SESSION 4C

NEW USES OF EXISTING MOLECULES

SESSION ORGANISER MR G. SANSOME

POSTERS 4C-1 to 4C-5

BAS 568 02 H AND BAS 569 02 H: TWO NEW POST-EMERGENCE HERBICIDES FOR BROAD-LEAVED WEED CONTROL IN CEREALS

S. STRATHMANN, M. LANDES, B. JUNG

BASF Aktiengesellschaft, Postfach 220, D-6703 Limburgerhof, GERMANY

ABSTRACT

The combinations of fluoroglycofen-ethyl plus dichlorprop isomer P or mecoprop isomer P (trademark: Estrad® = BAS 568 02 H and Estrad M® = BAS 569 02 H) are new selective herbicides which have been developed for post-emergence use in cereals.

Fluoroglycofen-ethyl is particularly effective against weeds which are difficult to control in cereals such as Galium aparine, Veronica spp. and Viola spp. Due to its contact activity it is very little dependent on climatic conditions which makes it an ideal partner for other herbicides like the phenoxy type herbicides.

The addition of dichlorprop-P or mecoprop-P as systemic foliar herbicides provides a wide spectrum of activity for controlling Papaver rhoeas, Stellaria media, Matricaria chamomilla, Lamium spp. and most of the cruciferous weeds including volunteer oilseed rape (Brassica napus). The optical active isomer of the phenoxy herbicides in BAS 568 02 H and BAS 569 02 H allows the use of only the active principle of these compounds and therefore contributes to a reduction in the rate of active ingredient applied under field conditions.

Because of the good crop tolerance BAS 568 02 H and BAS 569 02 H can be applied from the 3-leaf stage of the crop onwards. The relative temperature insensitivity and the wide flexibility in application timing makes both products suitable for autumn treatments as well as early and normal spring applications.

INTRODUCTION

Commercial formulations of the optical active isomer of dichlorprop and mecoprop are well established under the trademark Duplosan® in the European herbicide markets (Nuyken et al., 1987).

Fluoroglycofen-ethyl is a diphenylether herbicide which acts primarily as an inhibitor of photosynthesis and respiration (Maigrot et al., 1989). A relatively low use rate of this active ingredient is required for post-emergence weed control (20 - 40 g a.i./ha). Fluoroglycofen-ethyl acts rapidly and its herbicidal efficacy is relatively independent of temperature (Apted et al., 1989).

Fluoroglycofen-ethyl and the optical active isomer of dichlorprop or mecoprop appear to be particularly useful herbicide partners having complementary modes of action and weed spectrum (Morvan et al., 1991). The paper describes the herbicidal efficacy and crop safety of the new ready formulations BAS 568 02 H and BAS 569 02 H.

MATERIALS AND METHODS

The following formulations were used at application rates of 2.0 kg/ha each:

- o BAS 568 02 H: fluoroglycofen-ethyl + dichlorprop-isomer P (1.5 + 48.5 %, WP)
- o BAS 569 02 H: fluoroglycofen-ethyl + mecoprop-isomer P (1.5 + 48.5 %, WP).

As herbicide standards the ready formulations of bifenox + mecoprop (187.5 + 462.5 g/l, SC) at 4.0 l/ha, ioxynil + mecoprop-ester (180 + 540 g/l, EC) at 2.0 l/ha and fluoroglycofen-ethyl + triasulfuron (80 + 30 g a.i./kg, WG) at 0.5 kg/ha were utilized.

The trials reported were carried out over a period of three cereal seasons in a randomized block design with three or four replications. The plot size was 10 - 15 m^2. All applications were made using a knapsack sprayer with TeeJet 110 03 nozzles, operating at a pressure of 2.5 - 3.0 bar and a spray volume of 250 - 300 l/ha. Weed control and crop selectivity were evaluated by visual assessments based on a scale of 0 - 100 %; the 0 % stands for no weed control or crop injury whereas 100 % represents total weed control or crop loss. Yields were determined by harvesting the trials with a small plot combine.

The results in this paper are based on 138 field trials carried out with BAS 568 02 H and 56 with BAS 569 02 H respectively throughout Europe.

RESULTS

Herbicidal efficacy

As table 1 shows, the herbicidal effect is clearly improved against major cereal weeds by the addition of fluoroglycofen-ethyl to dichlorprop-P or mecoprop-P. Especially interesting appears the level of activity that was achieved in the control of Galium aparine.

TABLE 1. Complementary activity of fluoroglycofen-ethyl in combination with phenoxy type herbicides (W-Europe 1989 - 1990). ( ) = number of trials

Treatment		Trial series 1: % weed control			Trial series 2: % weed control	
kg AI/ha		BAS 568 02 H 0.03+0.97	dichlor-prop-P 1.5		BAS 569 02 H 0.03+0.97	meco-prop-P 1.5
Galium aparine	(8)	98	89	(4)	96	69
Papaver rhoeas	(4)	92	84	(2)	99	85
Polygonum aviculare	(3)	84	79	(2)	99	92
Stellaria media	(6)	98	94	(4)	100	96
Veronica hederifolia	(4)	98	93	(2)	97	58
Veronica persica	(2)	100	95	(4)	100	82

From the weed spectrum in table 2 it can be seen, that BAS 568 02 H provides good to excellent control levels of all important broadleaved weeds occurring in cereals in W-Europe. In comparison to the standard competitor, especially the superior efficacy against Galium aparine, Lamium spp. and Matricaria chamomilla should be mentioned.

TABLE 2. Weed spectrum of BAS 568 02 H compared to a standard (W-Europe 1989 - 1991). ( ) = number of trials

Treatment kg AI/ha		% weed control BAS 568 02 H 0.03 + 0.97	 bifenox + mecoprop 0.75 + 1.85
Aethusa cynapium	(2)	94	86
Arabidopsis thaliana	(3)	100	100
Capsella bursa-pastoris	(2)	96	95
Daucus carota	(2)	98	88
Fallopia convolvulus	(4)	95	96
Fumaria officinalis	(3)	100	100
Galeopsis tetrahit	(4)	100	98
Galium aparine	(48)	96	88
Lamium spp.	(8)	99	95
Matricaria chamomilla	(17)	90	83
Papaver rhoeas	(18)	92	93
Raphanus raphanistrum	(2)	98	97
Sinapis arvensis	(4)	99	96
Stellaria media	(22)	93	93
Veronica hederifolia	(25)	97	97
Veronica persica	(8)	95	93
Viola spp.	(16)	93	94

The great flexibility in application timing and the relative temperature insensitivity of BAS 568 02 H is demonstrated in table 3: With autumn treatments as well as with early or normal spring applications constantly high weed control levels were achieved. These trials show that the product can be used safely even under unfavourable weather conditions.

Besides the good performance against G. aparine and M. chamomilla, BAS 568 02 H was also superior compared to the standard in the control of S. arvensis, S. media and V. hederifolia.

TABLE 3. Timing flexibility of BAS 568 02 H for postemergence weed control in winter cereals (W-Europe 1989 - 1991). ( ) = number of trials

Timing Treatment		% weed control autumn BAS 568 *	Ref. **	early spring BAS 568 *	Ref. **	normal spring BAS 568 *	Ref. **
Galium aparine	(11)	92	84	92	90	96	88
Matricaria chamomilla	(2)	97	90	99	99	97	99
Sinapis arvensis	(2)	91	76	99	97	99	99
Stellaria media	(5)	97	94	96	95	97	93
Veronica hederifolia	(14)	92	85	94	80	93	75

* BAS 568 02 H = fluoroglycofen-ethyl + dichlorprop-P (30 + 970 g AI/ha)
**Ref. = fluoroglycofen-ethyl + triasulfuron (40 + 15 g AI/ha)

Another criterion for the stable and reliable efficacy of BAS 568 02 H under unfavourable weather conditions, like cool temperatures and rain, is the speed of efficacy (table 4). In one to two weeks after treatment the herbicidal efficacy of BAS 568 02 H was nearly complete whereas the competitor compound showed a relatively slower performance.

TABLE 4. Speed of herbicidal efficacy (France 1989 - 1990). ( ) = number of trials

Treatment kg AI/ha		% weed control (7 - 15 DAT) BAS 568 02 H 0.03 + 0.97	ioxynil + mecoprop-ester 0.36 + 1.08
Galium aparine	(16)	80	61
Matricaria chamomilla	(2)	96	73
Stellaria media	(10)	80	65
Veronica hederifolia	(10)	84	49
Veronica persica	(7)	94	77
Viola arvensis	(5)	73	18
Viola tricolor	(2)	81	48
overall weed control		84	56

To widen the herbicidal spectrum against grass weeds, tank mixtures of BAS 568 02 H with isoproturon are very interesting (table 5). Apart from excellent control of Alopecurus myosuroides, isoproturon improved simultaneously also the performance against other weeds in particular M. chamomilla and S. media.

TABLE 5. Grass and broadleaved weed control with isoproturon tank mixtures (France 1989 - 1990). ( ) = number of trials

Treatment kg AI/ha		% weed control BAS 568 02 H + IPU 0.03 + 0.97 + 1.5	BAS 568 02 H 0.03 + 0.97
Alopecurus myosuroides	(4)	98	0
Galium aparine	(5)	99	99
Matricaria chamomilla	(3)	100	93
Papaver rhoeas	(2)	99	96
Stellaria media	(3)	99	96
Veronica hederifolia	(3)	99	98
Viola arvensis	(3)	95	86
Viola tricolor	(4)	95	92

Yield results

The most important aim of using herbicides is to prevent yield losses. It can be seen in table 6 that with the use of BAS 568 02 H or BAS 569 02 H the yield of winter barley and winter wheat increased by 10 - 30 % in comparison to untreated.

TABLE 6. Effect on yield by using BAS 568 02 H and BAS 569 02 H (W-Europe 1989 - 1990). ( ) = number of trials

product/	crop	yield (t/ha) untreated		treated	
BAS 568 02 H/ (2 kg/ha)	winter-barley (8)	6.10	A	7.01	B
	winter-wheat (9)	5.89	A	7.51	B
BAS 569 02 H/ (2 kg/ha)	winter-wheat (3)	7.85	A	8.23	A

Tukey-test ($p = 0.05$)

Crop tolerance

Selectivity trials with BAS 568 02 H and BAS 569 02 H in winter barley and winter wheat demonstrated that shortly after treatment slight symptoms sometimes can appear on the cereal leaves (table 7). These little necrotic spots are only of temporary nature and grow out relatively fast. Table 8 also confirms that even under weed free conditions neither the single nor the double application rate of the product affected the cereal yield in a negative way.

TABLE 7. Crop safety: Number of trials in different crop injury classes (W-Europe 1989 -1991).

product/	crop	crop injury classes* 0 - 5 %	5 - 10 %	> 10 %
BAS 568 02 H/				
(2 kg/ha)	winter-barley	42	1	0
	winter-wheat	62	3	0
	durum	3	2	0
BAS 569 02 H/				
(2 kg/ha)	winter-barley	27	2	0
	winter-wheat	31	1	0

* assessments made 1 - 2 weeks after application

TABLE 8. Crop safety: Effect of BAS 568 02 H on yield under weed free conditions (France 1989 - 1990). ( ) = number of trials

Treatment	Yield (t/ha) untreated	BAS 568 02 H		ioxynil+mecoprop-ester		SED
application rate		1 n	2 n	1 n	2 n	
winter-barley (11)	7.10	7.18	7.17	7.30	7.01	0.57
winter-wheat (9)	8.91	8.81	8.77	8.72	8.62	0.40
durum wheat (1)	2.62	2.60	2.65	2.69	2.63	0.04

1 n = standard application rate
2 n = double application rate

CONCLUSION

Both new ready formulations BAS 568 02 H (fluoroglycofen-ethyl + dichlorprop-P) and BAS 569 02 H (fluoroglycofen-ethyl + mecoprop-P) gave excellent weed control as post-emergence treatments.

The combination of the contact herbicide fluoroglycofen-ethyl with the systemic nature of the optical active isomer dichlorprop-P or mecoprop-P showed interesting complementary activity. Especially worth mentioning are the following aspects:

- the improved level of control of a number of weed species in particular G. aparine, Veronica spp., Viola spp., M. chamomilla, P. rhoeas, P. aviculare, S. arvensis and S. media.
- the relative temperature insensitivity and hence a much better flexibility in timing of the products for treatments in autumn, early spring or normal spring.
- the high speed of activity which results in more reliable weed control under unfavourable weather conditions.

o *the better prevention of yield losses due to improved herbicidal activity (10 - 30 % yield increase compared to untreated).*

The first registrations of the new compounds in Europe are expected in France in 1992.

REFERENCES

Apted, J.E.; Cornes, D.W.; Scott, T.A.J.; Ryan, P.J. (1989) The efficacy and crop tolerance of a new herbicide formulation containing triasulfuron and fluoroglycofen-ethyl. Proceedings 1989, Brighton Crop Protection Conference-Weeds, 1, 193-198.

Maigrot, P.H.; Perrot, A.; Hede-Hauy, L.; Murray, A. (1989) Fluoroglycofen-ethyl: A new selective broadleaf herbicide for cereals. Proceedings 1989 Brighton Crop Protection Conference - Weeds, 1, 47-51.

Morvan, Y.; Panis, P.E.; Strathmann, S. (1991) Fluoroglycoféne-éthyl + Dichlorprop-P nouvelle association antidicotylédones de postlevée précode des céréales. Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent, 56

Nuyken, W.; Menck, B.-H.; Haden, E. (1987) Duplosane - die neue Generation der optisch aktiven Wuchsstoffe Dichlorprop und Mecoprop. Mededelingen van de Faculteit Landbouwwetenschappen Rijksuniversiteit Gent, 52, 1139-1146.

® *registered trademark of BASF AG, Ludwigshafen/GERMANY*

A MIXTURE OF TERBUTHYLAZINE AND CYANAZINE FOR THE CONTROL OF POA ANNUA AND BROAD-LEAVED WEEDS IN CEREALS

T.A.J.SCOTT. W.MAURER, D.CORNES, P.RYAN.

Ciba-Geigy Agrochemicals, Whittlesford UK.

ABSTRACT

Field trials undertaken between 1988 and 1991 have shown that terbuthylazine and cyanazine applied in combination (SL444) control *Poa annua* and most broad-leaved weeds. Terbuthylazine and cyanazine both have residual and contact activity, thus consistently high levels of control are achieved with application from autumn pre-emergence through to a post emergence application to established weeds in the spring. Generally weed growth stage or size has little effect on weed sensitivity to SL444. Application can be made in both the autumn or spring to winter wheat and barley and in the spring to spring wheat and barley.

INTRODUCTION

SL444 is a formulated product containing terbuthylazine(261g AI/l) and cyanazine(306g AI/l). The application rate is 1 l/ha for the contact and residual control of certain broad-leaved weeds and *Poa annua* when applied pre and post-emergence in autumn sown wheat and barley. Control of certain broad-leaved weeds is also achieved by a post-emergence spring application to autumn and spring sown wheat and barley. Both active ingredients separately, have a history of usage in UK cereals, cyanazine as 'Fortrol' (MAFF No. 00924) and terbuthylazine as a component of the previously ACAS Approved 'Mofix 500L' (terbuthylazine+bromofenoxim). (Deaville 1974)

The usage rates of cyanazine and terbuthylazine as SL444, are less than those currently or previously recommended for cyanazine and terbuthylazine (in the previously mentioned formulations).

Both cyanazine and terbuthylazine have contact and residual activity, being particularly suited for use in cereals for the control of a range of weed species at a relatively low total application rate.

In this paper results are presented and discussed for crop safety and weed control resulting from the use of SL444 or a tank-mix of terbuthylazine and cyanazine in field trials undertaken between 1988 and 1991, with applications made in the autumn/winter or spring.

MATERIALS AND METHODS

Weed control and crop safety was evaluated utilising SL444 or a tank-mix of terbuthylazine ('Gardoprim 500FW') 261g AI/l and cyanazine 306g AI/l. The tank mixture with a resolved active isomer of mecoprop ('Duplosan New System CMPP') 600g AI/l was assessed. A formulation of ioxynil+bromoxynil+cmpp (Swipe 560EC) was used as a standard treatment.

Field trials were of a randomised complete block design with three replicates and plots of 3 x 8 m for efficacy trials and four replicates and plots of 3 x 12 m for crop safety trials. All applications were made using a precision plot sprayer with 6 Lurmark F02 - 110 nozzles operating at a pressure of 207 kPa and spray volume of 200 l/ha.

Efficacy trials were carried out in commercially-grown crops utilising areas of natural weed infestation. Crop safety trials were placed in crops with low weed populations and applications were made using at least double the anticipated use rate. A range of application timings for both the crops and the weeds were evaluated to determine efficacy and safety at many growth stages (Tottman 1987) and under various environmental conditions.

Weed control was evaluated throughout the seasons by visual assessments and plant counts. Weed control is expressed on a 0-100% scale where 0 = no control and 100 = complete control. Crop safety was assessed usually as vigour, density of stand or chlorosis on a 0-100% scale where 0 = no effect and 100 = complete crop loss, in addition trials were harvested to determine grain yield using a plot combine. Statistical analysis was undertaken for yield data using a Tukey test. (data not presented)

The crop phytotoxicity data presented is the maximum observed throughout the season, weed control is from the visual assessment or plant count.

RESULTS AND DISCUSSION

Crop safety

Results are presented from applications of double rate SL444 or the tank-mix of terbuthylazine + cyanazine, in the autumn/winter to winter wheat and barley and in the spring to winter and spring wheat and barley. Crop safety data was collected from single rate applications in the weed control trials and generally crop phytotoxicity was absent or negligible.

Autumn/winter pre- emergence application to winter wheat and barley

SL444 has been applied in five trials with no crop phytotoxicity being observed. This data was obtained from single rate applications in the weed control trials.

Autumn/winter post-emergence application to winter wheat - Table 1

SL444 has been applied in sixteen trials utilising double rate applications with little or no crop phytotoxicity being observed. Where yield was determined there was no difference from the untreated. In three trials maximum phytotoxicity ratings of 11%, 12% and 14% were recorded, these were always less than those recorded for isoproturon (16%, 17% and 19%) and good recovery was observed. Where crop phytotoxicity from SL444 was recorded, it was generally as crop thinning in spring, with rarely any effect showing in the autumn. At one site in weed control trials at the recommended rate, moderate crop thinning was recorded (10%), this was associated with the degree of stone within that soil (15%) (ADAS Pamphlet 3001), otherwise phytotoxicity was either absent or negligible. There will be no recommendation for application to such soils on the product label.

Autumn/winter post-emergence application to winter barley - Table 1

In sixteen trials utilising double rate applications the phytotoxicity recorded was acceptably low or absent, yield determination indicated no difference to the untreated. In weed control trials at the recommended rate no crop phytotoxicity was recorded.

TABLE 1. SL444 crop safety (2.0 l/ha) autumn/winter

		Phytotoxicity %			Yield %		
Crop	GS at application	Number of sites	Mean	Range	Number of sites	Mean	Range
Winter wheat	11-21	16	2.5	0-14	3	100	96-100
Winter wheat* (l.0 l/ha)*	11-22	20	0.5	0-10	-	-	-
Winter barley	11-14	16	1.28	0-5	7	99.7	95-109

Soil types Sandy loam - Clay

Spring application to winter wheat and barley - Table 2

In the trials utilising double rate applications little or no phytotoxicity was observed with no effect on yield. In the twelve weed control trials at the recommended rate phytotoxicity was absent in barley and, with the exception of one site, in wheat.

Here 7% growth inhibition was recorded, this was associated with application to a very lush crop combined with a period of frosty weather immediately following treatment. This would be outside any proposed label recommendations.

Application to spring wheat and barley - Table 2

In the eight trials utilising double rate applications little or no phytotoxicity was observed. The crop phytotoxicity (8%) at one spring wheat site (double rate application) was associated with extreme manganese deficiency and was never any worse than standard or co-operators treatments. In weed control trials at the recommended rate, phytotoxicity was absent in barley and wheat.

TABLE 2. SL444 crop safety (2.0 l/ha) in the spring

		Phytotoxicity %			Yield %		
Crop	GS at application	Number of sites	Mean	Range	Number of sites	Mean	Range
Winter wheat	22-30	5	2.4	0-7	2	98	96-100
Winter wheat* (1.0 l/ha)*	21-32	8	0.9	0-7	-	-	-
Winter barley	22-32	5	0.6	0-1	2	100	100
Spring wheat	23-31	4	2	0-8	-	-	-
Spring barley	23-31	4	0	0	-	-	-

Soil Types Sandy loam - Clay (+Organic)

Weed control - Tables 3, 4, 5 and 6

SL444 or the tank-mix of terbuthylazine and cyanazine has been tested over a four year period in winter and spring cereals, applied in the autumn/winter or spring. SL444 has achieved excellent control of *Poa annua* and most major broad-leaved weeds species, these being controlled from pre-emergence (limited data) and early post-emergence application through to a spring post emergence application to established weeds (Table 3). Excellent control of *Matricaria spp.*, *Papaver rhoeas*, *Stellaria media* and *Veronica persica* was achieved at all application timings.

TABLE 3. The effect of application timing 1988-1991 (Major weeds)

SL444 (1.0 l/ha)	% Weed Control							
	Winter cereals						Spring cereals	
Weed	Pre-em. (autumn)		Post-em. (autumn)		Post-em. (spring)		Post-em. (spring)	
Poa annua	81	(2)	99	(8)	93	(3)	100	(1)
Poa trivialis		-	92	(4)	89	(1)		-
Galium aparine	77	(1)	35	(11)	72	(7)	70	(2)
Matricaria spp.	99	(3)	99	(12)	99	(6)	96	(1)
Papaver rhoeas	100	(1)	100	(8)	99	(6)	100	(3)
Sinapis arvensis	93	(2)	95	(4)	100	(2)	99	(2)
Stellaria media	98	(2)	99	(15)	98	(8)	99	(6)
Veronica hederifolia		-	84	(10)	100	(2)		-
Veronica persica	98	(4)	99	(10)	98	(7)	99	(6)
Viola arvensis	95	(2)	97	(9)	85	(7)	94	(4)

(-) = number of sites

Control of *Galium aparine* proved variable, good control was limited to the control of small, shallow rooted plants or those within dense crops. The addition of mecoprop in tank mixture allows complete control to be achieved. *Viola arvensis* is controlled from autumn/winter application, but in the spring some larger over wintered plants proved less sensitive, the addition of mecoprop enables good control of *Viola arvensis* to be maintained (Table 4).

TABLE 4. SL444 + mecoprop (tank mixture) spring 1991

Compound	GS	Number of sites	SL444	SL444+ mecoprop R	ioxynil+bromoxynil +cmpp
Dose (g AI/ha)			261+306	(261+306)+600	252+252+2016
Galium aparine	23-29	(4)	66	99	100
Viola arvensis	14-21	(4)	95	97	83

SL444 has been applied at forty nine activity sites and numerous weed species have been encountered and at varying growth stages. SL444 has consistently displayed high levels of broad-leaved weed control. The results presented in Table 5 have been collated from all application timings.

TABLE 5. Broad-leaved weed control (Mean results from 1989-1991)

SL444 (1.0 l/ha)	Number of sites	Mean %	Range
Aethusa cynapium	3	91	(81-100)
Alchemilla arvensis	5	99	(97-100)
Anagallis arvensis	7	100	100
Capsella bursa pastoris	4	100	100
Chenopodium album	5	98	(93-100)
Fumaria officinalis	6	100	100
Galium aparine	23	54	(0-100)
Geranium dissectum	1	100	100
Lamium purpureum	1	100	100
Lamium amplexicaule	1	100	100
Legousia hybrida	2	99	(97-100)
Matricaria spp.	23	99	(93-100)
Melandrium album	4	100	100
Myosotis arvensis	9	99	(97-100)
Papaver rhoeas	20	99	(98-100)
Polygonum aviculare	7	92	(73-100)
Polygonum convolvulus	9	96	(75-100)
Polygonum persicaria	2	100	100
Rumex obtusifolius	1	92	92
Senecio vulgaris	4	83	(72-100)
Sinapis alba	2	99	(98-100)
Sinapis arvensis	10	96	(83-100)
Stellaria media	34	99	(83-100)
Veronica hederifolia	13	88	(53-100)
Veronica persica	35	98	(78-100)
Vicia faba	1	96	96
Viola arvensis	25	92	60-100)

SL444 offers control of *Poa annua* and valuable activity on *Poa trivialis*. Optimum activity is achieved from early autumn post-emergence application (Table 6).

TABLE 6. Grassweed control (Mean results from 1989-1991)

		Final % Weed Control			
SL444 (1.0 l/ha)	Crop/situation	Application Timing	Number of sites	Mean %	Range
Poa annua	Autumn	Pre-em.	2	81	(80-82)
		Pre-em.*	2	95	(93-96)*
	Autumn	Post-em.	10	99	(95-100)
	Spring	Post-em.	3	93	(82-99)
	Spring cereals	Post-em.	1	100	100
Poa trivialis	Autumn	Post-em.	4	92	(78-100)
	Spring	Post-em.	1	89	89

* Assessment at spring regrowth

DISCUSSION

Double rate SL444 or the tank-mix of terbuthylazine and cyanazine was tested over a two year period on many varieties of winter and spring wheat and barley at growth stages from 11 - 32, a range of soil types and weather conditions being encountered. Usually phytotoxicity was absent, however where it did occur, the degree was invariably less than that caused by the approved standard treatment.

Recommended rate applications over a four year period in weed control trials also generally resulted in little or no phytotoxicity. Crop thinning occurred in winter wheat at one site after an early autumn application on a very stoney soil (15%). This damage was not observed with spring application on similar soils. The damage may have been associated with crop growth stage or more possibly with the degree of crop and weed cover at the time of application. In the spring, a dense crop and weed canopy would intercept much of the chemical so preventing it from reaching the soil. In the autumn and winter when crop and weed canopy is minimal (especially in wheat) and when most rainfall occurs there is a greater chance of chemical leaching through the soil profile and reaching crop roots, especially if heavy rainfall occurs after a period of soil moisture deficit.

SL444 (1.0 l/ha) or the tank-mix of terbuthylazine and cyanazine provided control, pre-emergence or post-emergence of a wide range of broad-leaved weeds and *Poa annua*. In common with all herbicides where root uptake contributes to weed control, very dry conditions after application can reduce the final level of control obtained. This was apparent from applications made during the dry winter of 1989/90 where the degree of control was more variable than 1988/89 or the late winter/spring of other years. In spring cereals weed control can be marginally lower than for the equivalent autumn timing given the same weed and similar growth stage, due to lack of soil moisture. In general, however, good weed control, both contact and residual was observed during the four years of testing, with the formulated product and tank-mix giving similar levels of activity.

Speed of activity is likely to be more rapid than with some commercial standards (sulfonylureas) though slower than hormone type herbicides. Post emergence application of SL444 may prove to be more reliable against *Veronica hederifolia* than pre-emergence applications. Although no data is presented from pre-emergence applications some germination of this weed subsequent to post-em applications, in effect a pre-emergence application to these weeds, reduced the final level of control. Weed control in winter cereals can be marginally reduced following applications made in the late spring to certain species (*Viola arvensis*), however a tank mixture with mecoprop ensures excellent control of weeds even at advanced growth stages. Significant grassweed activity can be claimed with *Poa annua* being controlled with post-emergence autumn/winter application (one leaf until early tillering) and satisfactory control being obtained from pre-emergence and spring applications. Interim results showed acceptable control of *Poa annua* from pre-emergence application, although final results showed slightly reduced control, which suggests a late subsequent germination is possible after a pre-emergence application of SL444. *Poa annua* may be sensitive to SL444 in spring cereals (only limited data available), soil moisture levels would however appear to be significant for the control of this weed in the spring. The sensitivity of *Poa trivialis* to SL444 in the autumn varies from season to season and weather conditions may be of more importance than growth stage at application and so this would have to be classifieded as moderately susceptible.

CONCLUSION

SL444 gave excellent control of *Poa annua* and most broad-leaved weeds. Application can be made from pre-emergence through to the spring in winter cereals and also post-emergence in spring cereals. A high degree of crop safety is generally achieved, but SL444 should not be used on 'very stoney soils' (15%), or on very lush crops in the spring. SL444 allows full rotational flexibility with no restrictions on following crops.

REFERENCES

Tottman, D.R. (1987) The decimal code for the growth stages of cereals, with illustrations. Annals of Applied Biology, 110, 441-454.

Deaville, P. (1974) Bromofenoxim + terbuthylazine - A new contact herbicide combination for broad-leaved weed control in spring cereals Proceedings 12th British Weed Control Conference 143-150.

ADAS MAFF Soil Texture (85) SYSTEM and pesticide use Pamphlet 3001.

DPX-E9636, EXPERIMENTAL SULFONYLUREA HERBICIDE FOR POTATOES

H. REINKE, A. ROSENZWEIG

Du Pont de Nemours (France) SA

J. CLAUS

E.I. Du Pont de Nemours and Company Inc., Wilmington, DE, USA

M. KREIDI

Du Pont de Nemours (Deutschland) GmbH

C. CHISHOLM

Du Pont (U.K.) Limited

P. JENSEN

Du Pont De Nemours (Agro) A/S Denmark

ABSTRACT

(DPX-E9636 (1-(4,6-dimethoxypyrimidin-2-yl)-3-(ethylsulfonyl-2-pyridylsulfonyl)urea) is a selective post-emergence herbicide for the control of certain annual and perennial grasses and broad-leaved weeds in potato crops.

To date, toxicological and environmental fate studies conducted with DPX-E9636 show favourable results. The low dosage of 7.5-15g AI/ha + surfactant provides control of grasses such as *Elytrigia repens*, *Echinochloa crus galli*, *Poa annua*. A range of important broad-leaved weeds such as *Sinapis* spp, *Galium aparine*, *Matricaria* spp, *Stellaria media*, *Amaranthus* spp are very sensitive. Flexible crop rotation is anticipated due to the low AI rate and rapid degradation of DPX-E9636.

INTRODUCTION

DPX-E9636 was first introduced at the Brighton Crop Protection Conference in 1989 (Palm et al., 1989) as a post-emergence herbicide in corn. The active ingredient has since been registered under the trademark 'Titus' in some countries in Europe. Further development has shown selectivity on some *solanaceous* crops. Field development tests over the last 5 years in *solanaceous* crops has been concentrated mainly on potatoes. DPX-E9636 has demonstrated excellent control of annual and perennial grasses as well as a range of broad-leaved weeds with good crop selectivity.

DPX-E9636 shows excellent results of weed control post-emergence in potatoes. Special situations for weed germination will allow a late pre-emergence application or a split treatment.

FATE IN SOIL AND THE ENVIRONMENT

DPX-E9636 degrades very rapidly via chemical pathways and hydrolysis. Microbial degradation plays a minor role. The rate of degradation of DPX-E9636 is affected by soil pH. The compound is most stable at neutral pH and degrades more rapidly in alkaline and acidic soils. Increasing temperature increases degradation in soils. The Laboratory Residue Bioassay (LRBsm) (Strek et al.) for detection of residues indicated no risks to following crops. (Strek et al., 1989)

The relatively low temperature in Nordic potato fields may suggest slower degradation than in southern and central European areas. The disappearance of DPX-E9636 in Danish soils was therefore studied in a number of tests to investigate following crop safety under suspected adverse conditions.

In laboratory residue bioassays, DPX-E9636 has been demonstrated to remain active on test plants of lentils during four to five months after treatment. As lentils are extremely sensitive to DPX-E9636, the laboratory method includes a high degree of safety margin, when used to predict a field re-crop situation.

Figure 1 illustrates partly the results from standard curve in light sandy soil typical for growing potatoes in Denmark and partly the LRBsm results from soil samples collected from potato fields test applied with DPX-E9636 at single treatment of 15 grams active ingredient per hectare compared with split treatment of 7.5 + 7.5 g AI/ha. The standard curve is determined by growing lentils in soil mixed with known concentrations of DPX-E9636 and measuring the lentil root inhibition at each selected concentration.

The results furthermore indicate that DPX-E9636 disappears faster in the soil when applied as a split treatment rather than as a single application. More research is in progress to determine rotational crop intervals.

MODE OF ACTION AND SELECTIVITY

DPX-E9636, like other sulfonylurea herbicides, inhibits cell division and growth by inhibiting the plant enzyme acetolactate synthase thereby blocking branched chain amino acid biosynthesis. The initial symptoms of DPX-E9636 activity is observed in meristematic tissues of treated sensitive plants.

Selectivity is based upon the differential rate of metabolism of the active compound into inactive metabolites in potatoes as opposed to sensitive weed species. Potato cultivars have shown good tolerance at rates up to 140 g AI/ha.

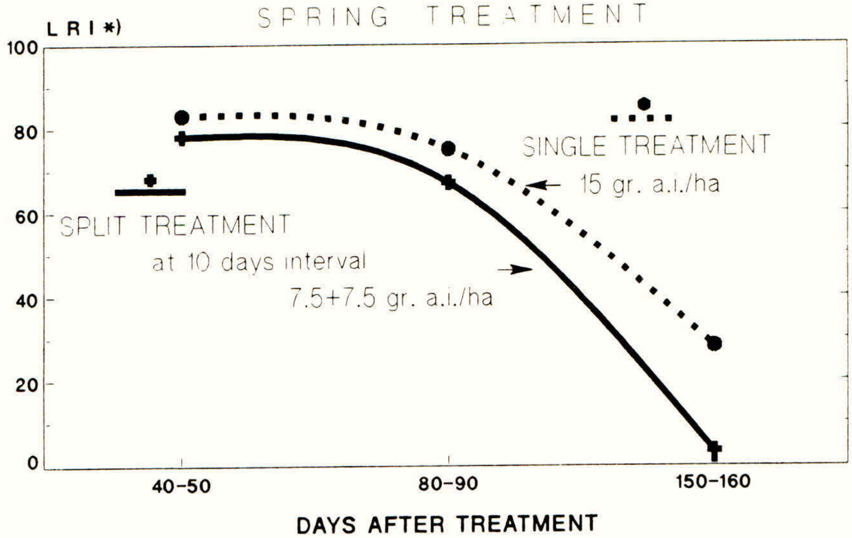
Field tests were undertaken using a range from 7.5-100 g AI/ha with surfactant. Young active growing annual weeds are much more sensitive to DPX-E9636.

Generally, young leaves of potatoes are more sensitive to DPX-E9636 than older ones, so newly emerged potatoes tend to be more sensitive.

FIGURE 1

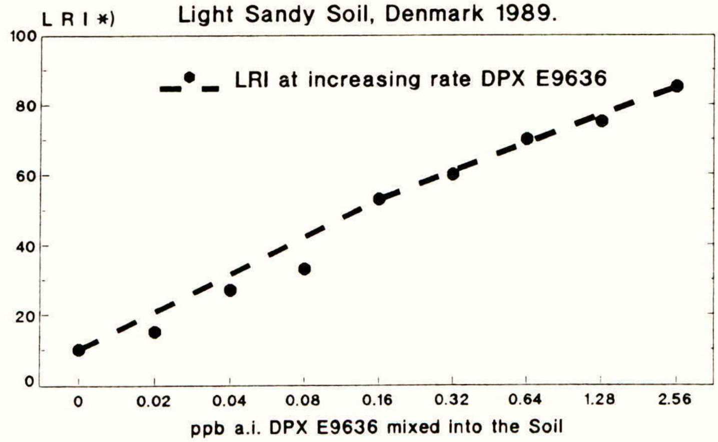
DPX E9636

Degradation in Danish Soil 1989



LRB(sm) STANDARD CURVE

Light Sandy Soil, Denmark 1989.



Soil: pH=7.2, Sand=87%, Silt=5%, Clay=5%, Humus=2.6%

**) L R I = LENTIL ROOT INHIBITION IN PERCENT OF UNTREATED CHECK*

Early treatments plus surfactant require lower rates up to 25 g AI/ha to be selective, later treatments are safe up to 100 g AI/ha (Figure 2a). The symptoms disappear within 30 days after treatment (Figure 2b). Climatic conditions that decrease the rate of metabolism in potatoes strongly, can cause some yellowing mainly on young leaves, that disappears within a short time when the situation is more favourable for the crop again.

FIELD PERFORMANCE

A wide spectrum of control of broad-leaved weeds, annual and perennial grasses has been observed in field tests (Table 1).

TABLE 1

Weed spectrum of DPX-E9636

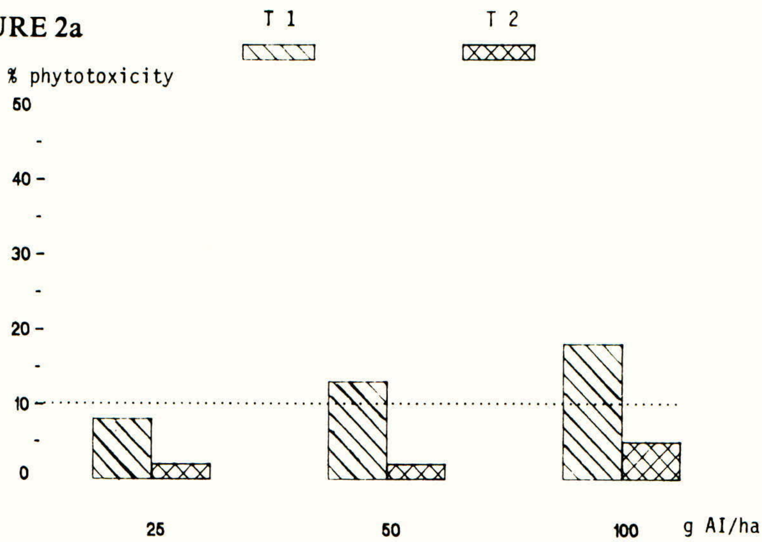
Grasses	Broad-leaved species
Alopecurus myosuroides	*Amaranthus hybridus*
Avena fatua	*Amaranthus retroflexus*
Digitaria sanguinalis	*Capsella bursa-pastoris*
Echinochloa crus-galli	*Chenopodium album*
Elymus repens	*Chenopodium ficifolium*
Elytrigia repens	*Diplotaxus erucoides*
Lolium multiflorum	*Fallopia convolvulus*
Panicum dichotomiflorum	*Galeopsis* spp
Panicum miliaceum	*Galinsoga parviflora*
Poa annua	*Galium aparine*
Setaria faberi	*Lamium* spp
Setaria glauca	*Matricaria* spp
Setaria viridis	*Mercurialis annua*
	Papaver rhoeas
	Polygonum lapathifolium
	Polygonum persicaria
	Raphanus raphanistrum
	Sinapis arvensis
	Solanum nigrum
	Solanum ptycanthum
	Solanum sarrachoides
	Stellaria media
	Thlaspi arvense
	Urtica urens
	Vicia spp
	Viola arvensis

Adjuvants such as surfactants or crop oil concentrates are essential for consistency of weed control and maximising the activity on certain species. Surfactants were used at rates of 0.1-25% v/v.

Annual grasses are generally most sensitive prior to tillering. Similarly, the efficacy on such sensitive broad-leaved weeds as *Sinapis* spp, *G. aparine*, *Matricaria* spp, *S.media*, *A.retroflexus* is greater when

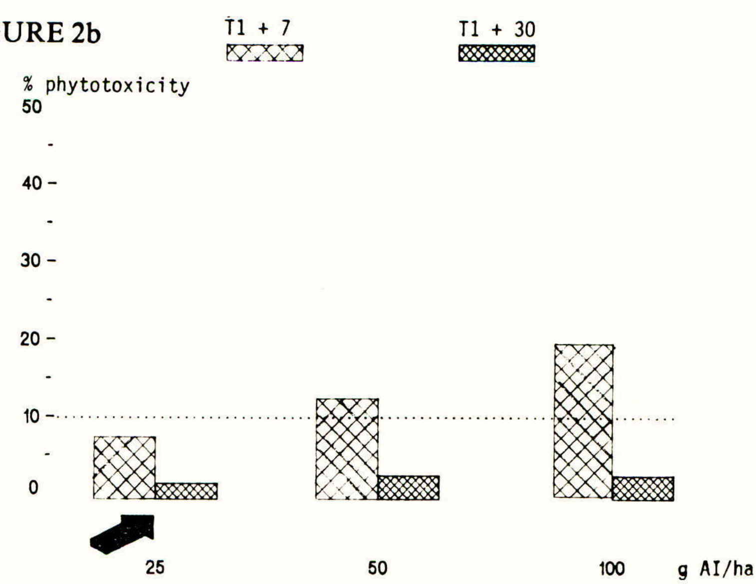
SELECTIVITY OF DPX-E9636 IN POTATOES

FIGURE 2a



Treatments incl. 0,1 % surfactant, interval T1 - T2 23 days
assessments 7 DAT

FIGURE 2b



Assessment of early timing (T1) 7 and 30 DAT

Dame Marie Research Farm 1988

they are small. Perennial grasses need to have enough growth and number of shoots to absorb the active ingredient, e.g. 10-20 cm is appropriate for Elytrigia repens.

7.5-15 g AI/ha plus surfactant provided good to excellent control of key weeds post-emergence to potatoes.

As perennial grasses emerge very late and need more shoots for optimal control, DPX-E9636 applied as a split application has provided the best control.

Earlier emerging Poa annua is controlled at a high level at all early applications.

Late emerging Elytrigia repens needs a later spray for good control. This timing would not be optimal for advanced P.annua. Split application provides good control of Poa annua and Elytrigia repens and needs about half the total rate of an early single application for satisfactory control of both grasses (Table 2).

TABLE 2

Efficacy (% of untreated) of different rates and applications of DPX-E9636 on an annual and perennial grass weed.

		g AI/ha	P.annua	Elytrigia repens
1)	DPX-E9636	30	97	79
	DPX-E9636	25	95	74
	DPX-E9636	20	92	65
	DPX-E9636	15	95	57
2)	DPX-E9636	2x15	85	74
	DPX-E9636	2x7.5	85	79

2 parallel tests:

1) early application, 2) early application, followed by second treatment.

Torpe Research Farm 1989

The use of DPX-E9636 had no influence on yield or tuber quality. Tubers from previously treated potatoes showed that at rates up to 140 g AI/ha no visible differences vs untreated ones and no differences in seed potato quality vs control.

DISCUSSIONS AND CONCLUSIONS

DPX-E9636 is a new low rate product for grass and broad-leaved weed control in potatoes. Data from the registration package in corn shows favourable toxicology, no bioaccumulation, no risk to ground water or the environment as a whole when used at recommended rates and with good agricultural practice. There are no anticipated rotation restrictions or ploughing requirements because of rapid degradation of the active ingredient and its metabolites in the soil.

DPX-E9636 had no influence on tubers visibly and reproductively at all rates tested, even when some phytotoxicity was observed on young potato leaves at high rates or very early treatments. It was also equally safe on all varieties tested, an important advantage for post-emergence herbicides in potatoes.

In the small spectrum of registered products in potatoes, DPX-E9636 is considered as an improvement for weed control of problem weeds like G. aparine, Crucifera spp, Matricaria spp, S.media, Amaranthus spp and a broad range of grasses including Elytrigia repens.

Single and split post-emergence applications allow the farmer the flexibility to target weeds when they appear. Weed control in potatoes will be improved with DPX-E9636.

REFERENCES

Palm, H. L.; Liang, P. H.; Fuesler, T. P.; Leek, G. L.; Strachan, S. D.; Wittenbach, V. A.; Swinchatt, M. L. (1989): New low rate sulfonylureas for post-emergence weed control in corn. Brighton Crop Protection Conference - Weeds 1989 1, 23-28.

Beyer, E. M.; Duffy, M. J.; Hay, J. V.; Schlueter, D. D. (1988) Herbicides: Chemistry, Degradation, and Mode of Action, Vol 3, pp. 117-190.

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. Pesticide Biochemistry and Physiology 17, 18-23.

Strek, H. J.; Burkhart, D. C.; Strachan, S. D.; Peter, C. J.; et al. (1989): Use of bioassays to characterise the risk of injury to following crops by sulfonylurea herbicides. Brighton Crop Protection Conference - Weeds 1989 1, 245-250.

WEED CONTROL WITH PROSULFOCARB IN POTATOES

C. HEMMEN, M. KONRADT

Deutsche ICI, Agro Division, 6000 Frankfurt/Main 50, Germany

ABSTRACT

Prosulfocarb was tested in Germany in 1990 and 1991 for weed control in potatoes with a view to registration.
The product proved to be particularly effective against *Galium aparine* but other major weeds were also controlled well including *Stellaria media*, *Solanum nigrum*, *Galeopsis tetrahit*.
Mixtures with metribuzin or metobromuron performed well against *Polygonum species*, *Matricaria species and Chenopodium album*.
At the suggested rate of 4000 g AI/ha prosulfocarb showed excellent selectivity in potatoes just before or at emergence.

INTRODUCTION

Prosulfocarb was announced for the first time at the Brighton Conference of 1987 *(Glasgow et al, 1987)*. The first aim was to develop the product for weed control in cereals based on a reliable activity against *Galium aparine* and other important weeds.

After several years of field studies an EC of 800 g/l was registered under the trade name "*Boxer*". The registered dose rate in winter barley, winter rye and winter wheat for use in pre emergence and early post emergence is 5 l/ha equivalent to 4000 g AI/ha.

Prosulfocarb is in line with the German environmental requirements, in so far as there is no water catchment restriction and no soil carry over effect.

These considerations led to the development of the compound in potatoes (*Konradt* and *Hemmen* 1991; *Brendler* 1991, *Kees* 1991)

MODE OF ACTION

When applied to the soil prosulfocarb is absorbed by the germinating weed seedlings which are usually killed before emergence. Seedlings of some species may die after emergence. The compound inhibits the lipoid synthesis thus inducing a change in the cell membrane followed by a collapse of the plant.

Prosulfocarb belongs to the chemical group of thiocarbamates, but in contrast to most other thiocarbamates the compound is of low vapour activity. Therefore incorporation after treatment is not required and the product is used pre- or early post-emergence of weeds and cereal crops.

MATERIALS AND METHODS

Trials have been carried out in 1990 and 1991 throughout the main potato growing areas in West Germany on a wide range of potato varieties. Prosulfocarb has been used in all trials as an EC formulation containing 800 g/l of active ingredient at rates varying from 2400 to 4000 g/ha AI. The product was used at reduced dose rates in tank mixtures or spraying sequences with metribuzin or metobromuron. As a standard for comparison flurochloridone was used.

All trials were conducted in randomised blocks with 4 replicates and a plot size of 2.5 x 10 m.

Several assessments were undertaken, only the last one will be presented. The assessment date will be reported as "days after third treatment" (DAT3).

The most important weeds occurring in the described trials were *Galium aparine, Chenopodium album* and *Polygonum species*, to a lesser extent *Matricaria species*, *Stellaria media*, *Viola tricolor*. Therefore only assessments of the most important species will be presented.

RESULTS

In trials carried out prior to 1990 the best application time was at emergence or just before emergence of the potatoes. Earlier treatments were shown to have less residual effect. Post emergence treatments have to take into account a decrease in selectivity especially after dilution of the cuticle on leaves by rain giving a reduced activity on weeds having passed the cotyledon stage or *G. aparine* having reached the third whorl. Therefore the application time for prosulfocarb in the trials presented was at emergence of the potatoes.

1990 trials

In 1990 trials it appeared that prosulfocarb at 4000 g AI/ha gave reliable control of *G. aparine* (Table 1). Only in the Schleswig Holstein trial did the product show some weakness against *G. aparine* due to dry conditions after application. In mixture with metribuzin or metobromuron a reduction of the dose rate of prosulfocarb to 3200 or 2400 g/ha was possible.

Under the drought conditions in Schleswig Holstein during spring 1990 the tank mixture of prosulfocarb + metribuzin performed better than the spraying sequence prosulfocarb/metribuzin. Apparently the tank mixture had a cumulative effect on *G. aparine*. In the 1990 trials prosulfocarb was slightly superior on *G. aparine* than the standard flurochloridone.

Table 1

Control of Galium aparine in potatoes (%) 1990

Treatment (g AI/ha)	Trial Schleswig-Holstein Assessment 13 DAT 3	Trial Lower Saxony Assessment 13 DAT 3	Trial Bavaria Assessment 4 DAT 3
1. Untreated (weed cover % total/species)	25/10	-/9	90/10
2. T1: flurochloridone 625	88.75	95.00	99.25
3. T1/T3: prosulfocarb 3200/metribuzin 210	85.00	99.00	100.00
4. T2: prosulfocarb 4000	80.00	98.00	99.75
5. T2: prosulfocarb 2400 + metribuzin 350	97.50	MV	100.00
6. T2: prosulfocarb 3200 + metribuzin 350	95.00	98.00	100.00
7. T2: prosulfocarb 2400 + metobromuron 1000	100.00	MV	100.00
8. T2: prosulfocarb 3200 + metobromuron 750	100.00	90.00	100.00

T 1 = 10 days after plantation

T 2 = at emergence of potatoes

T 3 = 10 cm height of potatoes

m.v. = missing value

Table 2

Control of Chenopodium album in potatoes (%) 1990

Treatment (g AI/ha)	Trial Baden-Württemberg Assessment 13 DAT 3	Trial Bavaria I Assessment 4 DAT 3	Trial Bavaria II Assessment 18 DAT 3
1. Untreated (weed cover % total/species)	-/5	90/20	7/28
2. T1: flurochloridone 625	100.00	99.25	99.75
3. T1/T3: prosulfocarb 3200/metribuzin 210	100.00	100.00	100.00
4. T2: prosulfocarb 4000	100.00	94.25	96.50
5. T2: prosulfocarb 2400 + metribuzin 350	100.00	100.00	99.75
6. T2: prosulfocarb 3200 + metribuzin 350	100.00	100.00	100.00
7. T2: prosulfocarb 2400 + metobromuron 1000	100.00	100.00	100.00
8. T2: prosulfocarb 3200 + metobromuron 750	100.00	100.00	100.00

The 1990 assessment of *Chenopodium album* (Table 2) showed good performance from tank mixes based on prosulfocarb and metribuzin or metobromuron and from the spraying sequence prosulfocarb/metribuzin. In some trials prosulfocarb alone was somewhat inferior depending on the degree of weed infestation.

Table 3

Control of Polygonum convolvulus in potatoes (%) 1990

Treatment (g AI/ha)	Trial Schleswig-Holstein Assessment 13 DAT 3	Trial Baden-Württemberg Assessment 13 DAT 3	Trial Bavaria Assessment 4 DAT 3
1. Untreated (weed cover % total/species)	25/30	-/8	90/15
2. T1: flurochloridone 625	77.50	100.00	81.75
3. T1/T3: prosulfocarb 3200/metribuzin 210	82.50	100.00	99.50
4. T2: prosulfocarb 4000	75.00	100.00	94.00
5. T2: prosulfocarb 2400 + metribuzin 350	98.75	100.00	98.75
6. T2: prosulfocarb 3200 + metribuzin 350	100.00	100.00	100.00
7. T2: prosulfocarb 2400 + metobromuron 1000	100.00	100.00	100.00
8. T2: prosulfocarb 3200 + metobromuron 750	100.00	100.00	100.00

T 1 = 10 days after plantation

T 2 = at emergence of potatoes

T 3 = 10 cm height of potatoes

Mixtures based on prosulfocarb + metribuzin or metobromuron performed well against *Polygonum convolvulus* (Table 3). In mixture with metribuzin the minimum rate for prosulfocarb giving acceptable weed control was 3200 g/ha while in mixture with metobromuron it was 2400 g/ha. Prosulfocarb alone may give an excellent control depending on soil moisture. Under dry conditions like in Schleswig Holstein in spring 1990 efficacy against *Polygonum convolvulus* may decrease.

<u>1991 trials</u>

Despite the adverse effects (dry conditions) prosulfocarb performed well in 1991 against *G. aparine* at the dose rate of 4000 g/ha (Table 4). Lower rates (3200/2400 g/ha) gave a reduction in efficacy under difficult conditions (Schleswig Holstein trial). Results obtained in 1991 against *G. aparine* were similar to those of 1990.

Table 4

Control of Galium aparine in potatoes (%) 1991

Treatment (g AI/ha)			Trial Bavaria Assessment 20 DAT 3	Trial Schleswig-Holstein Assessment 20 DAT 3	Trial Lower Saxony Assessment 28 DAT 3
1.	Untreated (weed cover % total/species)		10/90	40/23	14/64
2.	T1:	flurochloridone 750	90.00	63.75	45.00
3.	T1:	prosulfocarb 4000	99.00	93.75	95.33
4.	T2:	prosulfocarb 3200	99.00	87.50	98.00
5.	T2:	prosulfocarb 2400	97.00	71.25	95.67
6.	T2/T3:	prosulfocarb 3200 / metribuzin 350	100.00	95.00	97.33
7.	T2:	prosulfocarb 3600 + metribuzin 350	100.00	95.00	99.00
8.	T2:	prosulfocarb 3200 + metobromuron 500	99.00	91.25	98.33

T 1 = 10 days after plantation

T 2 = at emergence of potatoes

T 3 = 10 cm height of potatoes

Under the conditions of 1991 prosulfocarb failed against *Chenopodium album* (Table 5) except for one trial carried out in Bavaria under more favourable conditions (rainfall). Reliable control of this species was possible with tank mixes of metribuzin or metobromuron or with a treatment of 3600 g/ha prosulfocarb at emergence or just before emergence followed by 350 g/ha of metribuzin at post-emergence.

Table 5

Control of Chenopodium album in potatoes (%) 1991

Treatment (g AI/ha)			Trial Schleswig Holstein Assessment 20 DAT 3	Trial Bavaria Assessment 14 DAT 3
1.	Untreated (weed cover % total/species)		40/11	6/21
2.	T1:	flurochloridone 750	92.50	86.67
3.	T1:	prosulfocarb 4000	75.00	94.67
4.	T2:	prosulfocarb 3200	76.25	90.00
5.	T2:	prosulfocarb 2400	62.50	98.00
6.	T2/T3:	prosulfocarb 3200 / metribuzin 350	98.75	99.67
7.	T2:	prosulfocarb 3600 + metribuzin 350	97.50	100.00
8.	T2:	prosulfocarb 3200 + metobromuron 500	97.50	99.67

T 1 = 10 days after plantation

T 2 = at emergence of potatoes

T 3 = 10 cm height of potatoes

The same observations were made for *Polygonum species* where complete control with prosulfocarb was not possible in 1991. However, under wet conditions (Bavaria) excellent results where achievable with prosulfocarb alone as well as with mixtures based on metribuzin and metobromuron (Table 6).

Table 6

Control of Polygonum spp. in potatoes (%) 1991
(Polyg. persicaria, Polyg. aviculare, Polyg. convolvulus)

Treatment (g AI/ha)			Trial Schleswig-Holstein Assessment 20 DAT 3	Trial Lower Saxony Assessment 28 DAT 3	Trial Bavaria Assessment 14 DAT 3
1.	Untreated (weed cover % total/species)		8/11	14/10	90/10
2.	T1:	flurochloridone 750	76.25	50.00	94.00
3.	T1:	prosulfocarb 4000	66.25	100.00	97.67
4.	T2:	prosulfocarb 3200	56.25	76.67	98.00
5.	T2:	prosulfocarb 2400	47.500	66.67	94.00
6.	T2/T3:	prosulfocarb 3200 / metribuzin 350	87.500	83.33	100.00
7.	T2:	prosulfocarb 3600 + metribuzin 350	92.50	76.67	99.67
8.	T2:	prosulfocarb 3200 + metobromuron 500	95.00	83.33	98.33

T 1 = 10 days after plantation

T 2 = at emergence of potatoes

T 3 = 10 cm height of potatoes

CONCLUSION

From trials carried out in potatoes during 1990 and 1991 it can be concluded that the dose rate of prosulfocarb should not be below 3600 g/ha if applied alone. This covers weed species like *Galium aparine, Solanum nigrum, Galeopsis tetrahit, Stellaria media.*

Prosulfocarb showed reliable control of *Galium aparine*. Against *Polygonum species, Matricaria species* and *Chenopodium album* there may be a reduction in efficacy under dry conditions. These species were well controlled with tank mixtures of 3200 g/ha of prosulfocarb and 350 g/ha metribuzin or 1000 g/ha metobromuron.

The years 1990 and 1991 were characterized by dry conditions in spring time at most trial locations. The pre-emergence activity of prosulfocarb like for all soil herbicides is strongly dependent on soil moisture to achieve reliable weed control. This uncertainty is compensated by adding mixing partners like metribuzin or metobromuron. However when applied after emergence of part of the weeds the herbicidal effect is less dependent on soil moisture.

Table 7

Spectrum of activity of prosulfocarb and prosulfocarb mixtures in potatoes

	prosulfocarb 4000 g/ha	prosulfocarb + metribuzin 3600 + 350 g/ha	prosulfocarb + metobromuron 3600 + 1000 g/ha
Galium aparine	+++	+++	+++
Viola arvensis	++	+++	+++
Matricaria species	++	+++	+++
Solanum nigrum	+++	+++	+++
Galeopsis tetrahit	+++	+++	+++
Chenopodium album	++	+++	+++
Stellaria media	+++	+++	+++
Mercurialis annua	+	+++	++
Polygonum convolvulus	++	+++	+++
Polygonum persicaria	++	+++	+++
Polygonum aviculare	++	+++	+++
Galeopsis tetrahit	+++	+++	+++
Myosotis arvensis	+++	+++	+++

+++ excellent
++ fair
+ moderate

REFERENCES

Brendler, F. (1991): *Unkrautbekämpfung 1991, Zeitschrift Kartoffelbau 3/1991, 92-96*

Glasgow, J.L.; Gore, N.R.; Kurtz, P.J. (1987): *SC 0574 - a new selective herbicide for use in winter cereals. - Proceedings 1987 British Crop Protection Conference - Weeds* **1**, *27-33*

Konradt, M.; Hemmen C. (1991): *Was tun gegen Klettenlabkraut in Kartoffeln?*
Zeitschrift Kartoffelbau **3**/*1991, 133-135*

Kees, H. (1991): *Erste Erfahrungen mit Boxer zur Unkrautbekämpfung im Kartoffelbau. Mitteilungen der Deutschen Phytomedizinischen Gesellschaft 3/1991.*

TOLERANCE OF SOME FOREST TREE SPECIES TO IMAZAPYR

J. LAWRIE, D.V. CLAY*

Department of Agricultural Sciences, University of Bristol, AFRC Institute of Arable Crops Research, Long Ashton Research Station, Long Ashton, Bristol BS18 9AF, UK

ABSTRACT

Soil in tanks was sprayed with imazapyr at 0.75 kg a.e./ha and kept outdoors for different weathering periods. Sitka spruce planted into soil with zero weathering was killed, but was not affected when planted into soil weathered for 6 weeks. Ash planted into soil with zero or 6 weeks weathering was severely damaged; there was no growth reduction after 3 or 6 months weathering, although occasional leaves showed some distortion.

Overall spraying of dormant Corsican pine and Japanese larch with 0.125 kg a.e./ha imazapyr was not damaging but 0.5 kg a.e./ha caused stunting of growth and needle damage on larch and more severe damage on pine. Both species were damaged by imazapyr applications either to the shoots or to the soil surface; application to wet soil caused slightly more damage than to dry soil. Overall spraying of larch was slightly less damaging when trees were dormant compared with those at the bud swelling stage.

Imazapyr appears to have potential for use in forestry, but dose and conditions at the time of application would be critical.

INTRODUCTION

Imazapyr, an imidazolinone herbicide, controls a wide range of annual and perennial herbaceous and woody weeds, through both foliar and root uptake. Imazapyr is registered in the United States for site preparation and 'conifer release' application in loblolly pine (*Picea taeda*) (Winfield and Bannister, 1988). It is Approved in the UK for weed control in non-crop areas and is under development for pre-planting use in forestry.

In the experiments reported here, tolerance of container-grown forestry crops to imazapyr applied either pre- or post-planting, was investigated. In the pre-planting experiment (1), the length of time required after an imazapyr treatment before trees could be safely planted was investigated. Ash (*Fraxinus excelsior*), a species sensitive to imazapyr, was compared with Sitka spruce (*Picea sitchensis*), a more tolerant species (Lawrie and Clay, 1989). With post-planting treatments (Experiments 2-5) the relative tolerance of two other conifer species, Corsican pine (*Pinus nigra* var. *maritima*) and Japanese larch (*Larix kaempferi*) to imazapyr applied to shoots or to roots were compared as were the effects of applications to dry and wet soil.

MATERIAL AND METHODS

Imazapyr ('Arsenal'; 250g a.e./l) was used at the dates and doses shown in TABLES 1-5.

Pre-planting treatment (Exp. 1)

'Osma Flow' PVC tanks with a 25 l capacity (42.5 x 28 cm) with fifteen 12 mm diameter drainage holes in the base and a 20 mm depth of 'Hydralica' (expanded clay granules) to prevent

* Present address: Avon Vegetation Research, Nailsea, Bristol BS19 2YF

waterlogging were filled with sandy loam soil (3% o.m. pH 6.7) to 20 mm below the top of the tank in August. The filled tanks were left outside to consolidate and given overhead watering to supplement natural rainfall. Two weeks before treatment, tanks were placed under a poly-ethylene tunnel and the soil surface in half of them permitted to dry out.

Tanks of soil with either dry or wet soil surfaces; 7% and 19.3% soil moisture content at 0-5 mm depth, respectively, were sprayed with imazapyr on 29 September 1989 using a laboratory track sprayer (LTS) fitted with a boom with three flat fan 11002 Teejets delivering 252 l/ha at 280 kPa pressure. After treatment tanks were placed outside on gravel for different weathering periods (0, 1.5, 3 and 6 months) after which they were transferred to a deep-freeze (-15°C). Tanks were removed from the deep-freeze on 5 April 1990 and thawed out under cover. On 9 April 1990 they were planted with four 2-year-old ash trees, and four 1-year-old spruce trees, per tank and placed outside.

Post-planting treatment (Exp. 2-5)

All trees used were 2-year-old transplants. They were planted on 4 March 1987 in a sandy clay loam soil with added (15% v/v) sand and 1.7g/l 'Osmocote' (18:11:10, N:P:K), in 16.5 cm diameter pots for experiments 2 and 3 and in 20 cm diameter pots for experiments 4 and 5. Additional fertilizer was added to pots in experiments 4 and 5 in spring 1988, using two 'Osmocote Plus' (15:10:12, N:P:K) tablets per pot.

In experiments 2, 4 and 5, imazapyr was applied (on the dates shown in TABLES 2-5) to the foliage only using the LTS fitted with a 8002E Teejet delivering 428-414 l/ha at 175 kPa pressure. In experiment 3, in which soil moisture at treatment was varied, the dry soil treatment was prepared by spraying 200 ml of dry soil (88.6% d.m.) for each pot with the required doses of imazapyr. The treated soil was then shaken for one minute in a polythene bag before spreading it over the surface soil of the pots. For the wet soil treatments a soil drench of 50 ml of solution at the required imazapyr concentration was applied to each pot. Excess spray deposits (Exp. 2) were washed off the foliage with a hose and coarse rose 65 hours after spraying, to minimise any contamination of the soil.

Two replicate tanks/pots were used in experiment 1, four in experiments 2 and 3, and three in experiments 4 and 5. After treatment, plants were placed outside in randomized blocks and watered by rain supplemented by hand-watering (Exp. 1) or trickle irrigation (Exps. 2-5) as required. Plant condition was scored at intervals on a 0-7 scale, 0 = plant dead, 4 = 50% growth inhibition, and 7 = healthiest untreated. At the end of the experiments shoot fresh weights were recorded. Root fresh weight was recorded in experiment 1 only.

RESULTS

Pre-planting imazapyr treatments (Exp. 1)

Trees planted in soil which was wet when sprayed with imazapyr appeared to be more damaged than those planted in soil that was dry when sprayed. However, the differences were not statistically significant and the results have, thus, been pooled.

Ash planted in soil that had not been weathered after imazapyr treatment was severely damaged by both herbicide doses, making no new shoot growth (TABLE 1). Planting after a 6-week weathering period produced new shoot and root growth but these were reduced by 35-57% compared with the untreated controls and many leaves showed severe distortion. Imazapyr at 0.75 kg/ha had no adverse effect on ash planted after a 3-month weathering period but 1.5 kg/ha reduced shoot and root growth. When planted after 6 months weathering, ash was virtually unaffected by either dose of imazapyr. However, occasional distorted leaves were produced on some plants at different times during the growing season.

New growth of Sitka spruce planted after a zero weathering period was severely stunted. After 6 weeks of weathering, 0.75 kg/ha imazapyr caused no adverse effects but 1.5 kg/ha reduced shoot and root growth. No adverse effects from either dose were observed when spruce was planted after longer weathering periods.

TABLE 1. Effect of imazapyr residues in the soil on shoot and root weight of Ash and Sitka spruce (SS) (Experiment 1)

Dose (kg a.e./ha)	Weathering period (Months)[b]	Fresh Wt (g) 1990 Shoot		10 Sept 1990[a] Remaining Shoot		Root	
		Ash	SS	Ash	SS	Ash	SS
0.75	0	0.0***	0.50***	5.8***	4.30**	13.5***	4.20***
	1.5	11.9**	4.96	9.3*	5.89	31.0***	11.54
	3	16.4	4.20	11.5	5.21	44.0	8.49
	6	21.8	4.40	12.0	6.49	50.0	7.83
1.5	0	0.0***	0.03***	5.6***	3.57***	13.2***	1.31***
	1.5	9.6***	3.88**	7.0***	4.82	21.2***	6.95*
	3	14.1*	4.32	9.1*	5.79	39.1*	9.49
	6	17.9	4.54	12.2	5.59	46.6	7.75
Untreated		18.2	4.95	11.3	5.69	49.7	9.44
SED							
treated v treated		2.19	0.589	1.17	0.552	5.29	1.179
untreated v treated		1.90	0.510	1.01	0.478	4.58	1.021
(df 135)							

[a] Values are pooled values of soil moisture treatments
[b] Number of months soil weathered before freezing/planting
* Indicated values significantly lower than untreated at:
* = P=0.05, ** = P=0.01, *** = P=0.001

Tolerance of tree spp. to imazapyr as a post-planting treatment (Exp. 2-5)

Experiment 2

There was no clear evidence of damage or growth reduction on either Corsican pine or Japanese larch when dormant plants were treated with imazapyr at 0.125 and 0.25 kg/ha (TABLE 2). On larch, 0.5 kg/ha caused slight damage, with thickening of needles and general stunting, while pine was more severely affected with stunting of stems creating a bushy and stunted effect with little new growth.

Imazapyr at 2.0 kg/ha caused severe reduction in the growth and final weight of both larch and pine. Generally the pine growth was poor, even on untreated plants.

TABLE 2. Tolerance of dormant pine (CP) and larch (JL) to imazapyr applied to the foliage on 17 March 87 (Experiment 2)

Dose (kg a.e./ha)	Score of condition (0-7 scale)				Total shoot Fresh wt (g)	
	6 July 87		30 Sept 87		18 Nov 87	1 Dec 87
	CP	JL	CP	JL	CP	JL
0.125	4.5	6.8	3.8	6.0	51.2	79.0
0.25	4.0	5.0	3.0	5.8	51.5	57.5
0.5	2.0*	6.0	2.0*	6.3	28.4	63.5
1.0	2.8	4.8	3.0	4.8	38.6	61.1
2.0	3.3	1.5*	2.8	2.3*	38.7	40.8*
Untreated	4.8	5.6	4.9	6.5	57.8	76.9
SED treated v treated	1.45	0.98	1.59	0.95	27.49	19.81
untreated v treated (df 19)	1.26	0.85	1.38	0.82	23.81	17.16

* Indicates values significantly lower than untreated at P=0.05

Experiment 3

Root uptake of imazapyr by larch caused necrosis of needles and stunting of shoots at 0.9 kg/ha in dry soil and 0.3 kg/ha in moist soil when scored in July and September (TABLE 3). Larch shoot weight reduction was 44% at 0.9 kg/ha in wet soil compared to 10% in dry soil.

Corsican pine growth was poor resulting in some missing plots. Growth of pine was stunted by imazapyr at 2.7 kg/ha in dry soil and 0.9 kg/ha in wet soil in July and September and final weight was reduced by 46% and 72% by 2.7 kg/ha in dry and wet soil, respectively. On both species 2.7 and 8.1 kg/ha imazapyr were damaging.

Experiment 4

There was an indication from the scores of some stunting of new growth with imazapyr at 0.1 and 0.3 kg/ha on 3-year-old Corsican pine but there was no significant reduction in the weight of new growth at either of these doses (TABLE 4).

Imazapyr at 0.9 and 2.7 kg/ha applied to trees while dormant, or at the bud swelling stage, caused severe damage to new growth, preventing needle extension from the 'candles' and causing significant growth reductions. Different growth stages at treatment did not affect the response to the imazapyr dose range.

TABLE 3. The effect of imazapyr applied to wet and dry soil on 18 March 1987 to dormant pine (CP) and larch (JL) (Experiment 3)

Treat-ment	Dose (kg a.e./ha)	Score of condition (0-7 scale) 6 July 87 CP	6 July 87 JL	30 Sept 87 CP[a]	30 Sept 87 JL	Total shoot Fresh wt (g) 18 Nov 87 CP	1 Dec 87 JL
Dry Soil	0	5.1	6.0	3.7	6.3	54.9	65.5
	0.1	5.8	5.8	5.5	4.5	69.4	39.7
	0.3	5.0	5.2	4.8	5.3	65.4	40.5
	0.9	4.5	3.8*	3.8	3.8*	67.0	59.2
	2.7	3.3	2.3*	1.0	1.5*	29.4	29.9*
	8.1	2.3*	1.3*	1.0	1.0*	24.2	21.3*
Wet Soil	0	5.3	6.5	4.7	7.0	67.3	53.6
	0.1	4.8	5.5	4.3	5.3	63.6	56.3
	0.3	4.0	4.5*	3.5	3.8*	44.0	50.0
	0.9	4.5	2.5*	2.5	2.8*	55.0	29.9
	2.7	2.5*	2.3*	0.5*	1.8*	18.6*	26.5
	8.1	1.8*	1.0*	0.5*	1.0*	18.3*	12.8*
SED treated v treated (df 33)		1.36	0.92	1.55	1.04	19.95	14.67

[a] Score of new growth only
* Indicates values significantly lower than corresponding untreated at P=0.05

TABLE 4. Effect of imazapyr on foliage of Corsican pine, applied on 2 or 23 Feb 88 (Experiment 4)

Dose (kg a.e./ha)	Application date	Score of condition (0-7 scale) 12 May 88	6 Sep 88	23 Jun 89	Fresh wt. of 1989 growth (g) 1 Aug 89
0.1	2 Feb[a]	7.0	6.0	5.3	278
	23 Feb	6.3	5.7	5.3	215
0.3	2 Feb	6.0	5.0*	5.3	191
	23 Feb	6.3	7.0	6.0	238
0.9	2 Feb	4.3*	1.7*	1.7*	67*
	23 Feb	4.0*	2.0*	2.0*	71*
2.7	2 Feb	3.7*	1.0*	1.0*	0*
	23 Feb	3.0*	1.0*	1.0*	0*
Untreated	2 Feb	7.0	6.7	6.0	227
	23 Feb	7.0	6.0	5.7	193
SED (df 18)		0.49	0.62	0.73	48.7

[a] 2 Feb = Tree dormant, 23 Feb = Bud swelling stage
* Indicates values significantly lower than corresponding untreated at P=0.05

Experiment 5

Imazapyr at 0.3 kg/ha or less did not cause any appreciable damage to larch when applied as a soil drench or foliar spray either to dormant plants or those at the bud swelling stage (TABLE 5). Needle chlorosis was noted on some plants 3 months after treating with 0.3 kg/ha as a soil drench at bud swelling.

The score data indicates that imazapyr at 0.9 kg/ha and above was highly damaging when applied as a soil drench at either date with little effect on shoot fresh weight. In contrast foliar applied imazapyr at 0.9 kg/ha did not cause damage at either date but 2.7 kg/ha was highly damaging, particularly when applied at the bud swelling stage, but again this had little effect on shoot fresh weight.

TABLE 5. Effect of imazapyr applied to shoots or roots of Japanese larch on 2 or 18 Feb 88 (Experiment 5)

Dose (kg a.e./ha)	Application		Score of condition (0-7 scale)		Total shoot fresh wt. (g)
	Method	Date	12 May 88	6 Sept 88	16 Jan 89
0.1	RD[a]	2 Feb[b]	6.7	6.7	207
		18 Feb	7.0	6.7	250
	FS	2 Feb	6.7	7.0	227
		18 Feb	6.3	5.7	205
0.3	RD	2 Feb	6.3	7.0	205
		18 Feb	5.7	7.0	243
	FS	2 Feb	6.7	6.7	200
		18 Feb	5.7	6.3	250
0.9	RD	2 Feb	4.7*	4.3*	193
		18 Feb	4.0*	3.7*	182
	FS	2 Feb	6.3	6.3	282
		18 Feb	7.0	6.3	262
2.7	RD	2 Feb	4.7*	2.7*	163
		18 Feb	3.3*	1.3*	154
	FS	2 Feb	3.3*	5.0	218
		18 Feb	1.7*	3.3*	168
Untreated	RD	2 Feb	6.7	6.3	199
		18 Feb	6.0	6.3	237
	FS	2 Feb	7.0	5.7	163
		18 Feb	6.7	6.7	208
SED (df 38)			0.83	0.84	42.3

[a]RD = Root drench FS = Foliar spray
[b]2 Feb = Trees dormant
18 Feb = Bud swelling stage
* Indicates values significantly lower than corresponding untreated value at P=0.05

DISCUSSION

The method used to study effects of residues of imazapyr from pre-planting applications sought to overcome the problem of planting in different weather conditions and adverse effects of winter cold on establishment. Therefore, tanks were sprayed at one date and planted at one date. To create the various weathering periods, tanks were stored in the deep-freeze after weathering until they could be planted. Some breakdown or movement of imazapyr may have occurred during the freezing/thawing periods. Analysis of imazapyr residues in the soil showed >80% was still present in the 0-5 cm layer in the un-weathered tanks frozen after treatment and stored at -15°C for six months (data not presented). However, there was some evidence of downward movement, perhaps through soil particle movement down cracks. Where tanks had been left outdoors for six months after spraying, analysis of the soil showed 0.02-0.11 mg/kg (on a dry soil basis) of imazapyr was present in different layers, mainly between 5 and 10 cm. This could account for the erratic development of leaf symptoms and on the ash trees planted in soil weathered for 6 months. As the ash used required root pruning before planting they may have been more susceptible to damage from imazapyr in the regions of maximum hair-root development. The results obtained for ash and Sitka spruce are consistent with information from other experiments and field experience. Winfield and Bannister (1988) showed that Corsican pine, Japanese larch and Sitka spruce could be planted 18-19 weeks after imazapyr pre-treatment. In contrast Lund-Høie and Rognstad (1990) reported that *Picea abies* planted four weeks after treatment was severely damaged but safe after 7-9 months.

Dougherty (1988) working on loblolly pine (*Pinus taeda*) showed that imazapyr at 0.58 kg/ha, applied as an overhead spray, was safe and increased the survival rate of pine in weedy situations, although it reduced leader height. Netzer (1986) found greater survival of pines (*Pinus barksiana* and *P. resinosa*) and European larch (*Larix decidua*) when 0.23 kg/ha imazapyr was applied as an overhead spray. The work reported here indicates that there may be potential for overall spraying of low doses of imazapyr in dormant conifers in UK conditions. However, timing of imazapyr application is important, and if it is sprayed over conifers when in active growth, severe damage can occur (Christensen, 1988). The possible difference in reaction to different levels of imazapyr between Corsican pine and Japanese larch found by our work may have been due to the amount of herbicide intercepted by each species. Corsican pine with needles present has a greater surface area to retain and absorb herbicide compared with the bare larch branches.

Doses of imazapyr greater than 0.3 kg/ha caused damage to larch when applied directly to wet soil whereas more than 0.9 kg/ha was needed to cause damage in dry soil. With pine doses greater than 0.9 kg/ha were damaging in both wet or dry soil. This indicates that application to wet soil may lead to more damage, at least with larch. Soil moisture can affect the toxicity of imazapyr to crops since it is less well adsorbed on wet soil compared to dry and availability to the crop is increased (Wehtje *et al.,* 1987; Subagyo, 1989). Low pH, soil type and type of clay present can also affect adsorption (Wehtje *et al.,* 1987; Subagyo, 1989).

Our experiments have confirmed the potential of imazapyr as a pre-planting treatment and the possibility of its use as a directed spray to dormant conifers. However, dose, date of application and soil moisture can be critical in crop tolerance. Although imazapyr has a broad spectrum of activity for controlling grass weeds (Clay and Lawrie, 1988; Winfield and Bannister, 1988), woody weeds such as *Rhododendron ponticum* (Lawrie and Clay, unpublished results) and other species (Lund-Høie and Rognstad, 1990), its phytotoxicity to trees requires further investigation to establish fully its potential for safe use in forestry tree crops.

ACKNOWLEDGEMENTS

This work was financed by a grant from the Forestry Commission. We thank Cyanamid of Great Britain Ltd for the supply of imazapyr, the staff of the plant handling section, L.A.R.S. for growing the experimental plants and Mrs M. Griffin for typing this paper.

REFERENCES

Christensen, P. (1988). Danish results with a new herbicide, imazapyr, in forestry. *Aspects of Applied Biology 16, 1988. The practice of weed control and vegetation management in forestry, amenity and conservation areas*, 105-112.

Clay, D.V.; Lawrie, J. (1988). Herbicides for grass control in forestry: pot experiments on efficiency and crop tolerance. *Aspects of Applied Biology 16, 1988. The practice of weed control and vegetation management in forestry, amenity and conservation areas*, 113-122.

Dougherty, P.M. (1988). The influence of weed control on establishment of loblolly pine on a Georgia piedmont pasture site. *Proceedings, Southern Weed Science Society, 41st annual meeting 1988. Environmental legislation and its effect on weed science*, 193-197.

Lawrie, J.; Clay, D.V. (1989). Tolerance of forestry and biomass broad-leaved tree species to soil-acting herbicides. *Proceedings 1989 Brighton Crop Protection Conference - Weeds*, 347-354.

Lund-Høie, K.; Rognstad, A. (1990). Effect of foliar-applied imazapyr and glyphosate on common forest weed species and Norway spruce. *Crop Protection* **9,** 52-58.

Netzer, D.A. (1986). Effect of spring-applied sulfometuron and imazapyr on newly-planted tree seedlings in Northern Wisconsin. *Proceedings, North Central Weed Control Conference* 1986, 115-117.

Subagyo, T. (1989). Studies on imazapyr, a herbicide for minimum tillage purposes in areas infested with Lalang (*Imperata cylindrica* [L.] Raeuschel) Ph.D. thesis, University of Reading, p. 173.

Wehtje, G.; Dickens, R.; Wilcut, J.W.; Hajek, B.F. (1987). Sorption and mobility of sulfometuron and imazapyr in five Alabama soils. *Weed Science* **35,** 858-864.

Winfield, R.J. and Bannister, C.J. (1988). Imazapyr for broad-spectrum weed control in forestry. *Aspects of Applied Biology 16, 1988. The practice of weed control and vegetation management in forestry, amenity and conservation areas*, 79-88.