbicide application was carried out in a spray volum of 300 l/ha using knapsack sprayer fitted with a flat fan nozzele and operating pressure was 2.5 bars.

The experiment was arranged in a randomized complete block designe with 4 replication. Plot size was 2.4 m X 10 m.

Controlled environment: In growth chamber, wild oat was grown in plastic pots containing a mixture of sandy clay loam and peat (1:1 v/v) and thinned to 5 plants per pot. Supplemental light from sodium vapor lamps was supplied to maintain a 12-h photoperiod. Growth chamber temperatures were 17 C,day and 12 C,night. The plants were subirrigated throughout the growth period.

The rate , time and other conditions for application of the herbicides were similar to those mentioned for the field experiment.

RESULTS AND DISCUSSION

Field experiment: Fenoxaprop-p at 75 g/ha and clodinafop-propargil at 80 g/ha as individual or tank-mixed application of each with tribenuron at 15 g/ha,controlled wild oat *(A. ludoviciana),* completely. Tribenuron alone or in combination with the graminicides, completely controlled charlock. However, no interaction effect were observed between clodinafop-propargil or fenoxaprop-p and tribenuron on wild oat and charlock (table 1). The number of panicles and biomass of wild oat, from individual application of tralkoxydim at 300 g/ha or diclofop-methyl at 900 g/ha were significantly less than tank-mixed application of them with tribenuron at 15 g/ha (table 1).

Tank-mixed application of tribenuron plus fenoxaprop-p or clodinafop-propargil , as well as individual application of them with one week interval, gave significantly higher grain yield, compared to the other treatments (table 1).

Controlled environment: Adding tribenuron to diclofop-methyl or tralkoxydim, similar to the field experiment,reduced their efficacy in control of wild oat , significantly (table 1). While, no antagonistic effect of tribenuron on fenoxaprop-p and clodinafop-propargil was observed (table 1.)

Table 1. Effect of treatments on wild oat and grain yield.

Treatments	field experiment			G.C.
	wild oat		grain yield	wild oat biomass
(Herbicides)	panicles (no/m2)	biomass (g/m2)	kg/ha	g/pot
Weedy Check	19 c*	478 c	525 f	6.65 a
Tribenuron (alone) **	56 a	1295 a	2529 e	6.95 a
Clodinafop-propargil (+ trib.)	0 d	0 d	3656 a	3.15 de
Clodinafop-propargil (& trib.)	0 d	0 d	3602 ab	2.95 e
Fenoxaprop-p (+ trib.)	0 d	0 d	3645 a	3.90 bc
Fenoxaprop-p (& trib.)	0 d	0 d	3653 a	3.73 c
Tralkoxydim (+ trib.)	38 b	1203 a	2412 e	3.58 cd
Tralkoxydim (& trib.)	27 c	1095 a	2752 de	2.35 f
Diclofop-methyl (+ trib.)	25 bc	710 b	2965 cd	4.35 b
Diclofop-methyl (& trib.)	17 c	375 c	3204 bc	3.10 de

G.C.= Growth chamber
* Numbers followed by the same letters within a column are not significantly differ at the 5% level using Duncan's Multiple Range Test.
** In treatment tribenuron (alone), because of effective control of charlock, the number of panicles and biomass of wild oat, in field experiment, were higer than weedy check. In weedy check population of charlock was 21 plants/m2.
(+ trib.)= Tank-mixed application of the graminicides plus tribenuron.
(& trib.)= Individual application of the graminicides and tribenuron with one week interval.

REFERENCES

Hatzois, K K.; Penner, D (1985) Interactions of herbicides with other agrochemicals in higher plants. *Review of Weed Science.* 1, 1-63.

Humburg, N E; Colby, S R; Hill, E R; Kitchen,L M; Lym, R G; McAvoy, W J; Prasad, R (1989) Herbicides handbook. sixth edition. Weed Science Society of America, IL.pp. 115-117.

Jensen,K I N; Caseley, J C (1990) Antagonistic effects of 2,4-D and bentazon on control of *Avena fatua* with tralkoxydim. *Weed Research.* 30, 389-395.

Muller, T c; Witt, W W; Barrett, M (1989) Antagonism of johnsongrass *(Sorghum halepense)* control with fenoxaprop, Haloxyfop, and sethoxydim by 2,4-D. *Weed Technology,* 3, 86-89

O'Sullivan, P A; Friesen, H A; Vaden Born W H (1977) Influence of herbicides for broadleaved weeds and adjuvants with diclofop methyl on wild oat control *Canadian Journal of Plant Science,* 57, 117-125

Wharton, T F; Shaw, D R (1987) Antagonistic responses of graminicides and broadleaf herbicides. *Proceedings Southern Weed Science Society,* 40, 86.

Zadoks, J c; Chang, T T; Konzak, C F (1974) A decimal code for the growth stage of cereals. *Weed Research.* 14, 415-421.

ORGANOSILICONES AS ADJUVANTS FOR GRAMINICIDES

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ABSTRACT

The performance of three structurally analogous organosilicone surfactants has been compared with that of oil, and a mixture of oil + 'conventional' surfactant, as adjuvants for five graminicides against four grass species. Specific responses to these trisiloxane surfactants were evident but, in general, organosilicones were comparably beneficial to oil with quizalofop, fluazifop and fenoxaprop. Cycloxydim was more, and tralkoxydim much more enhanced by oil than by any of the organosilicones. The organosilicones were not phytotoxic, nor did they reduce crop selectivity on broad or narrow leaf species. Benefits of the organosilicones observed over a range of concentrations applied in low and high spray volumes indicated that spray run-off, resulting from their 'superspreading' behavior, is not a concern under typical conditions of use on arable crops. Similarly, benefits observed with three types of formulations indicated that antagonism of trisiloxane surface activity by pesticide formulants is unlikely to be a concern at field level.

INTRODUCTION

Silwet L-77 (TSE8M; CAS Registry Number 27306-78-1), already registered as an adjuvant in Eire and various non-European countries, was granted its ADJ number (No. 0193) for adjuvant use in the UK in July, 1995. That authorization is directed towards use with cereal fungicides, to which TSE8M can bring considerable benefits (Green & Green, 1992; Green & Packe-Drury-Lowe, 1992; Laverick, 1993). This organosilicone is also used as a trace element additive (Rimmer *et al.*, 1992). Since it is common practice to tank-mix agrichemicals, it is of practical interest whether TSE8M may also be of value with graminicides.

Differences in adjuvant activity among organosilicones, associated with their chemical structure, have been observed previously (Gaskin & Stevens, 1993), and were most evident on graminaceous species. Accordingly, TSE8M was compared with two analogous trisiloxanes, Silwet® 408 (TSE8; CAS Registry Number 67674-67-3) and Silwet 806 (TSA) surfactants, that also are used as agricultural adjuvants.

These trisiloxanes are all superspreading surfactants. Improved spray coverage is a potentially important benefit, for instance by resulting in the deposition of greater amounts of graminicide at the base of grass leaves where uptake is likely to be maximized (Whitehouse, 1981). However, inappropriately high concentrations of organosilicone applied in high spray volumes may result in run-off (Stevens, *et al*, 1994). Accordingly, initial investigations compared performance over a four-fold concentration range when applied in two spray volumes.

Some surfactants commonly used in agrichemical formulations may affect the performance of trisiloxanes (Murphy, *et al.*, 1991). To observe of any such interactions, graminicides that are formulated as SC, EC and as oil-in-water emulsion (EW) were selected for investigation.

MATERIALS AND METHODS

General

Plants were grown in pots (9 cm; 3 or 4 replicates) of loam soil amended with grit (30%) plus Vitavax slow-release fertilizer and were subirrigated. Seed was germinated in a standard glasshouse, plants were thinned to three per pot, and thereafter plants were grown in a gauze-sided glasshouse. Plants were allocated to treatments in a randomized block design.

Growth stages at spraying were:	wheat (cv. Avalon) & wild oats	Z15, 22
	blackgrass	Z15, 23
	ryegrass	Z14, 24
	sugar beet & rape	4 true leaves

Graminicides (Table 1) were applied at several reduced rates, to enable observation of adjuvant effects, being applied by a track sprayer through a Lurmark 01-F80 nozzle. Plants were visually assessed around 10 DAT to assess the rapidity of herbicide action, and overall efficacy was determined as fresh weight of the foliage at between 27 and 36 DAT. Data were subjected to variance stabilizing transformations, as required, prior to analysis of variance, with regression being used to examine the effect of organosilicone concentration in the initial study (see below).

Table 1. Chemicals

Product	a.i.[1]	Supplier	Formulation
Silwet L-77 (TSE8M)	trisiloxane-EO_8-CH_3	OSi Specialties[2]	100% product
Silwet 408 (TSE8)	trisiloxane-EO_8-H	OSi Specialties	100% product
Silwet 806 (TSA)	trisiloxane-AO	OSi Specialties	100% product
Actipron (oil)	mineral oil + emulsifier	Bayer	97% oil
Agral (NPE8)	nonylphenol-EO_8-H	Zeneca	92%
Pilot	quizalofop-ethyl	AgrEvo	SC
Laser	cycloxydim	BASF	EC
Fusilade	fluazifop-P-butyl	Zeneca	EW
Cheetah Super	fenoxaprop-P-ethyl	AgrEvo	EC
Grasp	tralkoxydim	Zeneca	SC

[1] EO = ethylene oxide; AO = polyalkyleneoxide

[2] Newman Agrochemicals are the UK distributor for L-77

Effect of organosilicone concentration and of spray volume

An initial study applied quizalofop (25 and 50 g a.i. ha^{-1}), cycloxydim (60 and 120 g a.i. ha^{-1}) and fluazifop (44 and 88 g a.i. ha^{-1}) to wheat in 100 and 200 l ha^{-1} alone or with the addition of TSE8M (0.05, 0.1, 0.15, 0.2%). The TSE8M treatments were compared with the recommended adjuvant for each graminicide, respectively: 1% oil, 0.8% oil, and 0.375% oil +

0.1% NPE8. Adjuvants also were applied alone at their highest concentrations as a phytotoxicity check.

Effect of organosilicone chemistry

All three organosilicones were tested with the same three graminicides applied in 200 l ha^{-1} at slightly modified rates (respectively: 25 and 50 g, 48 and 120 g, 32 and 80 g), against a wider range of grass species: wheat, wild oat, blackgrass and perennial ryegrass. Crop selectivity was checked by examining phytotoxicity to rape and sugar beet. In the absence of a consistent response to concentration in the previous study, the trisiloxanes were added at two levels (0.075% and 0.15%).

Cereal herbicides

In a third stage of experimentation, the organosilicones were tested, again in 200 l ha^{-1}, in combination with the cereal herbicides fenoxaprop (10, 21 and 31 g a.i. ha^{-1}) and tralkoxydim (25, 50 and 75 g a.i. ha^{-1}). No adjuvant is recommended for use with fenoxaprop, but oil + NPE8 (recommended with tralkoxydim) was added to both chemicals to ensure adhesion of spray to foliage despite the presence of minimal amounts of wetter at the low rates of application. This oil-based treatment was used as the basis for comparison with the trisiloxanes. Efficacy of weed control was evaluated against wild oat and blackgrass. Graminicide and organosilicone, at their highest levels, were applied to wheat to check on crop selectivity.

RESULTS AND DISCUSSION

Effect of organosilicone concentration and of spray volume

When applied alone at maximum concentrations TSE8M was less phytotoxic than oil, though neither adjuvant produced a significant deleterious effect on the wheat. Preliminary statistical examination of the graminicide data indicated that many of the parameters (a.i., a.i. rate, spray volume, adjuvant/concentration) were interactive, requiring analysis be performed individually for each a.i. As a result it is not possible to provide summary data, and rather than present data for all 60 treatments (3 a.i. x 2 rates x 2 volumes x 5 adjuvant/concentrations), which the authors will be happy to provide on request, the salient findings are summarized below.

Applied in 200 l ha^{-1}, TS8EM was equivalent to oil as an adjuvant for quizalofop, with no trend in performance related to concentration of the organosilicone. In 100 l ha^{-1}, the effect of TSE8M increased with concentration, but was less than that of oil. Visual assessments indicated that the trisiloxane enhanced the rapidity of action of quizalofop, but not that of cycloxydim and fluazifop.

The higher dose of cycloxydim was more effective than the lower dose only when applied in 100 l ha^{-1}, suggesting that spray coverage might be an important factor. Contradictorily, the effectiveness of TSE8M was inversely related to its concentration, matching that of oil at 0.05%, at which level the organosilicone is the more cost-effective of the treatments.

Applied in 200 l ha^{-1}, TSE8M at 0.2% was significantly more effective with fluazifop than the recommended oil-based adjuvant. Regardless of application volume, 0.05% organosilicone was comparable to oil + NPE8, and so a viable alternative both in terms of performance and of cost.

Clearly the possible effects of the different formulation types on the performance of the trisiloxane cannot be separated from innate differences in activity among the actives. Nonetheless the beneficial results obtained with all three formulations indicate that the antagonism of trisiloxanes by pesticide formulants seen in laboratory physical-chemical tests is unlikely to be a practical concern. That the highest concentration (0.2%) of TSE8M was the most effective adjuvant treatment with fluazifop when applied in the higher of the two spray volumes is a clear indication that spray run-off is also not a concern. It is known from laboratory studies (not reported) that TSE8 and TSA behave similarly to TSE8M in respect both of formulant antagonism and of spreading with potential for spray run-off.

Effect of organosilicone chemistry

None of the adjuvants applied alone had a significant phytotoxic effect on any of the four grasses (wheat, wild oat, blackgrass and perennial ryegrass) or the two broad-leaf crops (rape and sugarbeet). Neither did any of the adjuvants induce a herbicidal effect of the graminicides on the crops. This was as expected because the selectivity of these a.i. has a sound biochemical basis and is not dependent on, for instance, differential spray retention which might be jeopardized by adjuvants.

Table 2. Effect of adjuvants on herbicidal efficacy of graminicides

Adjuvant	Concentration (%)	Shoot fresh weight[a] (g)		
		quizalofop	cycloxydim	fluazifop
Untreated	n/a	22	22	22
None	0	17	8.3	5.7
Oil ± NPE8[b]	various[b]	4.1	3.1	3.1
TSE8M	0.075	7.2	4.8	3.5
	0.15	6.2	4.7	3.6
TSE8	0.075	11	5.3	3.4
	0.15	4.4	4.5	3.3
TSA	0.075	9.6	4.7	4.1
	0.15	5.3	4.3	3.1
LSD (P=0.05) = $\log_e$ (weight) ±		0.58	0.27	0.26

[a] average of three species: wheat, wild oat, blackgrass

[b] refer to Methods and Materials for composition and concentration for each herbicide

It is not practicable to present the full data set for this experiment (>150 treatments of graminicide x rate x plant x adjuvant x concentration + untreated and no-adjuvant controls + adjuvant-alone phytotoxicity checks). Preliminary examination of these data indicated that it was possible to combine data for analysis of both rates of each herbicide across wheat, wild oat and blackgrass (Table 2). Fluazifop was the most effective herbicide in the absence of adjuvant but, nonetheless, was improved by all the adjuvant treatments. TSA at 0.075% was the only organosilicone treatment which was significantly less effective than the oil + NPE8 adjuvant recommended. Similarly, all adjuvants improved the efficacy of quizalofop, with the exception of TSE8 and TSE at the lower concentration (0.075%), the only treatments which were significantly less effective than 1.0% oil. All adjuvants also improved the efficacy of cycloxydim but, in contrast to the previous experiment, no organosilicone matched 0.8% oil. This is in keeping with an earlier report of TSE8M as an adjuvant for sethoxydim and clethodim (Rahman & James, 1989).

The graminicides were applied to perennial ryegrass only at their highest rate alone or in combination with their recommended oil adjuvant (see Methods and Materials) and with the higher concentration (0.15%) of each organosilicone. All treatments, except quizalofop alone, had a significant herbicidal effect relative to unsprayed controls. All adjuvants improved the effectiveness of the three graminicides, the organosilicones being statistically equivalent to the oil adjuvant with quizalofop and fluazifop, but being surpassed by 0.8% oil with cycloxydim.

Cereal herbicides

In the absence of graminicide none of the adjuvants had a significant phytotoxic effect on either the weeds (blackgrass and wild oat) or the crop (wheat). Likewise, in combination with the herbicides no adjuvant caused a reduction in the fresh weight of wheat relative to untreated controls.

In the absence of adjuvant, tralkoxydim had no significant effect on either weed. With this a.i. the oil-based adjuvant was much more effective than the organosilicones (data not presented). In contrast, the organosilicones were effective with fenoxaprop, and noticeably increased the rapidity of action of the lowest rate on wild oat. Preliminary examination of the fenoxaprop efficacy data demonstrated that comparisons among adjuvant treatments were possible by pooling variance across the three rates of a.i. and the two weeds (Table 3). With the exception of the lower concentrations (0.075%) of TSE8M and TSE8, all the trisiloxane treatments significantly enhanced the activity of the herbicide, which the oil-based adjuvant did not, TSA being the most effective adjuvant. The higher concentration (0.15%) of the organosilicones was always the more effective, once again implying that spray run-off does not occur from applications made in 200 l ha^{-1}.

Table 3. Effect of adjuvants on herbicidal efficacy of fenoxaprop-P-ethyl

Adjuvant	Concentration (%)	Shoot fresh weight[a] (g)		Statistics[b]
		Blackgrass	Wild oat	
Untreated	n/a	15	29	a
none	0	7.2	12	b
oil + NPE8	0.375 + 0.1	2.3	7.8	bcd
TSE8M	0.075	5.0	12	bc
	0.15	2.8	6.3	cd
TSE8	0.075	3.6	10	bcd
	0.15	2.3	7.3	cd
TSA	0.075	2.1	7.0	cd
	0.15	1.5	6.0	d

[a] average of three rates of a.i.

[b] treatments sharing common postscripts are not significantly different (P=0.05)

CONCLUSIONS

This glasshouse study has shown that organosilicones can match the efficacy of oil adjuvants, and can do so at rates which would be cost-effective in the field, with the graminicides quizalofop, fluazifop and fenoxaprop. Lack of benefit with tralkoxydim, coupled with equivocal results with cycloxydim (*cf.* first and second experiments) and a previous report in the literature indicate that, while trisiloxanes are suitable for use with 'fops', they are not the adjuvants of choice with 'dim' chemistry.

Additionally, it has been demonstrated that the organosilicone are neither phytotoxic, nor do they jeopardize selectivity to the crop.

This study has provided further evidence that responses to organosilicone surfactants may be specific. The agrichemical industry is encouraged to screen a variety of structures, as here, to ensure the selection of optimal organosilicone adjuvants.

Two concerns have been expressed previously about the use of superspreading trisiloxanes, namely that they may cause run-off of spray and that their activity may be lost as a result of physical-chemical antagonism of their surface activity by pesticide formulants. This study has demonstrated that neither is likely to be a problem under typical conditions of use on arable crops. Existing commercial use with fungicides and foliar nutrients substantiates this.

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REFERENCES

Gaskin, R E; Stevens, P J G (1993) Antagonism of the foliar uptake of glyphosate into grasses by organosilicone surfactants. Part 2: Effects of surfactant structure and glycerol addition. *Pesticide Science.* **38**, 193-200.

Green, C F; Green, D A (1992) Relocation of fungicides to stem bases of winter wheat using organosilicone copolymers in relation to disease suppression. *Abstracts Third International Symposium on Adjuvants for Agrochemicals.* London: Society of Chemical Industry.

Green, C F; Packe-Drury-Lowe, S J (1992) Foliar disease control on winter wheat following fungicide treatments applied with various spray adjuvants. *Abstracts Third International Symposium on Adjuvants for Agrochemicals.* London: Society of Chemical Industry.

Laverick, R M (1993) Effects of organosilicone copolymer applied with fungicides to winter wheat on true eyespot *Pseudocercosporella herpotrichoides. Annals of Applied Biology*, **122** (Tests of Agrochemicals and Cultivars 14), 58-59.

Murphy, G J; Policello, G A; Ruckle, R E (1991) Formulation considerations for trisiloxane based organosilicone adjuvants. *Proceedings Brighton Crop Protection Conference - Weeds*, 355-362.

Rahman, A; James, T K (1989) Effect of simulated rainfall and adjuvants on the activity of some grass herbicides. *Proceedings 42nd N.Z. Weed and Pest Control Conference*, 110-113.

Rimmer, H E; Green, C F; Jones, C; Green, D A (1992) Nutrient application to potatoes and wheat with various spray adjuvants. *Abstracts Third International Symposium on Adjuvants for Agrochemicals.* London: Society of Chemical Industry.

Stevens, P J G; Walker, J T S; Shaw, P W; Suckling, DM (1994) Organosilicone surfactants: tools for horticultural crop protection. *Proceedings Brighton Crop Protection Conference - Pests and Diseases.*, 755-760.

Whitehouse, P (1981) Factors affecting the activity of some foliage-applied wild oat herbicides in relation to their site of application. *Ph.D. thesis*, University of Bristol.

HOE 095404: A NEW HERBICIDE FOR BROADLEAF WEED AND SEDGE CONTROL IN RICE

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ABSTRACT

Hoe 095404 (proposed common name: ethoxysulfuron) is a new herbicide for safe use in both transplanted and direct seeded rice. It controls a very broad spectrum of important broadleaf weeds as well as annual and perennial sedges. Depending to the weed species and geographical use area the dose rate ranges from 7,5-15 g a.i./ha in tropical areas of Southeast Asia to 45-60 g a.i./ha in temperate zones of rice production in Brazil, the US and Europe.

Hoe 095404 can be used from early post emergent to late post emergent application timings and easily be adjusted to all water management systems. It is therefore an ideal combination partner for early complete weed control with graminicides like Anilofos, Butachlor, Propanil and also for a later oneshot solution together with Fenoxaprop-p-ethyl.

INTRODUCTION

Hoe 095404 (proposed common name: ethoxysulfuron) is a new sulfonylurea herbicide, under development by AgrEvo for control of a broad spectrum of broadleaf weeds and sedges in rice, sugarcane and cereals (Hacker *et al.*, 1995). Rice will be one of the major uses for Hoe 095404 because of its excellent selectivity in all different production systems of rice and its specific activity on typical paddy rice weeds. The mode of selective action of Hoe 095404 has been presented by Köcher and Dickerhof (1995). Details of the specific performance in Thailand and in Japan have been discussed in separate publications (Sitchawat & Khattiyakarun, 1995; Nakajima *et al.*, 1995).

This paper describes the use of Hoe 095404 as part of a total weed control management in global rice production.

MATERIALS AND METHODS

Hoe 095404 has been intensively tested in different rice production systems. The first step of development was aiming for the description of the single molecule. In a second development schedule, field trials have been conducted to integrate Hoe 095404 as a tool for complete weed management in rice. The presented trial results are from standard plot trials (4 - 20 m^2) in a randomised block design. Efficacy and crop tolerance evaluations are based on visual ratings, using a 0 - 100 % score. The presented ratings are about 6 weeks after application. For spray applications water dispersible granules (WDG) containing 150 or 600 grams active ingredient per kilogram product have been used. For countries where granular applications are used, extruded clay granules with different % active ingredient have been tested.

RESULTS AND DISCUSSION

Rice crop tolerance

Hoe 095404 can be used safely in all rice production systems. It is fully selective in all types of seeded rice (dry drilled, pre germinated wet seeded, pre germinated water seeded) and all types of transplanted rice.

The selectivity is not influenced by the rice growth stage at application time, the water management or other environmental factors.

Weed control

Hoe 095404 controls a wide range of broadleaf weeds and annual as well as perennial sedges in rice all over the world (Table 1). Also the weeds listed under suppression can be controlled in early growth stages and higher rates, but the efficacy will not be consistent. Side effects of control of Echinochloa species have been observed under specific conditions of very uniform stands of Echinochloa crus-galli with a maximum of one leaf per plant. In most situations Hoe 095404 will not control grasses and needs to be mixed with a graminicide for complete weed control.

Table 1. Weed control by Hoe 095404 at 7,5 - 60 g a.i./ha in seeded and transplanted paddy rice.

	Broad leaf weeds and water ferns		Sedges
Controlled	*Alternanthera tenella*	*Marsilea crenata*	*Cyperus difformis*
	Aneilema keisak	*Marsilia minuta*	*Cyperus esculentus*
	Aeschynomene rudis	*Monochoria hastata*	*Cyperus ferax*
	Aeschynomene selloi	*Monochoria vaginalis*	*Cyperus iria*
	Aeschynomene virginica	*Oenanthe javanica*	*Cyperus rotundus*
	Alisma canaliculatum	*Polygonum hydropiper*	*Eleocharis filiculmis*
	Alisma lanceolatum	*Potamogetum distinctus*	*Fimbristylis annua*
	Alisma plantago-aquatica	*Potamogetum natans*	*Fimbristylis diphylla*
	Ammannia baccifera	*Rotala indica*	*Fimbristylis littoralis*
	Ammannia coccinea	*Sagittaria guayanensis*	*Fimbristylis miliacea*
	Ammannia multiflora	*Sagittaria latifolia*	*Scirpus juncoides*
	Bergia aquatica	*Sagittaria ontevidensis*	*Scirpus maritimus*
	Butomus umbellatus	*Sagittaria pygmaea*	*Scirpus mucronatus*
	Commelina diffusa	*Sagittaria sagittifolia*	*Scirpus supinus*
	Eclipta alba	*Sagittaria trifolia*	
	Ipomoea aquatica	*Salvinia molesta*	
	Ipomoea hederacea	*Sesbania exaltata*	
	Ipomoea lacunosa	*Sphenoclea zeylanica*	
	Lindernia procumbens		
	Ludwigia linifolia		
	Ludwigia octovalvis		
Suppression	*Alternanthera hiloxeroides*		*Cyperus serotinus*
	Caperonia castanaefolia		*Eleocharis kuroguwai*
	Heteranthera limosa		
	Heteranthera reniformis		
	Sesbania exasperata		

The dose rate listed in Table 1 presents a rather wide range from 7,5 - 60 g a.i./ha, because efficacy results from all over the world are put together.

Results from Italy (Table 2) and Thailand (Table 3) demonstrate the need for specific dose rates under different rice growing conditions. In both cases the rice is wet seeded. The development of the weeds in Italy is slow, a first treatment to 2 - 4 leaf weeds is only necessary 18 - 20 days after seeding. Such a weed growth stage was reached in Thailand only 10 days after seeding. Applications at similar growth stages still require different dosage rates, 30 - 60 g a.i./ha in Italy, 7,5 to 15 g a.i./ha in Thailand.

Results from both countries show the good efficacy on broadleaf weeds like *Alisma, Sphenoclea* and *Ludwigia* as well as on sedges like *Fimbristylis, Cyperus* and *Scirpus* species. Additional combination partners for a completion of the broadleaf and sedge spectrum are therefore in most cases not needed.

With later application timings, the efficacy will be reduced. This was observed, at the very late timing in Italy, where higher rates could not compensate for the reduced efficacy. Yet such late applications are more salvage type treatments, and should not be necessary in a timely weed management programme.

In Thailand on the other hand, only a slight loss of efficacy occurred, proving the high application flexibility within the frame of normal weed control measurements.

Table 2. Efficacy of Hoe 095 404 at different application timings in Italy. Average of 3 trials.

		Alisma plantago		*Scirpus mucronatus*		*Heteranthera reniformis*	
Application days after wet seeding		18 - 20	31 - 37	18 - 20	31 -37	18 - 20	31 - 37
Hoe 095404	30 g a.i./ha	97	72	93	49	68	35
	60 g a.i./ha	99	75	99	52	75	35
Bensulfuron	30 g a.i./ha	58	58	99	38	75	36
	60 g a.i./ha	64	64	99	38	83	39

Table 3. Efficacy of Hoe 095404 at different application timings in Thailand. Average of 2 trials.

Weed population		*Sphenoclea zeylanica* *Ludwigia linifolia*		*Fimbristylis miliacea* *Cyperus iria/difformis*	
Application days after wet seeding		10	20	10	20
Hoe 095404	7,5 g a.i./ha	88	73	99	94
	15.0 g a.i./ha	97	97	100	98
Bensulfuron	6,2+1,2 g a.i./ha	80	99	100	94
+ Metsulfuron	12,4+2,6 g a.i./ha	99	100	100	94

For a complete weed control in rice, also grass weeds have to be controlled mainly *Echinochloa* and *Leptochloa* species. Hoe 095404 can be tankmixed with most of the available rice herbicides for grass control, thus being a valuable component of one-shot solutions, as tankmixtures or preformulated combination products.

For early post emergent weed control, combinations with Anilofos are very suitable (Table 4). Applications 6 - 7 days after seeding show the lack of grass control with Hoe 095404, the strength of grass control by Anilofos, yet its insufficient control of a complex of dicot weeds and sedges. Together both products provide equal or more complete weed control than Thiobencarb + Propanil or Butachlor + Propanil. Due to its wide application window, Hoe 095404 is also a very suitable combination partner for later one-shot applications. Applications 12 - 15 days after seeding, demonstrate reduced grass control of both Anilofos and Propanil, whereas Hoe 095404 still controls all other weeds close to 100 %. For such late postemergent applications, to control already tillered grasses, more suitable graminicides need to be used together with Hoe 095404, like Fenoxaprop-p-ethyl. 12 - 15 days after seeding with grasses starting to tiller, Fenoxaprop-p-ethyl controls grasses better than Anilofos or Propanil and Hoe 095404 maintains its control of all other weeds.

Similar results have been reported also from Thailand by Sitchawat and Khattiyakarun (1995). For an early postemergent application 5 days after seeding combinations of Hoe 095404 + Thiobencarb (7,5 + 2000 g a.i./ha) or Hoe 095404 + Butachlor (7,5 + 750 g a.i./ha) controlled a weed population similar to that listed in Table 5. 10 days after seeding the combination of Hoe 095404 + Propanil (7,5 + 2000 g a.i./ha) was superior to the combinations with either Thiobencarb or Butachlor.

Table 4. Efficacy of Hoe 095404 in combinations for complete weed control - Thailand.

		Grasses	Broad leaf weeds	Sedges
Application 6 -7 days after seeding				
Hoe 095404	8 g a.i./ha	0	100	100
Anilofos	300 g a.i./ha	97	52	88
Hoe 095404 + Anilofos	8 + 300 g a.i./ha	98	98	100
Thiobencarb + Propanil	1333 + 667 g a.i./ha	95	97	99
Butachlor + Propanil	688 + 688 g a.i./ha	93	98	100
Application 12 - 15 days after seeding				
Hoe 095404	10 g a.i./ha	0	96	100
Anilofos	375 g a.i./ha	84	55	88
Hoe 095404 + Anilofos	10 + 375 g a.i./ha	83	99	100
Hoe 095404 + Propanil	10 + 1000 g a.i./ha	73	98	97
Hoe 095404 + Fenoxaprop-p-ethyl	10 + 40 g a.i./ha	92	89	92

Wet seeded rice. Average from 4 trials. Grasses: *Echinochloa crus-galli, Leptochloa chinensis.* Broad leaf weeds: *Sphenoclea zeylanica, Monochoria vaginalis, Marsilea crenata.* Sedges: *Cyperus difformis, Cyperus iria, Fimbristylis miliacea.*

The high flexibility for combinations with graminicides is also demonstrated with the summarized trial results from Brazil (Table 5). Combinations of Hoe 095404 with Fenoxaprop-p-ethyl, Propanil and Quinclorac did control Cyperus iria and had a particular strength on Aeschynomene rudis. Heteranthera reniformis was more difficult to control, whereas Cyperus iria was better controlled than the standards. The degree of grass control was according to the specific strength of Propanil and Fenoxaprop-p-ethyl, the latter one in particular superior for the control of Ischaemum rugosum.

Table 5. Efficacy of Hoe 095404 in combination for complete weed control - Brazil

		Echinochloa species	*Ischaemum rugosum*	*Cyperus iria*	*Heteranthera reniformis*	*Aeschynomene rudis*
Hoe 095404 + Fenoxaprop-p-ethyl	60 g a.i./ha 60 g a.i./ha	86	99	92	68	96
Hoe 095404 + Propanil	60 g a.i./ha 3600 g a.i./ha	75	65	88	75	98
Hoe 095404 + Quinclorac	60 g a.i./ha 375 g a.i./ha	77	0	89	75	96
Pyrazosulfuron + Propanil	20 g a.i./ha 3600 g a.i./ha	75	82	79	82	84
Metsulfuron + Fenoxaprop-p-ethyl	2 g a.i./ha 60 g a.i./ha	84	98	9	98	89

Early (grasses pre tillered) and late applications (grass tillered) are put together.
Average from 8 trials.

Table 6. Efficacy of Hoe 095404 in combinations for complete weed control - Italy

	Echinochloa crus-galli	*Heteranthera limosa*	*Scirpus maritimus/ mucronatus*	*Butomus umbellatus*
Hoe 095404 + Propanil 60 + 4200 g a.i./ha followed by Propanil 4200 g a.i./ha	99	92	100	100
MCPA + Propanil 200 + 4200 g a.i./ha followed by Propanil 4200 g a.i./ha	97	80	100	100
Hoe 095404 + Molinate 60 + 2540 g a.i./ha	94	88	100	100
Bensulfuron + Molinate 60 + 2540 g a.i./ha	93	87	100	100

Wet seeded rice. Applications with Propanil in drained fields, applications with Molinate in flooded fields. Average from 2 trials.

For complete weed control in rice, often 2 application of herbicides are necessary. As in the case of Italy, two sequential applications of Propanil (4200 g a.i./ha followed by 4200 g a.i./ha) are needed for sufficient Echinocloa control. Hoe 095404 added to one application at 60 g a.i./ha will control all other weeds like Heteranthera limosa, Scirpus species and Butomus umbellatus (Table 6). Similar dicot weed and sedge control is possible with applications in the flooded paddy. In that case tankmixtures with Molinate for added grass control are possible.

CONCLUSIONS

Hoe 095404 is a very flexible to use herbicide for rice

1. Hoe 095404 has excellent selectivity in dry and water seeded as well as in transplanted rice.
2. Hoe 095404 controls almost all of the economically important broadleaf weeds and sedges in rice.
3. The way of application can be adjusted to all types of rice production and water management.
4. Hoe 095404 can be combined with most herbicides for grass control from early to late postemergent applications.

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REFERENCES

Hacker, E; Bauer, K; Bieringer, H; Kehne, H; Willms, L (1995) Hoe 095404 - a new sulfonylurea for post emergent weed control in rice, cereals, and sugarcane. Proceedings 1995 Brighton Crop Protection Conference - Weeds (in press).

Köcher, H; Dickerhof, G (1995) Mode of selective action of the herbicide Hoe 095404. Proceedings 1995 Brigthon Crop Protection Conference - Weeds (In press).

Nakajima, T; Chiba, N; Schubert, H (1995) Hoe 095404, a novel herbicide for use in Japanese paddy rice cultivation. In: Proc. 15th Asian Pacific Weed Sci. Soc. (In press)

Sitchawat, T; Khattiyakarun, S (1995) Hoe 095404, a novel herbicide controlling broadleaves sedges alone or in combination with grass herbicides as one-shot application in direct seeded rice in Thailand. In: Proc. 15th Asian Pacific Weed Sci. Soc. (In press)

Bauer, K; Hacker, E; Kehne, H; Willms, L; Köcher, H; Nakajima, T (1995) Hoe 095404, a new sulfonylurea-type herbicide for use in rice. In: Proc. 15th Asian Pacific Weed Sci. Soc. (In press)

THE INHERITANCE OF CHLORSULFURON RESISTANCE IN PERENNIAL RYEGRASS : STRATEGIC IMPLICATIONS FOR MANAGEMENT OF RESISTANCE

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ABSTRACT

Inheritance studies were conducted on chlorsulfuron resistant *Lolium perenne* which had been selected previously by mass screening. Pair crosses of susceptible and resistant plants gave F1 progeny which showed intermediate levels of resistance (ED_{50}) with respect to parental response. Maternal effects were also detected in patterns of inheritance in full sib progeny from crosses both amongst resistant plants and between susceptible and resistant individuals. There was noticeable variation in mean response of seedling familes from a randomly mated population of 50 resistant plants to a dose of chlorsulfuron giving 92% mortality in susceptible populations. Mean growth performance in 14 of these seedling families was equivalent to that of unsprayed controls. In conjunction with other studies, it is postulated that resistance to chlorsulfuron was conferred by additive minor genes inherited in a quantitative manner but that the response to cycles of selection may be extremely rapid. These data are discussed in context of the management of herbicide resistance in weeds which is inherited polygenically.

INTRODUCTION

Resistance to the acetolactate synthase (ALS) inhibitor herbicides has been widely observed in both weed and crop species and a number of mechanisms including altered target site sensitivity and herbicide degradation may give rise to functional resistance. The number of ALS genes encoding for resistance varies amongst species and multiplicity of genes has been postulated to account for the complexity of observed inheritance patterns (Swanson et al., 1989). Whilst resistance at the whole plant level due to insensitive ALS enzyme has been shown in several cases (Devine et al., 1991; Saari et al., 1992; Christopher et al., 1992), to date there is only one confirmed case of single gene resistance to ALS inhibitor herbicides (Mallory-Smith et al., 1990).

Knowledge of the mode of inheritance of resistance traits is however central to predicting the likelyhood and rate of evolution of herbicide resistance in a species (Maxwell and Mortimer, 1994). It has been postulated that reduced herbicide application rates may enhance evolution of polygenic resistance, whilst high application rates may increase the likelyhood of major gene resistance (Gressel, 1995). In this paper we report genetic analyses of resistance to chlorsulfuron in a cultivar of *Lolium perenne* and the responses of individual plant families to an experimental cycle of selection with chlorsulfuron.

MATERIALS AND METHODS

Materials

Genetic analysis was conducted using plants resistant to chlorsulforon selected from a population of *Lolium perenne* L. cv. Devon Eaver. This commercial cultivar exhibits considerable natural genetic variation and resembles a natural population previously unexposed to ALS-inhibitor herbicides (Mackenzie, 1994).

Resistant plants were obtained by mass screening for resistance using a technique based on post-emergence exposure to herbicide in hydroponic culture (Mackenzie et al., 1995). Unselected stock material was screened using two different application rates giving an estimated mortality of 99.99% and 90%, respectively. Putative resistant plants (individuals retaining a central green shoot and substantial root system) were selected after 4 weeks exposure to herbicide, transferred to nutrient solution and with confirmation of active growth, potted on into compost.

Three resistant phenotypes (coded 'R1', 'R2', 'R3') were selected from a screening of 6.5 x 10^5 individuals at the higher application rate and ninety five phenotypes (coded 'r1....r95') from a screen of 4.1 x 10^5 individuals at the lower rate. In dose response tests on tillers, R phenotypes were up to four-fold resistant (ED_{50} R/S) whilst the relative resistance of r phenotypes was normally distributed across a range from susceptible to highly resistant (ca 100 fold resistant), Mackenzie et al., 1995.

Genetic analysis

Inheritance of chlorsulfuron resistance was investigated in R phenotypes by pair crosses involving the reciprocal mating of known parents. At flowering, individual inflorescences were placed in pollination bags to control pollen flow. Crosses including selfs were made for all possible permutations of phenotypes R1, R2, R3, and S1 and S2 (two randomly chosen susceptible phenotypes), using 36 clonally propagated mature plants per phenotype, to yield full-sib sets of progeny.

Seedlings of progeny from each cross were assessed for biomass response to chlorsulfuron over a range of doses (0, 3, 9, 27, 83 and 250 g chlorsulfuron ha^{-1}), together with seedlings randomly taken from the unselected stock population. Sprayings were replicated twice on individual pots containing five plants per family (where seed stocks allowed). Seedlings were sprayed at the two to three leaf stage and the fresh weight of green biomass determined after a further three weeks growth in a controlled environment. ED_{50} estimates were calculated following Brain and Cousens, 1989.

Response to selection

Cloned plants of all r1...r95 phenotypes were grown in a protected external environment to initiate flowering and then maintained as an isolated randomly mating population in a glasshouse in summer 1993. Plants were regularly watered and pot locations periodically re-randomised with respect to one another during flowering. Demes of flowering plants were marked as anthers emerged and pollen transfer amongst plants encouraged by gentle tapping in the early morning. Infructescences were excised at maturity and stored individually. Families of seedlings from fifty phenotypes of the total of 95 were then raised in a controlled environment (24 ^{o}C, 16 h d^{-1} lighting) together with a seedling family of the original unselected stock population. Nine seedlings from each maternal parent (3 seedlings in each of 3 0.5 l pots) and 150 seedlings of the stock population (3 seedlings in each of 50 pots) were sprayed with 5g ha^{-1} chlorsulfuron. This application rate had been shown previously to give a 30% reduction in fresh weight yield in comparison to unsprayed plants in glasshouse conditions. A further 20 pots served as unsprayed controls. Each of these contained 3 seedlings randomly chosen with equal likelyhood from susceptible and resistant stocks.

RESULTS

Genetic analysis

A very low level of selfing amongst plants was detected (2.7%). Continous variation in yield response was present in individual plants at F1 in all crosses and there was no evidence of discrete qualitative responses (R/S). Table 1 gives the ED_{50} (± s.e) values of F1 progeny. There were no significant differences in ED_{50} amongst progeny from selfed R phenotypes, resistance being on average five fold greater than the mean ED_{50} of crosses of susceptible plants. In all but one case, ED_{50} values of F1 progeny of crosses among resistant phenotypes exceeded both those exhibited by familes from crosses to susceptible parents and by families from selfed resistant phenotypes (R1,R2 and R3). ED_{50} values for progeny from R x S crosses tended to be intermediate between those for selfed R plants and selfed susceptible material but with noticeable variation. Significant ($P<0.05$) maternal effects were conspicuous in crosses of S phenotypes to R3 , S1 to R2 and S1 to R1 as well as in crosses R2 x R3 and R1 x R2.

Response to selection

Figure 1 ranks the mean performance of the 50 seedling families of r phenotypes with that of the population of unsprayed plants and of the susceptible stock population. Mortality of seedlings in families of r phenotypes in response to spraying was low (3% of all seedlings) in comparison to the susceptible stock population in which all but 12 (8%) individuals died.

Figure 1. Mean (± sem) seedling family responses of 50 r phenotypes of *L. perenne* to chlorsulfuron. Families are ranked in performance. Hatched column is the response of a composite sample of unsprayed plants and the solid column the response of surviving susceptible plants. See text for details.

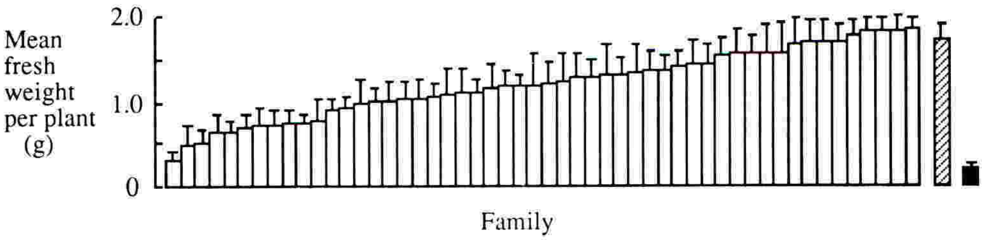

Table 1. ED$_{50}$ responses in progeny of *Lolium perenne* from crosses of selfed plants, pair crosses and the original unselected population. The respective maternal parent in pair crosses is italicised. * ED$_{50}$ approximated, since all sprayed plants died.

Cross	ED$_{50}$ g chlorsulfuron (a.i.)	s.e.
Unselected population	4.10	0.995
Selfed		
S1	3.05	0.700
S2	1.5 *	
R1	17.42	0.605
R2	18.03	0.690
R3	14.10	0.825
Inter-crossed		
R1 X R2	22.89	0.689
R1 X *R2*	28.23	0.870
R1 X R3	32.34	0.769
R1 X *R3*	30.19	0.919
R2 X R3	23.00	0.970
R2 X *R3*	14.89	0.650
R1 X S1	10.73	0.537
R1 X *S1*	13.77	0.707
R1 X S2	16.88	0.640
R1 X *S2*	14.12	0.845
R2 X S1	10.85	0.995
R2 X *S1*	7.27	0.736
R2 X S2	8.12	0.958
R2 X *S2*	7.69	0.795
R3 X S1	10.31	0.830
R3 X *S1*	8.67	0.927
R3 X S2	12.88	0.727
R3 X *S2*	5.52	0.943
S1 X S2	2.12	0.836
S2 X S1	4.30	0.574

Variation in mean family performance after spraying was noticeable with some familes displaying highly susceptible progeny and low mean scores. However the mean performance of 14 families out of the 50 sprayed was not statistically significant from the performance of unsprayed controls.

DISCUSSION

The patterns of inheritance of ED_{50} (Table 1) suggest that the resistance trait in the R phenotypes was not recessive since mean F1 performance of R x S crosses was intermediate between resistance and susceptible parental responses. Thus dominant chlorsulfuron resistant traits may be present in phenotypes R1,R2 and R3 but a single dominant allele was not involved. Partial dominance of a single allele by itself is also unlikely due to the demonstration of significant maternal effects amongst crosses. Such variation due to maternal effects implicates non-nuclear encoded modifier genes in the *L. perenne* genome or pleiotropic effects of nuclear genes. Either are likely to result in biometrical variation in resistance assuming resistance alleles are governed by other nuclear encoded genes. Confirmation of the quantitative inheritance of chlorsulfuron resistance in r1...r95 phenotypes has been reported earlier, the narrow sense heritability of response being high with a mean coefficient of 0.62, (Mackenzie et al., 1995).

Assay of ALS enzyme activity in R1 (and the most resistant r phenotype) indicated that an altered ALS target enzyme was not the mechanism responsible for the observed levels of chlorsulfuron resistance reported here (Mackenzie et al.,1995). In these phenotypes, cross resistance was also shown to metsulfuron-methyl, to a lesser extent to tralkoxydim, imazamethabenz, and isoproturon, but not to sulfometuron-methyl, fluazifop-P-butyl, diclofop-methyl, imazapyr, sethoxydim and chlorotoluron (Mackenzie, 1994). It is postulated that the resistance mechanism present in the R and r populations of resistant *Lolium* phenotypes described here is the enhanced capacity to degrade ALS-inhibitor herbicides mediated by mixed function oxidase enzyme activity possibly with the involvement of the cytochrome P450 enzyme complex. Since a large number of loci are involved in the expression of P450 enzymes (Durst et al., 1995), quantitative inheritance of resistance is highly likely.

Polygenic inheritance of resistant traits will result in segregation of genes within interbreeding individuals and the expression of genotypic variation within populations. Under selection this will result in a shift in mean population response, in relation to selection intensity. In the study of response to selection, the dose applied was a third of the recommended field rate of chlorsulfuron and resulted in 92% mortality in the susceptible stock population. Figure 2 indicates that 28% of the seedling families achieved equivalent growth to unsprayed controls which reflects a significant elevation in mean population resistance after a single cycle of selection. The data also confirm the expectation of continuous variation in response to herbicide in progeny of survivors after selection for a polygenically inherited trait.

It is a tenet in the literature that the evolution of herbicide resistance under polygenic inheritance will be slower than when a single dominant major gene is involved. The basis of this argument is that incremental resistance is only achieved by the accumulation of minor additive genes as a result of segregation and recombination within superior genotypes over cycles of selection, the process being slowed by mortality of phenotypes intermediate in resistance under high dosage. The experimental study reported here suggests that this evolutionary process may however be relatively rapid. Over two cycles of selection of r phenotypes with chlorsulfuron, (initial mass selection and further selection from interbreeding survivors giving conservatively estimated 90% and 92% mortality respectively) highly resistant individuals evolved. The extent to which the emergence of resistance would have been delayed by higher selection intensities remains unknown but phenotypes R1...R3 were originally selected with a selection intensity giving at least 99.99% mortality. Since polygenic inheritance of resistance is present in both R and r phenotypes it would seem unlikely that higher selection intensity would substantially delay the emergence of resistance in these populations and from a strategic management point of view would cause little preventative delay on the emergence of resistance.

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REFERENCES

Brain, P.; Cousens, R. (1989) An equation to describe dose responses where there is stimulation of the growth at low doses. *Weed Res.* 29: 93-96.

Christopher, J.T.; Powles, S.B.; Holtum, J.A.M. (1992) Resistance to acetolactate synthase-inhibiting herbicides in annual ryegrass (*Lolium rigidum*) involves at least two mechanisms. *Plant Physiol.* 100: 1909-13.

Devine, M.D.; Marles, M.A.S.; Hall, L.M. (1991) Inhibition of acetolactate synthase in susceptible and resistant biotypes of *Stellaria media*. *Pestic. Sci.* 31: 273-80.

Durst F. ; Benveniste I. ; Sala J.P.; Wreck-Reichart D. (1995, in press) The role of cytochrome P450 in herbicide metabolism. In *Herbicide resistance in weeds and crops.* De Prado (ed), Kluyer Press.

Gressel, J. (1995) Catch 22 - Mutually exclusive strategies for delaying/preventing polygenically vs. monogenically inherited resistance. *Eighth International Congress of Pesticide Chemistry - Options 2000.* N.N. Ragdale, P.C. Kearney and J.R. Plimmer (eds) *American Chemical Society*, pp 330-339.

Mackenzie, R. (1994) *The potential for evolution of herbicide resistance in weed species.* Ph.D. thesis, University of Liverpool, pp 221.

Mackenzie, R.; Mortimer, A.M.; Putwain, P.D.; Bryan, I.B.; Hawkes, T.R. (1995, in press) The potential for evolution of herbicide resistance: selection, characterisation and polygenic inheritance of resistance to chlorsulfuron in perennial ryegrass. In *Herbicide resistance in weeds and crops*, De Prado (ed), Kluyer Press.

Maxwell B. D. ; Mortimer A.M. (1994) Selection for herbicide resistance In *Herbicide Resistance in Plants.* S.B. Powles and J.A. M Holtum (eds), Lewis Publishers, pp 1- 25.

Mallory-Smith, C.A.; Thill, D.C.; Dial, M.J.; Zemetra, R.S. (1990) Inheritance of sulfonylurea herbicide resistance in *Lactuca* sp. . *Weed Tech.* 4: 787-790.

Saari, L.L.; Cotterman, J.C.; Smith, W.F.; Primiani, M.M. (1992) Sulfonylurea herbicide resistance in common chickweed, perennial ryegrass, and russian thistle. *Pestic. Biochem. Physiol.* 42: 110-118.

Sweetser, P.B.; Schow, G.S.; Hutchinson, J.M. (1982) Metabolism of chlorsulfuron by plants: biological basis for selectivity of a new herbicide for cereals. *Pestic. Biochem. Physiol.* 17: 18-23.

SEED LONGEVITY OF *Bromus rubens* L. AND *Bromus rigidus* Roth.

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ABSTRACT

The seeds longevity of *Bromus rubens* and *Bromus rigidus* was investigated in order to formulate non-chemical control methods. The seeds of these species were collected and stored in cloth bags during July of the years 1988, 89, 90, 93 and 94. The seeds which were aged less than 6 years showed good germination in darkness at the temperatures 20°C, 25°C and 30°C. In the case of those of 7 years of age, however, the rates of germination were slow at 20°C but higher at 25°C and 30°C.

INTRODUCTION

The most difficult weeds to control in crops, are those which are similar to them in their morphology , physiology and ecology, and in cereals the grass weeds (belonging to the family Graminae) have assumed a great importance.

In Algeria, *B. rubens* and *B. rigidus* are becoming increasingly very important as grass weeds infesting cereals crops, and they have become the main problem to farmers. Infact, *Bromus* spp. have become very important weeds in winter cereals because of the utilization of herbicides which have reduced the incidence of other kinds of weeds and the increased use of minimum cultivation (Harradine, 1986).

In many different parts of the world e.g England, North and South America, Africa and Australia there is an increasing interest in annual Brome grasses (Mock & Amor, 1982). In N. America for example, the yield was reported to be reduced by 35% especially in the Idaho region (Massee, 1976). In Algeria and in Setif precisely, yield reductions due to *B.rigidus* were reported to be approximately 39% (Fenni, 1994).

B. rubens and *B. rigidus* are winter annuals, they germinate most rapidly between 15°C and 20°C but capable of germinating over a range from just above 0°C to greater than 30°C (Rossiter, 1966). Some *Bromus* spp. e.g. *Bromus diandrus* keep their viability even after 5 years of storage under laboratory conditions (Jauzein, 1989).

In the present work, all experiments on the viability of *B. rubens* and *B. rigidus* aged between 1 and 7 years were carried out at three different temperatures in the dark.

MATERIALS AND METHODS

The seeds of *B. rubens* and *B. rigidus* were harvested by hand from cereal fields near Setif (North East Algeria) during July of 1988, 89, 90, 93 and 94, and stored in cloth bags at ambient laboratory conditions. The experiments were carried out from April to May of 1995.

The region of Setif has a climate of cool, wet winters and warm to hot, dry summers. The average rainfall is 400 mm.

The seeds were placed in Petri-dishes on double thick filter paper kept moist with distilled water, and replicated four times. Each one contained 10 seeds and was incubated in the dark at 20°C, 25°C and 30°C. The seeds were considered germinated when the radical was visible and the observations were taken under a green soft-light. Seeds that did not germinate after 14 days of incubation were considered to be dead.

The shapes of cumulative germination curves were compared and the coefficient of velocity (CV) was calculated as follows:

$$CV = 100 \, . \, \frac{\sum Ni}{\sum Ni\,Ti}$$

Where N is the number of seeds germinated on day i and T is the number of days from sowing (Scott *et al.*, 1984).

RESULTS AND DISCUSSION

All the results showed that both *B. rubens* and *B. rigidus* seeds germinated at temperatures of 20°C, 25°C and 30°C (Figs. 1 and 2). The optimum for germination was obtained after 3 to 4 days and this was more than 60% for the seeds which were aged between 1 and 6 years but almost 100% for those which were harvested in 1990, 93 and 94. The results of *B. rubens* seeds were obtained at the three different temperatures, but those of *B. rigidus* were obtained at only two temperatures 20°C and 30°C.

In the case of the seeds which were 7 years of age, which were collected in 1988, an exception was observed. These showed very low germinations at 25°C and 30°C which were represented by 20% and 30% for *B. rigidus* and *B. rubens* seeds, respectively. The optimum germination was obtained at 20°C and was approximately 90% for *B.rigidus* and 80% for *B. rubens* .

From these preliminary results, the coefficient of velocity was found to decrease when the age increases. In general, this coefficient increases as more seeds are germinated and with shorter germination time. The lowest values of C.V were obtained from the seeds which were 7 years of age but a C.V of approximately 100% was obtained from the 1-year-old seeds. These values are represented in Fig. 3.

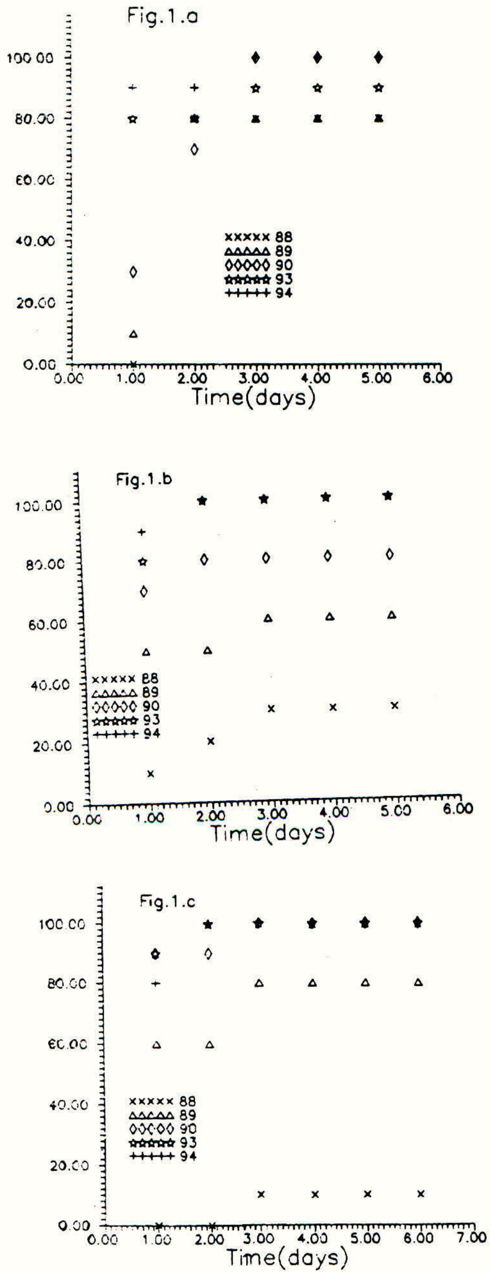

Fig. 1 Germination of *B. rubens* in dark at 20 °C (a), 25 °C (b) and 30 °C (c).

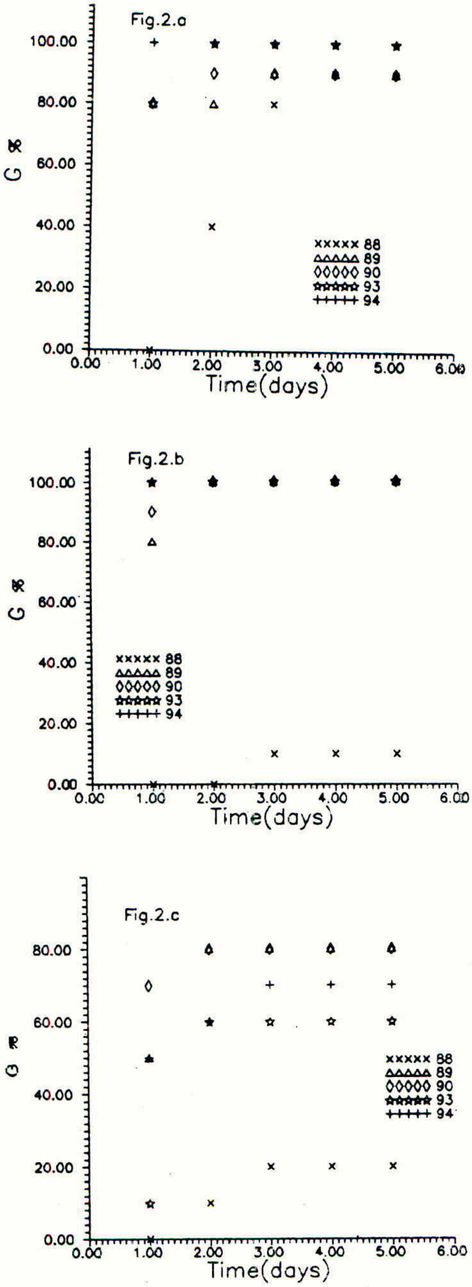

Fig. 2 Germination of *B. rigidus* in dark at 20 °C (a), 25 °C (b) and 30 °C (c).

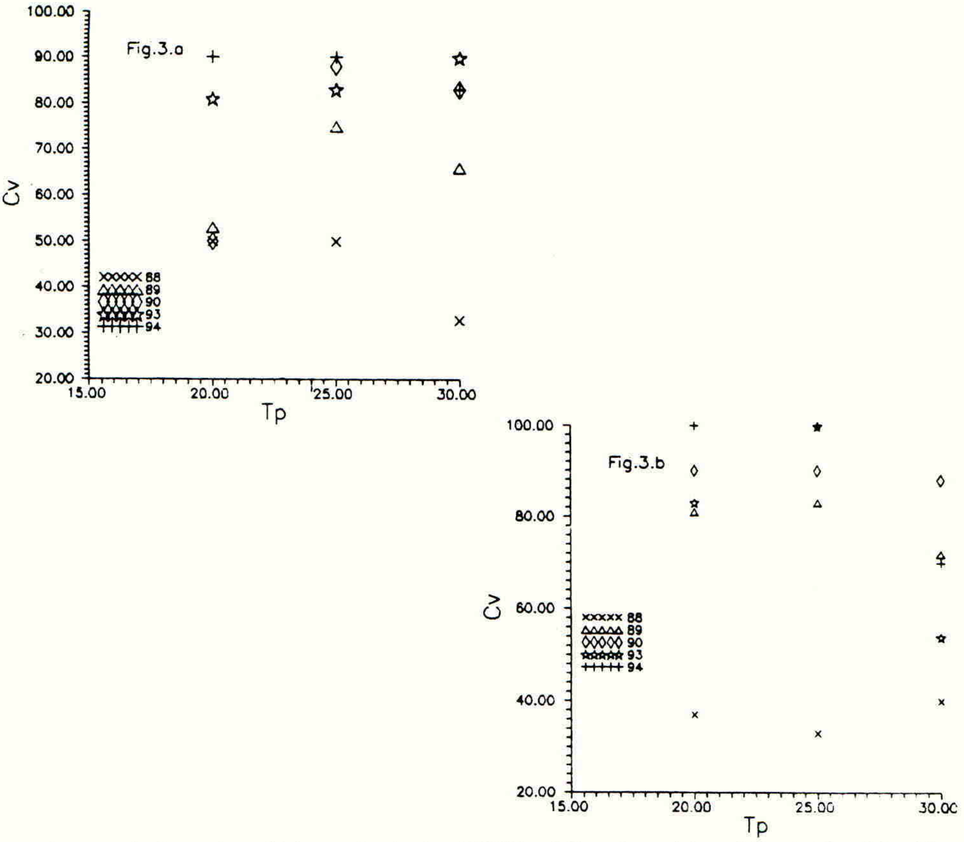

Fig.3 Variation of coefficient of velocity (CV%) of *B. rubens* (a) and *B. rigidus* (b) with temperature (°C).

Our results indicate that *B. rubens* and *B. rigidus* seeds aged 7 years show slow rates of germinations at 20°C but usually they are higher. These species, therefore, need, with age, low temperatures to germinate before they loose their viability and can be considered dead. As *Bromus* spp. seeds at the first age (less than one year) show high germination at low temperatures in dark (10°C to 20°C) (Harradine, 1986 ; Hilton, 1987 and Jauzein, 1989), in addition the time to G50 of *B. hordeaceus* which is reported to decrease when the temperatures rises from 10°C to 30°C (Flood, 1986), the question is whether seeds of these species need the same conditions as their first age to germinate.

This present work showed, therefore, that the two species keep their capacities for germination and their viability even after 7 years of storage under laboratory conditions (which are probably very similar to those applied in storage silos of cereals). They will germinate at sowing once good conditions are present (moisture and temp. 20-25°C), and these conditions prevail during autumn and early winter in the Setif region of Algeria.

REFERENCES

Fenni, M (1994) Competition between wheat (var. Mohamed Ben Bachir) and Brome grass (*Bromus rigidus* Roth). Communicated at the 5th Arab Congress of Plant Protection, November 27th- December 2nd, Fez, Morocco.

Flood, R G (1986) Germinations of soft brome (*Bromus hordeaceus*). In: *Plant Protection Quarterly* . **1(4)**, pp. 144 - 147.

Harradine, A R (1986) Seed longevity and seedling establishment of *Bromus diandrus* Roth. *Weed Research* . **(26)**, 173-180 .

Hilton, J R (1987) Photoregulation of germination in freshly-harvested and dried seeds of *Bromus sterilis* L. *Journal of Experimental Botany* . **187 (38)**, 286-292.

Jauzein, P (1989) Photosensibilité des bromes annuels (*Bromus* L.spp.). *Weed Research* . **(29)**, 53 - 63.

Massee, T W (1976) Downy brome control in dryland winter wheat with stubble-mulch fallow and seeding management. *Agronomy Journal* . **(68)**, 952-955.

Mock, I T; Amor R L (1982) Brome grasses (*Bromus* spp.) as contaminants of barley grain in the victorian Mulee. *Australian weeds* . **2 (1)**, 16-17.

Rossiter, R C (1966) The ecology of Mediterranean annual type pasture. *Advances in Agronomy* . **(18)**, 1-56.

Scott, S J; Jones R A; Williams W A (1984) Review of data analysis methods for seed Germination. *Crop Science* . **(24)**, 1192-1199.