Session 7C

Weed Control in Broad-leaved Crops

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THE COMPETITIVE EFFECTS OF BROAD-LEAVED WEEDS IN WINTER OILSEED RAPE

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ABSTRACT

The competitive effects of four weed species (*Stellaria media, Matricaria perforata, Galium aparine, Veronica persica*) on the growth and yield of winter oilseed rape were studied in 8 experiments over two years. The level of competition from specified weed densities varied widely between trials. For example, the densities of *S. media* causing a 5% yield loss varied from 1.4 - 464 plants/m^2. In general, *G. aparine* was most competitive and *M. perforata* and *V. persica* the least. Delayed drilling increased weed competition on one experiment but not on two others. Increased crop density slightly decreased competition

INTRODUCTION

In response to economic and environmental pressures UK arable farmers are being encouraged to optimise crop protection, so that pesticides are not used unnecessarily. For this approach to be successful the farmer must have at least some idea of the likely effects of the weeds, pests and diseases on the crop, so that he/she can assess the risks attached to differing control strategies. Threshold management systems are used for some pests and diseases and similar approaches have been tried with weeds. However, the serious consequences of incorrect decisions and the variability of crop responses to given weed densities, makes the successful use of predictive systems difficult. Some predictive success has been achieved in Germany in winter rape (Heitefuss, Kayser & Munzel, 1993) and in the UK research has identified the relative competitive abilities of a range of weeds in winter wheat (Wilson & Wright, 1990). In order to make progress, basic information on the effects of weeds on the growth and yield of the crops is essential.

Studies of the competitive effects of grass weeds, especially volunteer cereals, on winter oilseed rape were carried out in the late 1980's and clearly show the importance of crop vigour in determining the competitiveness of the weeds in this crop (Lutman, 1991). Poorly-growing rape crops are very sensitive to competition from aggressive grass weeds but vigorous crops will suppress even relatively high densities. Although competitive weeds such as volunteer cereals will often need to be controlled to prevent yield loss, the need for control of less competitive broad-leaved weeds in winter rape, is thought to be much more questionable. Early work, studying the effects of mixed infestations of broad-leaved weeds, frequently failed to detect yield benefits from their control (Bowerman, 1989; Davies, Walker & Whytock, 1989). But, in this work it was difficult to identify which weeds were important and at what densities they were reducing yields.

The eight experiments reported in this paper have attempted to identify the effects of a number of broad-leaved weeds on winter rape, with the aim of developing advisory guidelines on the need for their control in this crop.

MATERIALS AND METHODS

Eight randomised block or factorial experiments were carried out at four sites in the UK (Table 1) in the years 91/2 and 92/3. All trials had 3 or 4 replications. Plot size varied from 1.8 x 10m at Morley to 3 x 14m at Rothamsted and 2 x 20m at Boxworth and Aberdeen. Up to four broad-leaved weed species (*Stellaria media*, *Galium aparine*, *Matricaria perforata*, *Veronica persica*) were sown individually at a range of densities, in each trial. Maximum densities were intended to characterise the maximum yield loss the weed species could attain, as specified by the asymptote (A) in the hyperbolic model relating weed density to crop yield (Cousens, 1985). Weed free plots were established on all trials. Agronomic factors such as crop density and sowing date were also studied. Crops and weeds were counted in the autumn and were sampled to determine dry weights in Dec/Jan and March/April (data not presented). Rape crops were harvested at maturity and yields were recorded.

TABLE 1. Details of the eight experiments, including weed species studied and agronomy of the crops

Site*	Year	Sowing date	Rape plants/m² (autumn)	Cultivar	Weed species	Nitrogen rate (kg/ha)	Harvest date
RES	91/2	11.9.91	94	Libravo	*S. media* *G. aparine* *M. perforata* *V. persica*	176	27.7.92
RES E[x]	92/3	3.9.92	66	Falcon	*S.media* *G.aparine*	187	27.7.93
M		15.9.92	81				
L		29.9.92	72				
RES	92/3	15.9.92	77	Falcon	*M.perforata*	187	28.7.93
BOX	91/2	5.9.91	21,37,84[+]	Samourai	*M.perforata*	189	17.7.92
BOX	92/3	4.9.92	44,70,113[+]	Samourai	*M.perforata* *S.media*	176	22.7.93
AB	91/2	28.8.91	133	Samourai	*S.media*	165	6.8.92
AB E[x]	92/3	26.8.92	84	Rocket	*S.media*	180	1.9.93
M		3.9.92	57				
MOR	92/3	9.9.92	83	Capricorn	*S.media* *G.aparine*	200	26.7.93

* RES = Rothamsted, BOX = ADAS Boxworth, AB = Tillycorthie farm, SAC Aberdeen, MOR = Stonham farm, Suffolk (Morley Research Centre)
x Crop sowing date: E (early), M (middle), L (late)
\+ Crop densities identified in Tables 2 & 3 as: low (L), medium (M), high (H)

The data from each trial have been subjected to regression analyses, using the Maximum Likelihood Programme (Ross, 1978), so that crop and weed weights could be related to weed density. Using this technique the growth of crops and weeds at standard weed densities can be calculated, facilitating comparisons between sites and years. Hence, % yield losses at specific weed densities and the densities causing 5% yield loss have been calculated (Tables 2-4). The correlation coefficient (r^2) provides evidence of the 'quality' of the relationships between yields and weed density.

RESULTS

Stellaria media (common chickweed)

Chickweed was studied in 6 experiments (Table 2). In most of them it had a substantial effect on the rape, particularly in those harvested in 1993, and yield losses in the presence of chickweed were high. There were marked differences between sites. Chickweed was least competitive in Aberdeen in 1992, where the rape was the most vigorous in the autumn and winter. There were indications from data collected in the winter and early spring that relative and absolute growth of the crop and weed during this period was controlling the yield response. Yield losses were often substantial at 50 plants/m^2 and as the regression analyses on which these figures have been based were clearly hyperbolic, intraspecific competition played an increasing role as weed density increased to higher levels. Reducing crop density from 113 to 44 plants/m^2 at Boxworth in 1993 tended to increase slightly the competitive effect of the weed. Delayed sowing did not increase the competitiveness of the chickweed at Rothamsted but did at Aberdeen in 1993. The densities causing a 5% yield loss varied greatly between sites, from only 1.4 at Boxworth in 1993 to 464 plants/m^2 in Aberdeen in 1992.

TABLE 2. The effects of *Stellaria media* (common chickweed) (50 and 200 plants/m^2) on the yield of oilseed rape (t/ha), at 9% moisture

Site	Year	Weed free yield	% Yield loss caused by 50 plants/m^2	% Yield loss caused by 200 plants/m^2	No of *S.media*/m^2 causing a 5% yield loss	r^2
RES	92	2.97	12.3	18.2	15.5	0.37
RES E*	93	3.57	41.6	55.5	2.1	0.84
M		3.67	18.8	31.9	8.2	0.73
L		3.37	17.5	36.0	10.6	0.88
MOR	93	4.63	29.0	55.6	5.8	0.90
BOX L+	93	3.61	28.5	30.0	1.4	0.51
M		3.99	15.9	26.4	9.7	0.60
H		4.12	18.7	32.3	8.5	0.75
AB	92	3.75	0.6	2.2	464	0.24
AB E*	93	2.29	16.3	37.0	12.2	0.72
M		3.02	47.7	70.9	2.5	0.71

\+ Crop density: L (low), M (medium), H (high) - see Table 1
* Sowing date: E (early), M (middle), L (late) - see Table 1

Matricaria perforata (scentless mayweed)

At three of the four sites, mayweed at 100 plants/m^2, had little or no detectable effect on the yield of the rape (Table 3). As the maximum densities of mayweed were considerably higher than this in the Boxworth 93 and Rothamsted 92 experiments, 1124 and 264 plants/m^2 respectively, the rape was not affected by considerably higher densities. The mayweed at the fourth site (Rothamsted 93) was much more competitive, reducing yields appreciably, even at low densities. Rape growth was poor in the winter at this site and the mayweed was quite vigorous. Where the mayweed was unable to emerge through the rape canopy in the spring, its competitive effect tended to be low. As one might expect, the low density rape plots at the Boxworth site in 1992 and 1993 tended to be more affected by the mayweed than the higher density ones. The density of mayweeds causing a 5% yield loss varied from 2.6 to 261 plants/m^2, at the sites where a response was detected.

Galium aparine (cleavers)

This weed was only studied at three sites but it is clear that even very low densities had a considerable effect on the yields of rape. Yield losses of 5% followed competition from 0.4 - 9.9 plants/m^2. (Table 4). In the Rothamsted 93 experiment delayed planting did not increase the effects of the weeds, as on the later sowing both the rape and cleavers were less vigorous

TABLE 3. The effects of *Matricaria perforata* (scentless mayweed) (50 and 100 plants/m^2) on the yield of oilseed rape (t/ha), at 9% moisture

Site	Year	Weed free yield	% Yield loss caused by 50 plants/m^2	% Yield loss caused by 100 plants/m^2	No of *M.perforata*/m^2 causing a 5% yield loss	r^2
RES	92	2.92	No decrease in yield		-	
RES	93	3.15	41.0	51.5	2.6	0.71
BOX L+	92	2.25	14.5	29.0	17.3	0.31
M		2.30	No decrease in yield		-	
H		2.48	No decrease in yield		-	
BOX L+	93	3.48	1.7	3.5	144	0.52
M		3.88	0.9	1.9	261	0.40
H		3.96	No decrease in yield		-	

+ Crop density: L (low), M (medium), H (high) - see Table 1

TABLE 4. The effects of *Galium aparine* (cleavers) (10 and 50 plants/m^2) on the yield of oilseed rape (t/ha), at 9% moisture

Site	Year	Weed free yield	% Yield loss caused by 10 plants/m^2	% Yield loss caused by 50 plants/m^2	No of *G.aparine*/m^2 causing a 5% yield loss	r^2
RES	92	2.98	14.8	36.0	2.7	0.38
RES E*	93	3.48	49.4	78.0	0.49	0.88
M		3.94	47.9	68.8	0.43	0.85
L		3.17	28.2	62.4	1.3	0.94
MOR	93	4.06	5.0	24.8	9.9	0.38

* Crop sowing date: E (early), M (middle), L (late) - see Table 1

during the winter and spring. Not only did this weed reduce yields, it posed a serious contamination problem in the harvested rape seed. In the most severely affected plots on the Rothamsted 93 experiment almost 50% of the harvested seeds were cleavers. These figures for the competitive effect of cleavers may be a slight overestimate, due to delayed emergence of the seedlings, resulting in an increase in plant numbers after the main population assessments had been done. Assessments of the two Rothamsted experiments indicated later emergence to be low in autumn 91 but somewhat greater in 1992.

Veronica persica (common field speedwell)

This weed was studied in only one experiment (Rothamsted 92) (data not presented) and densities in excess of 1000 plants/m^2, although affecting rape growth in the spring, failed to have a detectable effect on yields. As with *S. media*, very high densities did not have an appreciably greater effect on yields than lower ones, due to the high level of intraspecific competition.

DISCUSSION

These eight experiments bring together, for the first time, a standardised set of data on the effects of individual species of broad-leaved weeds on the yields of winter oilseed rape. There were extreme differences in the responses of the crops to the studied weeds. For example, the densities of chickweed causing a 5% yield loss differed by a factor of more than 100. Earlier work had suggested that broad-leaved weeds, especially those of a prostrate growth habit, such as chickweed, would not have a great effect on crop yields. In some experiments this was true but in many it was not. In a previous publication 5% yield losses from chickweed were estimated to occur at densities in excess of 250 plants/m^2 (Lutman, 1993). The results presented in this paper indicate that this conclusion is not generally valid, as in most trials chickweed was appreciably more competitive.

Predictions based on weed numbers/m^2 are intrinsically flawed, as they take no account of crop vigour, nor of weed size. Predictions need to be based on some estimate of plant size (eg weight, leaf area, ground cover) (Kropff & Spitters, 1991). Preliminary investigations using the dry weight data collected in these 8 trials in December/January and March/April would suggest that both the absolute amount of rape present and the proportion of rape and weed are important when modelling predictions of yield loss. The more vigorous the rape and the lower the proportion of weed, the lower was the predicted yield loss. For example, as the rape in 1993 tended to be less vigorous during the winter than that in 1992, weed competition was greater in 1993. Paradoxically, weed free yields at Boxworth and Rothamsted tended to be higher in 1993, than in 1992. These 8 trials provide inadequate data for validating a predictive model and so more data sets are required.

Comparisons of the data in Tables 2 - 4, permit broad assessment of the relative competitive abilities of chickweed, scentless mayweed, cleavers and to a more limited extent, field speedwell. However, because of the wide variation in the competitive effects of the individual weeds it is not possible to draw firm conclusions. Overall, mayweed tended to be less competitive than chickweed and cleavers. Cleavers were similar to, or slightly more competitive than chickweed. In the Rothamsted 92 experiment speedwell was not as competitive as chickweed. The greater competitive ability of chickweed compared to mayweed, concurs with work in rape in Germany (Heitefuss *et al.*, 1993) but conflicts with research in winter wheat in the UK, where mayweed was appreciably more competitive (Wilson & Wright, 1990).

It has been shown that delayed sowing increases the susceptibility of rape to competition from grass weeds (Lutman, 1991). However, two of the three experiments reported here, that included sowing date as a factor, failed to confirm this conclusion for broad-leaved weeds. Although the late sown rape grew more slowly and tended to have lower yields, the weeds also grew less vigorously and equivalent weed densities caused similar losses in yield at each sowing date. In contrast, the Boxworth experiments showed that lowering crop density reduced weed free yield and increased sensitivity to weeds. This increased effect of weeds was not great, confirming some earlier trial results reported by Sansome (1991). The ability of rape to compensate for poor establishment, by increased branching, is well known and probably accounts for the relatively small effects of crop density on weed competition.

The precision of the calculated relationships between weed density and yield loss is evidenced by the high r^2 values recorded in most of the trials. Only in comparisons where the effects of the weeds were small were the r^2 values poor, but even so all exceeded the 5% level of significance.

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RIMSULFURON SELECTIVELY CONTROLS WEEDS IN POTATOES

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ABSTRACT

Post-emergence broad-leaved weed control options in potatoes are limited. Field experiments were conducted at Lethbridge and Vauxhaul, Alberta in 1991 and 1992 to determine the suitability of rimsulfuron to control weeds in potatoes. Rimsulfuron applied post-emergence at 15 to 30 g ha^{-1} effectively controlled *Descurainia sophia*, *Amaranthus retroflexus*, *Kochia scoparia*, and *Erodium cicutarium*. The potato cultivars Shepody, Norchip, Russet Burbank, Niska, and Amisk exhibited complete tolerance to rimsulfuron at rates up to 50 g ha^{-1}. At 80 and 120 g ha^{-1}, rimsulfuron caused slight yellowing and stunting of potatoes and delayed flowering. Tuber yields were often reduced by rimsulfuron at 120 g ha^{-1}. Rimsulfuron at 120 g ha^{-1} induced cracking of some tubers of all cultivars except Amisk. Quality factors such as specific gravity and chipping ability were not affected by rimsulfuron. Rimsulfuron would provide growers additional flexibility in their potato weed management programs.

INTRODUCTION

Potato production on the Canadian prairies has doubled in the last decade. However, weeds continue to reduce yields and profits (Van Gessel & Renner, 1990; Wall & Friesen, 1990). Potato growers in this region rely largely on soil applied EPTC and metribuzin to control weeds. Some potato cultivars are injured by metribuzin and weeds are sometimes poorly controlled with these herbicide treatments. Post-emergence broad-leaved weed control options are limited.

Rimsulfuron (DPX-E9636; DuPont Canada) has shown potential for selective control of weeds in potatoes (Reinke *et al.*, 1991). Field studies were initiated a) to determine rates of rimsulfuron required to control several troublesome broad-leaved weeds in potatoes and b) to determine the level of rimsulfuron tolerance of several commonly grown potato cultivars.

MATERIALS AND METHODS

Weed control

An experiment was conducted in 1991 and 1992 at Lethbridge, Alberta. The soil was a sandy clay loam with a pH of 7.8 and 4% organic matter content. Russet Burbank potatoes were planted at 2200 kg ha^{-1} in rows 1 m apart in mid-May of each year on land that been fallowed the previous year. *D. sophia*, *A. retroflexus*, *K. scoparia*, and *E. cicutarium* were planted 1 to 2 cm deep in respective 1.5 m wide strips perpendicular to the potato rows with a double-disc drill. This resulted in mean densities of 90 and 140 *D. sophia* m^{-2}; 210 and 170 *A. retroflexus* m^{-2}, 115 and 62 *K. scoparia* m^{-2}, and 114 and 240 *E. cicutarium* m^{-2} in 1991 and 1992, respectively.

Treatments consisted of a weedy control; hand-weeded control; and rimsulfuron at 5, 10, 15, 20, 30, and 50 g ai ha^{-1}. Agral 90 surfactant (900 g ai/litre alkyl phenol ethylene oxide; Zeneca Agro) at 0.2% v/v was included in all rimsulfuron treatments. Rimsulfuron was applied post-emergence in June with a small plot sprayer equipped with LF 2 flat fan nozzles delivering 170 L ha^{-1} at 275 kPa. Crop and weed species were at the following growth stages when rimsulfuron was applied: potato, seven to ten cm tall; *D. sophia*, two to six leaf; *A. retroflexus*, four to six leaf; *K. scoparia*, two to four cm tall; and *E. cicutarium*, two to six leaf. Treatments were arranged in a randomized complete block design with four replications. Individual plot size 4 m wide and 7 m long.

Potato tolerance was visually rated on a scale of 0 to 100 three weeks after herbicide application. Shoot fresh weight of each weed species was determined in a 1 m^2 area in mid-August. Total potato tuber yield was determined by harvesting the two centre rows in each plot. All data were subjected to analysis of variance. Treatment means were separated by the LSD test at the 5% level of significance.

Potato cultivar tolerance

An experiment was conducted in 1991 and 1992 at Vauxhaul, Alberta. The soil was a sandy clay loam with a pH of 7.7 and 3% organic matter content. Shepody, Norchip, Russet Burbank, Niska, and Amisk potato cvs were planted at 2200 kg ha^{-1} in rows 1 m apart in mid-May of each year. Border rows of Russet Burbank were planted between the various potato cultivars. Treatments consisted of a weedy control; hand-weeded control; and rimsulfuron at 15, 30, 50, 80 and 120 g ai ha^{-1}. Agral 90 surfactant at 0.2% v/v was included in all rimsulfuron treatments. Rimsulfuron was applied with a small plot sprayer delivering 170 L ha^{-1} at 275 kPa when potatoes were five to nine cm tall. Main plots were the herbicide treatments and sub-plots were single rows of each potato cultivar. Main plots were 5 m wide and 9 m long. Treatments were replicated four times within a randomized complete block design.

Potato tolerance was visually rated on a scale of 0 to 100 three weeks after herbicide application. Total potato tuber yield was determined by harvesting 4 m^2 of each cultivar in each plot. All data were subjected to analysis of variance. Treatment means were separated by the LSD test at the 5% level of significance.

RESULTS

Weed control

Rimsulfuron applied early post-emergence was efficacious on several broad-leaved weeds in both years (Table 1). *D. sophia* and *A. retroflexus* required 15 to 20 g ha^{-1}; *K. scoparia* required 20 to 30 g ha^{-1}; and *E. cicutarium* required 30 to 50 g ha^{-1} rimsulfuron for acceptable control.

TABLE 1. Shoot biomass of *Descurainia sophia*, *Amaranthus retroflexus*, *Kochia scoparia*, and *Erodium cicutarium* at various rates of rimsulfuron applied in potatoes.

		Shoot biomass (g m^{-2})							
		D. sophia		A. retroflexus		K. scoparia		E. cicutarium	
Treatment[a]	Rate (g ha^{-1})	1991	1992	1991	1992	1991	1992	1991	1992
Weedy control	-	1003	1536	3572	2325	2623	3222	2018	1929
Rimsulfuron	5	684	946	2296	927	2086	1932	2025	1797
Rimsulfuron	10	350	455	1723	559	945	1078	2013	1360
Rimsulfuron	15	192	222	706	94	728	520	1282	1236
Rimsulfuron	20	0	64	327	48	438	331	1053	895
Rimsulfuron	30	0	0	290	0	151	0	594	133
Rimsulfuron	50	0	0	78	0	83	0	394	68
LSD (0.05)		81	115	436	277	309	465	296	213

[a]The nonionic surfactant Agral 90 at 0.2% v/v was added to all rimsulfuron treatments.

Rimsulfuron up to 50 g ha^{-1} did not visually injure shoots or tubers of Russet Burbank potatoes in either year (data not shown). Tuber yield responded positively to rimsulfuron in both years and reflected the level of weed control attained (Table 2). Rimsulfuron at 20 g ha^{-1} gave comparable tuber yields to the hand-weeded control in both years.

TABLE 2. Russet Burbank total tuber yield at various rates of rimsulfuron applied to control weeds.

		Tuber yield (g m^{-2})	
Treatment[a]	Rate (g ha^{-1})	1991	1992
Weedy control	-	1023	1067
Hand-weeded control	-	1918	2644
Rimsulfuron	5	1454	1921
Rimsulfuron	10	1496	2196
Rimsulfuron	15	1676	2394
Rimsulfuron	20	1885	2646
Rimsulfuron	30	1823	2725
Rimsulfuron	50	1960	2814
LSD (0.05)		207	232

[a]The nonionic surfactant Agral 90 at 0.2% v/v was added to all rimsulfuron treatments.

Potato cultivar tolerance

Visual assessment of shoot growth indicated that all potato cultivars tolerated post-emergence rimsulfuron at rates up to 50 g ha^{-1} (Table 3). At 80 and 120 g ha^{-1}, potato tolerance to rimsulfuron differed among cultivars. Niska and Amisk appeared to tolerate rimsulfuron better than Shepody, Norchip, or Russet Burbank. Injured potatoes exhibited slight yellowing, were 5 to 7 cm shorter, and flowering was delayed by three to four days compared to untreated.

TABLE 3. Visual shoot injury of potato cultivars to various rates of rimsulfuron.

		Shoot injury (%)									
		Shepody		Norchip		R. Burbank		Niska		Amisk	
Treatment[a]	Rate (g ha^{-1})	91	92	91	92	91	92	91	92	91	92
Hand-weeded control	-	0	0	0	0	0	0	0	0	0	0
Rimsulfuron	15	0	0	0	0	0	0	0	0	0	0
Rimsulfuron	30	0	0	0	0	0	0	0	0	0	0
Rimsulfuron	50	10	0	10	0	5	10	0	5	0	0
Rimsulfuron	80	20	15	25	10	10	15	0	15	10	0
Rimsulfuron	120	35	20	35	20	20	25	10	20	10	10
LSD (0.05)		14	10	13	11	11	14	8	13	8	6

[a]The nonionic surfactant Agral 90 at 0.2% v/v was added to all rimsulfuron treatments.

Rimsulfuron at 80 g ha^{-1} did not significantly reduce tuber yield of any cultivar in either year (Table 4). Rimsulfuron at 120 g ha^{-1} reduced the tuber yield of Amisk in 1991, Shepody in 1992, and Norchip, Russet Burbank, and Niska in both years. Visual assessment of tubers indicated that rimsulfuron at 80 g ha^{-1} caused some cracking (fissures) of Norchip tubers in 1991 (data not shown). Rimsulfuron at 120 g ha^{-1} induced cracking of Niska tubers in in 1992 and Shepody, Norchip and Russet Burbank tubers in both years (5-20% of tubers were cracked). Amisk tubers were unaffected in both years. Tuber quality assessments such as specific gravity and chipping tests indicated that rimsulfuron did not affect tuber quality of any cultivar in either year at any rate (data not shown).

TABLE 4. Total tuber yield of potato cultivars at various rates of rimsulfuron.

Treatment[a]	Rate (g ha^{-1})	Tuber yield (g m^{-2}) Shepody	Norchip	R. Burbank	Niska	Amisk
1991						
Hand-weeded control	-	3048	2864	3385	4572	3524
Rimsulfuron	15	3277	2616	3448	4571	3641
Rimsulfuron	30	2917	2769	3662	4510	3559
Rimsulfuron	50	3015	2857	3591	4444	3457
Rimsulfuron	80	2992	2614	3177	4135	3254
Rimsulfuron	120	2978	2261	2973	3968	2976
LSD (0.05)		447	346	364	472	378
1992						
Hand-weeded control	-	5044	4195	4129	4268	4421
Rimsulfuron	15	5042	4188	4119	4269	4300
Rimsulfuron	30	5206	4319	4425	4081	4475
Rimsulfuron	50	5144	4169	4094	4250	4494
Rimsulfuron	80	4606	4050	3756	4075	4313
Rimsulfuron	120	4544	3841	3369	3788	4331
LSD (0.05)		491	352	383	389	269

[a]The nonionic surfactant Agral 90 at 0.2% v/v was added to all rimsulfuron treatments.

CONCLUSIONS

Rimsulfuron at 15 to 30 g ha^{-1} effectively controlled several troublesome broad-leaved weeds in potatoes. Five commonly grown potato cultivars were completely tolerant to rimsulfuron at these rates. Rimsulfuron would provide growers with additional flexibility in their potato weed management programs.

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BROAD-LEAVED WEED CONTROL IN SUGAR BEET IN THE PRESENCE OF CEREAL SHELTER CROPS

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ABSTRACT

Field experiments were conducted at loamy sand, sand and peaty loam sites over three consecutive years to identify herbicide sequences with the potential to combine satisfactory weed control in sugar beet without damaging intercropped barley, so rendering it ineffective as shelter from wind erosion. Treatments which gave good weed control generally caused unacceptable damage. Under predominantly dry soil conditions, pre-emergence herbicides applied at sandy sites did not always improve weed control but did cause excessive damage where the barley was close to emergence at the time of application. At the sandy sites, post-emergence phenmedipham + chloridazon and to a lesser extent phenmedipham + metamitron gave reasonable weed control without undue crop damage, as did the latter at the peaty sites, but a higher rate of metamitron caused unacceptable damage. Other phenmedipham + lenacil or phenmedipham + chloridazon/lenacil tank-mixes were sometimes adequately safe at sandy sites under the dry conditions. Residual herbicides proved less damaging than phenmedipham at peaty sites, even with irrigation to simulate wetter conditions, but gave unsatisfactory weed control.

INTRODUCTION

Sugar beet crops grown on sandy and peaty soils vulnerable to erosion by wind are frequently sheltered with barley, sown either before or shortly after the beet, and subsequently destroyed with a selective graminicide (Cousins & Prince, 1983). However, the early establishment and ultimate effectiveness of the shelter crop can be severely restricted by some broad-leaved weed herbicide programmes (Cleal, 1988). Field experiments were carried out on soils vulnerable to wind erosion to identify herbicide sequences with the potential to achieve satisfactory broad-leaved weed control without compromising the effectiveness of the shelter.

MATERIALS AND METHODS

Field experiments were carried out at three sites (Colney, Norfolk, loamy sand; Elveden, Suffolk, sand; Mepal, Cambs, peaty loam of 15-35% o.m.) in each of the years 1989 to 1991. Herbicide treatments for broad-leaved weed control were applied to sugar beet, drilled between 17 March and 4 April and sheltered with barley sown either 1-3 days later (Colney), 10-18 days earlier (Elveden) or 5-12 days earlier (Mepal). A control, untreated with herbicides, was included at the first two sites only.

At Colney and Elveden, treatments based on a pre-emergence application followed by either one or two post-emergence applications were compared with treatments based on one to three post-emergence applications applied as required for satisfactory weed control. At Mepal, where the peaty soil renders most pre-emergence herbicides ineffective, treatments based on a total of four post-emergence applications were compared (Table 1). Pre-emergence treatments were based on the following active ingredients: chloridazon (65% w/w SG, 'Pyramin DF'); chloridazon/propham/chlorpropham/fenuron (PCF) (200/20/30/20 g/l SC, 'Atlas Electrum') and chloridazon/lenacil (200/133 g/l SC, 'Advizor'). Additional active ingredients applied post-emergence included lenacil (either 80% w/w WP, 'Venzar' or 440 g/l SC, 'Vizor'); metamitron (70% w/w WG, 'Goltix WG'); phenmedipham (114 g/l EC, 'Betanal E') and phenmedipham/ethofumesate (80/100 g/l EC, 'Betanal Tandem'). Mineral oil (97% refined paraffinic oil, 'Actipron') was added to some post-emergence treatments. Pre-emergence sprays were applied between two and six days and between nil and five days after the beet was drilled at Colney and Elveden respectively. Post-emergence sprays were applied to cotyledon weeds, as far as conditions allowed, at all three sites in all years. Applications were made using CO_2 pressurised sprayers, fitted with flat fan nozzles (TeeJet 8003 or 8001 at Colney and Elveden and TeeJet 11001 at Mepal) operating at 2 bar pressure to give 240 l/ha and 80 l/ha volume for pre- and post-emergence sprays respectively. To simulate the effect of a wet season in the third successive year of dry soil conditions, 12.5mm irrigation was applied to the

TABLE 1. Herbicide treatments (g AI/ha) and sites tested.

Pre-emergence	Post-emergence	Site years[1] Colney/ Elveden	Mepal
650 chlor	285 phen	1-3	-
650 chlor	194 phen + 875 met	3	-
340 chlor / 204 P / 51 C / 34 F	285 phen	1-3	-
340 chlor / 204 P / 51 C / 34 F	194 phen + 875 met	3	-
400 chlor / 266 lenacil	285 phen	2, 3	-
400 chlor / 266 lenacil	194 phen + 875 met	3	-
-	194 phen	1-3	-
-	285 phen	1-3	1-3
-	399 phen	1-3	1-3
-	194 phen + 200 lenacil (WP)	1-3	-
-	285 phen + 200 lenacil (WP)	1-3	1-3[2]
-	285 phen + 176 lenacil (SC)	1-3	-
-	194 phen + 140 chlor/93 lenacil	1-3	-
-	285 phen + 140 chlor/93 lenacil	1-3	-
-	194 phen + 455 chlor	1-3	-
-	285 phen + 455 chlor	1-3	1,3[3]
-	97 phen + 438 met	1-3	2,3[4]
-	194 phen + 875 met	1-3	1-3
-	194 phen+875 met+1.0 litre mineral oil	-	1-3
-	1190 met + 1.7 litres mineral oil	1-3[5]	1-3
-	240 phen/300 ethofumesate	-	1-3[6]

chlor = chloridazon; met = metamitron; phen = phenmedipham;
P = propham; C = chlorpropham; F = fenuron.
[1] 1 = 1989, 2 = 1990 and 3 = 1991.
[2] 1190g metamitron + 1 litre mineral oil for 1st post-em. spray in 1989.
[3] 262g phenmedipham in 1989.
[4] rates increased to 194g phenmedipham + 875g metamitron for 3rd and 4th post-em. sprays.
[5] 399g phenmedipham for 2nd post-em. spray at Elveden only in 1991
[6] 1190g metamitron + 1 litre mineral oil for 1st post-em. spray in 1989; 160g phemedipham/ 200g ethofumesate for 1st post-em. spray in 1990 and for 1st and 2nd post-em. sprays in 1991.

Mepal site four days after the first and again eight days after the second post-emergence applications in 1991. Plots were 2m (four rows of beet) wide, containing either three inter-row drills of barley at Colney or overall drilled barley at Elveden. At Mepal, plots were either 2.8 (five rows) or 3.4m (six rows) wide, containing either two (1989 and 1990) or four inter-row drills of barley (1991). Plot length was between 10 and 15m.

The vigour of the barley shelter was scored visually when the effect of pre- and post-emergence applications became visible, using a 0-10 (Colney and Elveden) or a 0-9 linear scale (Mepal) where 0 = dead and 10 or 9 = completely healthy. Populations of broad-leaved weeds were assessed by counting plants within a $4m^2$ area along the centre inter-row gap of each plot (Colney and Elveden) or within five $0.1m^2$ quadrats/plot (Mepal, assessed in 1989 and 1990 only). A randomised block layout with four or five replicates was used and all data were subjected to analysis of variance. LSDs are quoted at the 5% confidence level but are only suitable for single pairwise comparisons.

RESULTS

Assessments of vigour prior to the application of post-emergence herbicides showed that all pre-emergence treatments in 1990 and most in 1991 reduced barley vigour at Elveden compared with the untreated control ($P<0.05$, data not presented). At Elveden, preceding phenmedipham with chloridazon (1990 and 1991), and to a lesser extent with chloridazon/PCF (1990), reduced barley vigour compared with the same rate of post-emergence phenmedipham alone (Table 2).

Of the post-emergence only treatments, increasing rates of phenmedipham tended to cause increasing damage to the barley. The 194g rate reduced barley vigour, compared to the control or the safest treatment, in only two experiments, whereas the 399g rate reduced it in all but two of the unirrigated experiments. The addition of lenacil to the lower two rates of phenmedipham did not further reduce barley vigour except at the irrigated site in 1991. Both formulations of lenacil gave similar results. Adding chloridazon/lenacil to either rate of phenmedipham appeared to increase damage at some sites and decrease it at others, especially at Elveden in 1990. Similarly, adding chloridazon to the lowest rate appeared to increase damage at Colney in 1990 but significantly decreased it at Elveden. The low rate phenmedipham + metamitron treatment was one of the safest at Mepal, but at Colney in 1990, adding metamitron to 194g phenmedipham made it less safe than the same rate of phenmedipham alone. Adding mineral oil to this mix caused the highest levels of damage at Mepal, especially in 1990, whereas the phenmedipham/ethofumesate treatment was moderately safe. While metamitron + oil was the most damaging treatment at Elveden in 1989 and one of the most damaging at this and the Colney sites in most years, it was one of the safest at Mepal.

Most treatments with a pre-emergence component were similarly effective in reducing weed populations at Colney in 1989 and 1990 and at Elveden in 1989 and 1991, but were generally no better than treatments with no pre-emergence application (Table 3). Compared to phenmedipham alone, which tended to give poor weed control at the 194g rate, adding lenacil at Colney in 1990 or chloridazon at Elveden in 1989 gave some further reductions in weed populations, but lenacil had an adverse effect at Mepal in 1990. At Elveden in 1991, adding lenacil to 285g phenmedipham, chloridazon/lenacil to 194g phenmedipham, or chloridazon alone to either rate enhanced weed control. Adding metamitron to 194g phenmedipham improved weed control at Elveden in 1989 and 1991, but the lower rate mix often gave poorer control and was not much better than the untreated control at Colney in 1989 and 1990. Adding oil to this mix gave a high level of weed control at Mepal, as did the phenmedipham/ethofumesate treatment. Metamitron + oil gave the best weed control at Elveden in 1990 and 1991 and at Colney in 1991, but consistently the poorest at Mepal.

TABLE 2. Effect of treatment on barley shelter vigour after 1st or 2nd post-em. application (0-10 score Colney & Elveden, 0-9 score Mepal).

Treatment	Colney			Elveden			Mepal		
	1989 7 May	1990 2 May	1991 8 May	1989 11 May	1990 9 May	1991 2 May	1989 8 May	1990 23 Apr	1991* 10 May
Untreated	9.0	9.0	9.5	10.0	10.0	9.5	-	-	-
650 chlor, 285 phen	8.3	7.8	9.5	9.5	3.3	3.0	-	-	-
650 chlor, 194 phen + 875 met	-	-	9.0	-	-	4.3	-	-	-
340 chlor/PCF, 285 phen	7.5	6.3	9.8	10.0	4.8	5.8	-	-	-
340 chlor/PCF, 194 phen + 875 met	-	-	9.0	-	-	3.0	-	-	-
400 chlor/266 lenacil, 285 phen	-	6.8	9.8	-	5.0	5.3	-	-	-
400 chlor/266 lenacil, 194 phen + 875 met	-	-	9.8	-	-	5.3	-	-	-
194 phen	7.8	8.3	9.5	9.8	6.5	5.3	-	-	-
285 phen	6.5	6.8	9.5	9.0	6.3	5.8	7.4	6.8	7.4
399 phen	5.8	6.3	9.5	9.3	5.8	4.5	6.4	6.3	6.8
194 phen + 200 lenacil (WP)	7.3	8.0	9.0	9.5	7.3	7.0	-	-	-
285 phen + 200 lenacil (WP)	6.3	7.3	9.3	9.3	6.0	5.5	8.0	6.7	6.6
285 phen + 176 lenacil (SC)	6.0	7.0	8.8	9.3	5.8	5.5	-	-	-
194 phen + 140 chlor/93 lenacil	5.8	8.8	9.0	10.0	8.0	6.8	-	-	-
285 phen + 140 chlor/93 lenacil	5.8	5.8	8.5	9.3	7.8	7.3	-	-	-
194 phen + 455 chlor	7.3	6.8	9.8	9.3	8.0	8.0	-	-	-
285 phen + 455 chlor	6.3	7.0	9.8	10.0	8.0	6.8	7.8	-	7.4
97 phen + 438 met	6.8	7.5	9.5	9.8	8.0	6.8	-	7.8	7.8
194 phen + 875 met	7.3	6.5	9.3	10.0	6.8	6.0	7.7	6.9	7.5
194 phen + 875 met + 1.0 litre oil	-	-	-	-	-	-	6.1	5.4	6.6
1190 met + 1.7 litres oil	6.3	6.5	9.3	7.5	5.8	5.0	8.1	7.6	7.5
240 phen/300 ethofumesate	-	-	-	-	-	-	7.1	6.9	7.0
LSD between treated and untreated	1.87	1.70	NS	0.83	1.47	2.02	-	-	-
LSD between treatments	NS	1.68	NS	0.86	1.49	NS	0.58	0.76	0.59

* irrigated site

TABLE 3. Effect of treatment on broad-leaved weed populations (weeds m/²).

Treatment	Colney			Elveden			Mepal	
	1989 26 Jun	1990 8 Jun	1991 12 Jun	1989 6 Jul	1990 24 May	1991 16 May	1989 19 Jun	1990 8 Jun
Untreated	45.1	67.3	32.9	64.9	34.7	43.9	-	-
650 chlor, 285 phen	21.3	38.6	17.6	39.6	9.2	2.1	-	-
650 chlor, 194 phen + 875 met	-	-	24.2	-	-	0.7	-	-
340 chlor/PCF, 285 phen	25.8	52.6	19.6	35.6	9.6	1.3	-	-
340 chlor/PCF, 194 phen + 875 met	-	-	29.8	-	-	0.2	-	-
400 chlor/266 lenacil, 285 phen	-	37.0	20.1	-	14.6	2.7	-	-
400 chlor/266 lenacil, 194 phen + 875 met	-	-	29.8	-	-	0.1	-	-
194 phen	24.6	44.4	34.4	33.8	24.4	13.2	-	-
285 phen	29.9	39.9	44.8	26.9	16.7	11.6	24.8	31.0
399 phen	19.8	29.9	25.2	24.7	11.4	6.6	25.6	25.0
194 phen + 200 lenacil (WP)	27.9	38.1	22.2	27.6	12.2	12.5	-	-
285 phen + 200 lenacil (WP)	27.0	28.1	38.0	23.4	15.8	3.3	29.4	43.8
285 phen + 176 lenacil (SC)	19.4	25.0	29.6	26.7	13.7	5.0	-	-
194 phen + 140 chlor/93 lenacil	28.7	39.9	29.5	29.5	16.6	6.8	-	-
285 phen + 140 chlor/93 lenacil	21.3	39.6	42.2	21.7	12.5	7.3	-	-
194 phen + 455 chlor	25.8	49.6	28.1	21.0	13.8	6.9	-	-
285 phen + 455 chlor	29.3	43.3	36.1	18.6	12.2	4.2	31.4	-
97 phen + 438 met	34.3	57.4	26.6	27.1	5.4	3.8	-	39.5
194 phen + 875 met	20.6	33.7	32.6	14.2	14.4	0.6	26.8	36.8
194 phen + 875 met + 1.0 litre oil	-	-	-	-	-	-	19.6	27.3
1190 met + 1.7 litres oil	28.7	31.9	21.1	15.3	4.8	0.8	47.6	61.0
240 phen/300 ethofumesate	-	-	-	-	-	-	22.8	21.5
LSD between treated and untreated	12.69	13.50	15.11	12.43	21.15	4.72	-	-
LSD between treatments	NS	13.88	15.28	10.88	20.51	4.28	9.89	16.46

DISCUSSION

At sandy sites, levels of damage were negligible where post-emergence treatments were applied to well established barley, but were substantial in some cases where the barley was less advanced. Where herbicides significantly reduced barley vigour, treatments which were least damaging generally gave the poorest weed control and *vice versa*, except for the low rate phenmedipham + metamitron at Elveden in 1990 which gave surprisingly good weed control. The best compromise post-emergence treatments at sites where damage occurred, were phenmedipham + chloridazon at Elveden (less reliable at Colney) and phenmedipham + metamitron at Mepal and to a lesser extent at the other two sites. Other treatments combining acceptable levels of barley damage and weed control were lower rates of phenmedipham (at Mepal, and at Colney and Elveden when the weed spectrum was susceptible), low rate phenmedipham + lenacil at Colney or Elveden in some years and phenmedipham + chloridazon/lenacil at Elveden. Phenmedipham + chloridazon or lenacil proved safe at Mepal but gave variable weed control. Here phenmedipham/ethofumesate was a better option, as the ethofumesate component did not cause as much foliar scorch as expected.

Sequences starting with a pre-emergence herbicide did not always improve weed control and tended to cause more damage to the barley during its critical early growth, especially at Elveden where pre-emergence sprays were applied just before or after the barley emerged. These effects were observed under predominantly dry soil conditions in all three years, and field experience suggests that levels of damage in wetter seasons could be unacceptable. Similarly, post-emergence treatments with a residual component, especially metamitron and possibly lenacil, could cause excessive damage on sandy soils under wetter conditions. On peaty sites the levels of foliar scorch caused by phenmedipham, especially when applied during periods of night frost, were generally more damaging than the reductions in vigour caused by residual herbicides, which typically have very limited activity on this highly organic soil type. Although when the peaty site was irrigated, metamitron + oil was less safe relative to phenmedipham, it remained one of the least damaging treatments. However, this combination gave consistently poor weed control, and applying metamitron in mixture with phenmedipham proved a better choice.

In conclusion, on sandy soils the potential for improving weed control by using a pre-emergence herbicide was outweighed by the potential increase in damage to the barley shelter. On both soil types, the results suggest that post-emergence herbicide programmes can be devised to prevent excessive damage to barley shelter, without compromising standards of weed control. These should start with a safe option, such as low rate phenmedipham either alone or mixed with chloridazon or metamitron, followed by more active mixes to improve levels of weed control later in the programme. In the absence of replicated results under wet conditions, it would be prudent to minimise the residual components of such a programme.

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NEW POSSIBILITIES FOR THE CONTROL OF PROBLEM WEEDS IN SUGARBEET WITH QUINMERAC PLUS CHLORIDAZON COMBINATIONS

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ABSTRACT

Formulated mixtures (= BAS 523 00 H, BAS 523 02 H) of the new active ingredient quinmerac with the standard herbicide chloridazon were developed by BASF AG with the aim to provide broadspectrum weed control in sugarbeets including problem weeds like *Galium aparine* and *Aethusa cynapium*. Trials carried out in the major sugarbeet growing countries in W-Europe show that BAS 523 00 H and BAS 523 02 H due to their good crop safety can be flexibly used pre- as well as postemergence. When applied preemergence both products provide the basis for weed control programs by eliminating the aforementioned problem weeds and thus allowing greater flexibility for postemergence treatments. Comprehensive broadspectrum weed control of the most important broadleaf weeds in sugarbeet under various environmental conditions was obtained with sequential applications of BAS 523 00 H resp. BAS 523 02 H applied at reduced rate preemergence followed by tankmixtures with phenmedipham postemergence. Also in straight postemergence herbicide programs BAS 523 00 H resp. BAS 523 02 H showed very good broadspectrum weed control when applied as multiple split treatments in combination with phenmedipham. The introduction of BAS 523 00 H and BAS 523 02 H into the major sugarbeet growing countries is expected in 1994.

INTRODUCTION

Over the last decade weed control practices in sugarbeet in W-Europe have undergone considerable changes which are characterised by an increase of multiple herbicide treatments either as sequences of pre- followed by postemergence or as straight postemergence applications. The reasons for these changes are basically thought to be twofold:

- An increase of the sugarbeet area where mechanical weed control methods are no longer used.
- An increase of weed species like *G. aparine*, *Polygonum spp.*, *A. cynapium* and *Mercurialis annua*, which are more difficult to control by conventional herbicides.

A survey conducted amongst sugarbeet growers in W-Europe by BASF revealed that weeds like *G. aparine*, *Chenopodium* *album, Polygonum spp., Chamomilla recutita, Stellaria media, Lamium spp.* and *Mercurialis annua* top the list of problem weeds. Additionally, weeds like *A. cynapium, Ammi majus* and *Conium maculatum* which are not easily controlled by currently available herbicides are found to be spreading in the typical sugarbeet growing areas in France (Montegut & Janzein, 1984). Similar observations on the increasing importance of *A. cynapium* as a problem weed in sugarbeet were made in Germany. Investigations on the effect of this weed on sugarbeet yield showed that *A. cynapium* even at relatively low plant densities of 8 plants/m² can reduce the sugarbeet yield by 10 t/ha (Dollinger, Kemmer & Hurle, 1992). Also with Galium aparine infestations yield losses up to 30 % were observed in sugarbeet (Röttele, 1980). These findings underline the necessity for efficient methods to control these problem weeds in order to avoid yield reductions.

The discovery of the new active ingredient quinmerac by BASF with activity particularly against *G. aparine, A. cynapium, C. maculatum* and *A. majus* offers new possibilities for the control of these problem weeds (Würzer et al., 1985). Combinations of quinmerac plus chloridazon formulated as BAS 523 00 H or BAS 523 02 H show a wide spectrum of activity against the most important weeds in sugarbeet and can be used in a flexible manner at pre- and postemergence applications. Results from trials carried out with these formulated mixtures in sugarbeet in France, Belgium, Germany and the Netherlands are reported.

MATERIAL AND METHODS

The trials were laid out as small plot trials using plot sizes of 10 - 20 m² in a randomised block design with 3- 4 replicates. Applications were made with a spray tractor or with a knapsack sprayer using water volumes of 200 - 300 l/ha. The following products were applied:
- BAS 523 00 H (60 g quinmerac + 300 g chloridazon AI/l, SC, tradename: Rebell T®)
- BAS 523 02 H (50 g quinmerac + 400 g chloridazon AI/l, SC, tradename: Rebell®, Fiesta®)

As comparison products resp. tankmix partners the following products were used:
- chloridazon (65 % AI, WG)
- metamitron (70 % AI, WG)
- phenmedipham (157 g AI/l, EC)
- phenmedipham + desmedipham + ethofumesate (62 + 16 + 128 g AI/l, EC)

Applications were made as single or sequential applications either preemergence or postemergence. The trials were evaluated at regular intervals for crop phytotoxicity and weed control using a 0 - 100 % scale:

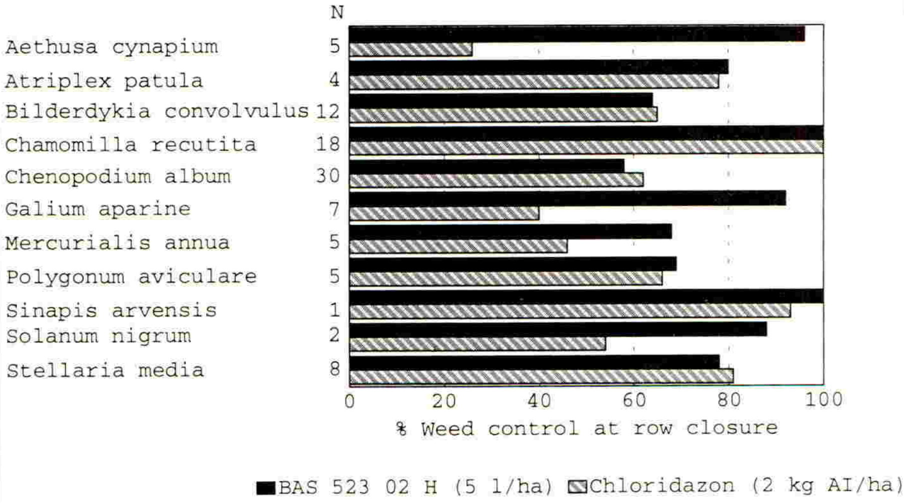
0 % = no crop damage, resp. no weed control
100 % = 100 % crop damage, resp. 100 % weed control

RESULTS AND DISCUSSION

Preemergence applications

When applied as a straight preemergence application in trials in Germany, Belgium and the Netherlands BAS 523 02 H at 5 l/ha showed superior control of problem weeds such as *G. aparine, S. nigrum, M. annua* and *A. cynapium* compared to chloridazon at 2 kg AI/ha. The herbicidal activity on other weeds was similar to chloridazon alone (Fig. 1).

Fig. 1: Herbicidal activity of BAS 523 02 H in sugarbeet applied preemergence in comparison to chloridazon (trials BE, NL, DE 1986 - 1993)

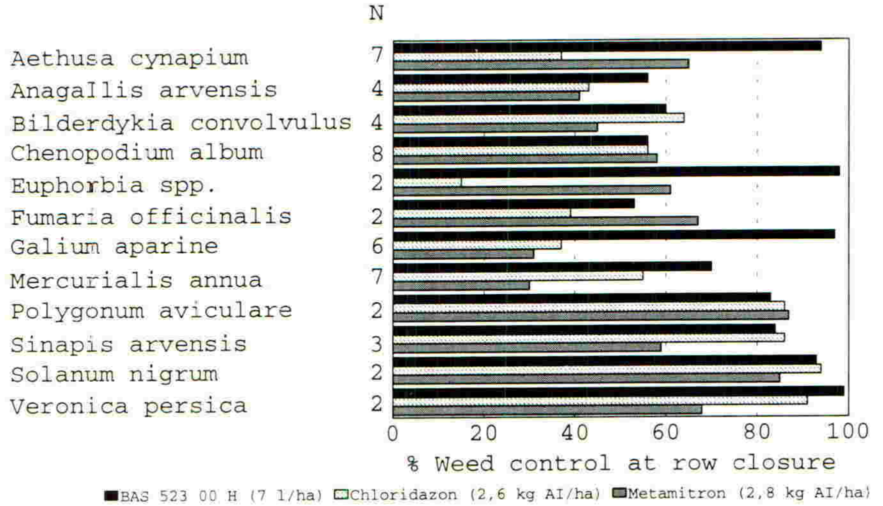


In preemergence trials in France BAS 523 00 H applied at 7 l/ha confirmed its excellent activity on *G. aparine*, on *A. cynapium* and on *Euphorbia spp.*in comparison to the standards chloridazon and metamitron (Fig. 2). Additionally the quinmerac in BAS 523 00 H enhanced the control of *M. annua* and *V. persica*. Despite the very good control levels obtained on the aforementioned weeds the spectrum of activity of BAS 523 00 H and BAS 523 02 H as straight preemergence applications is not sufficient to provide complete weed control in sugarbeet. Both products can, however, form useful basic components of weed control programs in sugarbeet.

Postemergence applications

As quinmerac and chloridazon are taken up by weeds both via roots and foliage BAS 523 00 H and BAS 523 02 H can also be used in early postemergence applications. In order to enhance the foliar activity and to broaden the weed spectrum both products should be applied in tankmix with phenmedipham.

Fig. 2: Herbicidal activity of BAS 523 00 H applied preemergence in sugarbeet in comparison to chloridazon and metamitron (trials FR, 1988 - 1993)



Moreover, the addition of oil concentrate as tested in previous trials has proved in former trials to be beneficial.

In a series of trials in Germany the tankmixture of low rates of BAS 523 02 H + phenmedipham was applied in multiple split treatments at the following timings (Fig. 3):

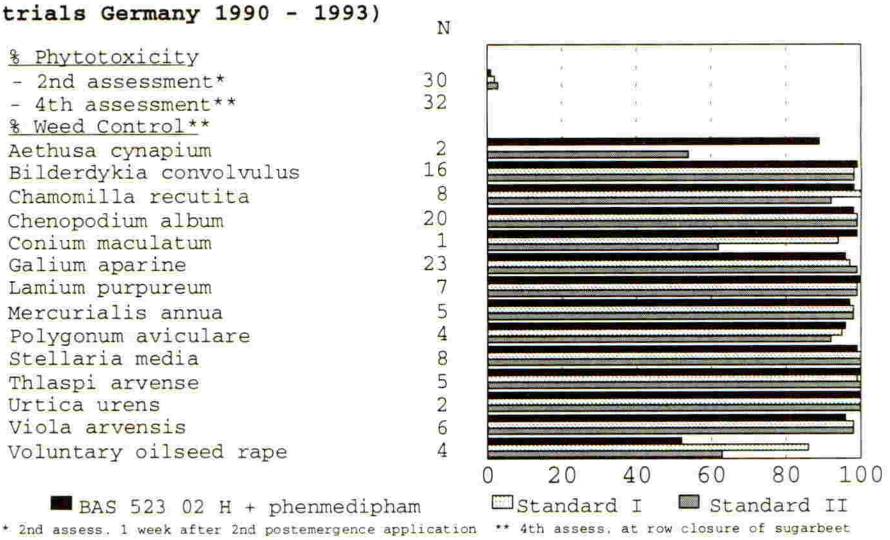
- 1st postemergence application: Weeds just emerging or in cotyledon stage
- 2nd postemergence application: New weeds emerging or in cotyledon stage resp. 6 - 12 days after 1st application
- 3rd postemergence application: New weeds emerging or in cotyledon stage resp. 6 - 12 days after 2nd application

At these timings the following treatments were compared:

- BAS 523 02 H + phenmedipham: BAS 523 02 H (1 - 1,5 l/ha) plus phenmedipham (235 g AI/ha)
- Standard I: Metamitron (700 g AI/ha) plus ready formulation of phenmedipham + desmedipham + ethofumesate (91 + 24 + 192 g AI/ha)
- Standard II: Ready formulation of phenmedipham + desmedipham + ethofumesate (124 + 32 + 256 g AI/ha)

The combination of BAS 523 02 H plus phenmedipham provided very good crop safety and excellent weed control against a wide spectrum of important weeds in sugarbeet including *G. aparine, L. purpureum, C. recutita* and the *Polygonum species*. The control levels of *A. cynapium* were markedly better than the standard, however, proved to be not quite sufficient. Due to the extended germination period sequential pre- and postemergence applications are required for efficient control of this problem weed.

Fig. 3: Herbicidal activity of BAS 523 02 H + phenmedipham combinations in sugarbeet applied as postemergence split applications in comparison to standard treatments (Summary of trials Germany 1990 - 1993)



System applications

The most reliable performance of quinmerac plus chloridazon combinations against the more difficult to control weeds has been demonstrated in a series of trials conducted in Germany over several years under varying environmental conditions (Fig. 4). The following herbicide programs were compared:

- BAS 523 02 H-System: BAS 523 02 H (3 l/ha) preemergence followed by 2 postemergence applications of BAS 523 02 H (1 1,5 l/ha) plus phenmedipham (235 - 314 g AI/ha)
- Standard System I: Chloridazon (1300 g AI/ha) preemergence followed by 2 postemergence applications of chloridazon (650 g AI/ha) plus ready formulation of phenmedipham + desmedipham + ethofumesate (91 + 24 + 192 g AI/ha)
- Standard System II: Metamitron (1400 g AI/ha) preemergence followed by 2 postemergence applications of metamitron (700 g AI/ha) plus ready formulation of phenmedipham + desmedipham + ethofumesate (91 + 24 + 192 g AI/ha)

The BAS 523 02 H system of sequential pre- and postemergence applications provided consistent control ratings of more than 95 % against a broad range of weeds including *G. aparine* and *M. annua*. Particularly interesting is the high control level of *A.cynapium* obtained with this system. The crop safety of this herbicide sequence was very good.

The results of all trials presented confirm the excellent potential of quinmerac plus chloridazon combinations as base herbicides for preemergence applications as well as for herbicide programs in sugarbeet consisting of sequential pre- plus postemergence or straight postemergence applications.

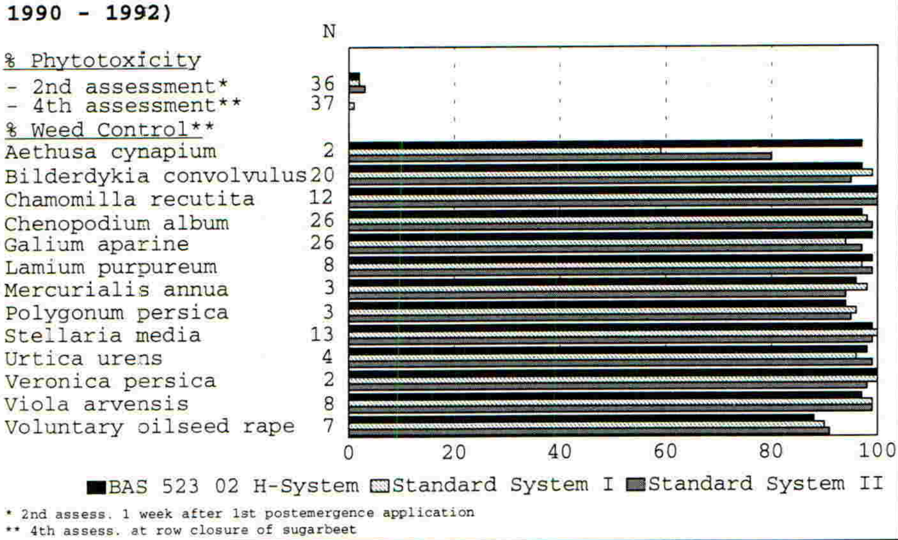


Fig. 4: Herbicidal activity of BAS 523 02 H in sugarbeet applied as pre- plus postemergence system applications in comparison to standard treatments (Summary of trials Germany 1990 - 1992)

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THE CROP TOLERANCE OF CABBAGE, BRUSSELS SPROUTS AND ONIONS TO PYRIDATE.

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ABSTRACT

Pyridate is a purely contact herbicide, with no residual activity. It is approved in the U.K. for use in maize, oilseed rape and cereals at a use rate of 2.0-2.5kg of product per hectare (900-1125 g AI/ha of pyridate) for broadleaved weed control. Work carried out with pyridate at double the efficacy rate (1800g AI/ha) demonstrated the tolerance of cabbage, Brussels sprouts and onions under U.K. conditions. Pyridate controls a wide range of species of weeds including *Galium aparine*, *Anchusa arvensis*, *Solanum nigrum*, *Chenopodium album*, *Senecio vulgaris* and *Veronica* spp. . This excellent activity against broadleaved weeds combined with good crop safety indicates that pyridate should perform well in the vegetable market when used within a growers herbicide programme.

INTRODUCTION

Pyridate is a pyridazine herbicide which has been marketed in the United Kingdom (U.K.) since 1976 for broadleaved weed control in maize, oilseed rape and cereal crops. It has also been marketed internationally for broadleaved weed control in certain vegetable crops. It is a foliar-acting herbicide with contact activity on annual dicotyledonous plants, especially *Galium aparine, Chenopodium album, Senecio vulgaris* and *Veronica spp.*. It controls weeds selectively in cereals, maize and other crops at 0.9-1.5kg AI/ha.

Effectiveness depends on the weed species and the stage of weed development, with smaller weed sizes being most sensitive. In sensitive plants the compound leads to an irreversible blocking of the Hill reaction in photosynthesis. Plants affected in such a way show leaf scorch and finally desiccation. Favourable growing conditions promote the herbicidal effect. The selectivity of pyridate derives from the ability of certain plants to rapidly deactivate the main active metabolite by forming glycosidic conjugates. Being a non-persistent contact herbicide, pyridate offers the advantage of specific weed control and, in addition, avoids any carry-over problems from soil residues (Anon, 1982).

As the weed spectrum and application timing in vegetables is similar to that in maize (ie. spring application, small weeds), the control can be expected to be similar. The results reported here concentrate on the tolerance of cabbage, Brussels sprouts and onions to pyridate applied at single and double rate.

METHOD AND MATERIALS

Pyridate has been tested in 20 small plot field trials in the U.K. since 1989 on a broad range of commercial vegetable crops. Sites were located where soil type, variety and climatic conditions were optimum for growth of the crop. The trials were of a randomised complete block design with four replicates, with the exception of the variety screens where one replicate was used. The plot size was 3m x 12m with a 3m untreated guard strip left between each replicate. Fungicide and insecticide applications were made by the grower when required, in accordance with good agricultural practice. Test applications were made using a CO_2-pressurised Ciba small plot sprayer fitted with six Lurmark 02-F110 nozzles (BCPC code: F110/0.80/3) and calibrated to deliver 200l/ha at 207kPa with a forward speed of $1ms^{-1}$. Pyridate was tested as a wettable powder formulation (45WP = 450g AI/kg). Both single and double rates were tested and applications were made at the growth stages stated in Table 1.

TABLE 1. Growth stages at application.

Crop	Growth Stage (No. of true leaves)
Cabbage	3-9
Brussels sprouts	4-9
Onions	1-5

Crop phytotoxicity was assessed at intervals from the first application up to harvest using a 0-100% scale where 0= no crop damage and 100= complete crop loss. Any assessment above 11% was deemed unacceptable.

Trials were harvested by hand and analysis of variance was performed on yield data using Tukeys t-test. Test treatments used were: 1, untreated; 2, 900g Al/ha of pyridate (efficacy rate) and 3, 1800g Al/ha of pyridate (double efficacy rate).

RESULTS

Cabbage

All the treatments were applied at 3-9 leaves of the crop. Pyridate was well tolerated at the single (900g Al/ha) rate. At the double (1800 g Al/ha) rate only a maximum of 5% crop phytotoxicity (average of 1.8%, see Table 2) was recorded with the exception of one site. At this site the double rate application was made at the 3-4 leaf stage and suggests that cabbage must have at least 4 true leaves before application of pyridate can be made safely.

The symptoms of any crop phytotoxicity were a distinctive yellow blotching on the sprayed leaves as they started to senesce naturally. New leaves emerging after application were totally unaffected and by the final assessment all sites, except the site sprayed at 3-4 leaves, the crop had recovered completely.

7 of the sites were harvested. These covered 5 single rates and 11 double rate applications, and no significant effects on yield were recorded. (Table 3 and Table 4)

Brussels sprouts

All the treatments were applied at 4-9 leaves of the crop. No treatment caused any unacceptable crop phytotoxicity at either the single or double rate (Table 2). The maximum crop phytotoxicity obtained was from a double rate application (1800g Al/ha) of pyridate which gave 11% phytotoxicity. This was similar to that seen in cabbage and was only transient in nature.

Pyridate applied at both the single and double rates caused no significant adverse effects on yield (Table 3 and Table 4) at the 3 sites harvested.

Onions

All the treatments were applied at 1-5 leaves of the crop. No treatment caused any adverse crop effects (Table 2). Only double rate treatments were taken to yield and no negative yield effects were recorded (Table 3 and Table 4).

TABLE 2. Average maximum % crop phytotoxicity.

Crop	Pyridate (g AI/ha)	Average max. % phytotoxicity (No. of trials)	Range (%)
Cabbage	900	0.33 (7)	0-2
	1800	1.8 (19)	0-15
B. sprouts	900	3.0 (3)	1-6
	1800	5.4 (8)	0-11
Onions	900	0 (3)	0
	1800	0 (8)	0

TABLE 3. Average crop yield as a percentage of the untreated.

Crop	Pyridate (g AI/ha)	Average yield of crop, % of untreated (No. of trials)	Range (% of untreated)
Cabbage	900	103.4 (5)	94-112
	1800	113.3 (7)	89-162
B. sprouts	900	101.3 (2)	99-103
	1800	96.4 (3)	94-103
Onions	900	- (-)	-
	1800	152.5 (2)	148-157

TABLE 4. Yield results with statistical analysis.

Crop	Yield of crop (% of untreated) Pyridate 900g Al/ha	Pyridate 1800g Al/ha	Coefficient of variance	LSD (5%)
Cabbage	108.76	111.74	11.02	26.36
Cabbage	111.88	152.92	20.09	2.74
Cabbage	102.21	88.7	12.41	3.06
Cabbage	94.49	101.69	20.01	5.06
Cabbage	99.63	105.44	9.98	7.96
Cabbage	-	102.93	11.69	0.25
Cabbage	-	108.04	10.94	7.12
B. sprouts	102	94	6.93	3.10
B. sprouts	99.31	93.56	7.39	1.44
B. sprouts	-	102.81	15.05	1.16
Onions	-	147.62	21.87	6.71
Onions	-	157.20	17.57	7.80

DISCUSSION/CONCLUSION

The results presented show that pyridate at single (900g Al/ha) and double (1800g Al/ha) rate is well tolerated by cabbage and Brussels sprouts after the four leaf stage and onions after the one leaf stage. Early application timings may cause crop damage due to insufficient leaf wax. Any crop effects that do occur at the earlier growth stages are confined to the sprayed leaves and effects are only seen when the leaves begin to senesce naturally. Later applications made up to 8 weeks before harvest do not result in any crop effects.

Pyridate has been tested on 11 different varieties of cabbage, 3 varieties of Brussels sprouts and 3 varieties of onions. In all cases double rate pyridate was found to be well tolerated by the crop.

Weed control results have not been presented in this paper as only those weeds already on the current label will be claimed for control in the vegetable crops proposed. The following weeds are susceptible to pyridate at the efficacy rate and are currently on the 'Lentagran' label;

Amaranthus sp.	*Solanum nigrum*	*Anchusa arvensis*
Galium aparine	*Fumaria officinalis*	*Galeopsis tetrahit*
Buglossoides arvensis	*Chrysanthemum segetum*	*Geranium sp.*
Chenopodium album	*Myosotis arvensis*	*Senecio vulgaris*
Lapsana communis	*Ambrosia artemisiifolia*	*Lamium purpureum*
Sonchus arvensis	*Veronica sp.*	*Euphorbia helioscopia*

Post-emergence herbicide choice still appears to be very difficult for many vegetable growers. Significant damage can be caused by currently marketed products including growth checks or plant loss (Norman, 1990). An acceptable herbicide has not only to show excellent weed control but also excellent crop tolerance to enhance the profitability of the crop due by meeting the stringent requirements on size, shape and finish of the produce setting the supermarket . Cabbages, Brussels sprouts and onions show excellent tolerance to pyridate at the label recommended rate and gives good double rate tolerance with a weed control spectrum that meets the needs of the vegetable grower.

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FOMESAFEN - A POST-EMERGENCE HERBICIDE FOR BROAD-LEAVED WEEDS IN GREEN BEANS *(PHASEOLUS VULGARIS)*

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ABSTRACT

Fomesafen, as a 250 g/l formulation with incorporated wetter, is a promising herbicide for use in green beans *(Phaseolus vulgaris)* which were tolerant of rates tested of up to 448 g AI/ha applied early post-emergence of the crop. Early application when weeds were small was the most effective, and the high selectivity of fomesafen allowed treatment of the crop at simple leaf stage. Fomesafen controlled a wide spectrum of broad-leaved weeds, killed volunteer oilseed rape and scorched foliage of volunteer potatoes. In three years experiments fomesafen at 224 g AI/ha gave the most reliable control. In some situations 112 g AI/ha was sufficient or a follow-up dose of 112 g AI/ha controlled later weed flushes. A herbicide programme is essential in the UK to achieve high levels of weed control and to remove species resistant to fomesafen *(Poa annua* and *Stellaria media)*.

INTRODUCTION

Green beans *(Phaseolus vulgaris)* are poor competitors with weeds and a high level of weed control is required to avoid yield loss, weed contaminant problems in produce and difficulties with machine harvesting in crops grown for quick-freezing and canning. A herbicide programme is normally required. In the UK few products are registered and on sands and highly organic soils a post-emergence herbicide, bentazone is the only option. Bentazone application must be delayed until the beans are at 1½ trifoliate leaf stage when weeds are sometimes too large for optimum control. An early post-emergence treatment was therefore sought.

Fomesafen was discovered at the Plant Protection Division, ICI (Colby *et al.*, 1983) and is used in soya beans. In France, fomesafen was registered in 1990 for post-emergence application in green beans. Fomesafen is mainly a foliar contact-acting herbicide but has some residual activity through the soil. Preliminary work at PGRO indicated that pre-emergence applications of 250 g AI/ha fomesafen were selective in beans but less effective than the standard monolinuron. Post-emergence applications of fomesafen were not selective in runner beans *(Phaseolus coccineus)* in ICI experiments, but green beans appeared highly tolerant. This research report summarises experiments from 1990 to 1992 with fomesafen for early post-emergence broad-leaved weed control in green beans.

MATERIALS & METHOD

Fomesafen as Flex W, an aqueous concentrate formulation of the sodium salt containing 250 g/l of the active ingredient incorporated with a wetter was used in the experiments. It was compared with the standard, Basagran, containing 480 g/l active ingredient bentazone. Applications were post-emergence of the crop; rates and timings are shown in Tables 1, 2 and 3 and at some sites other herbicides for broad-leaved weeds were sprayed overall, pre-emergence or pre-sowing. Treatments were applied using a Van der Weij plot sprayer with Lurmark flat fan nozzles 02-F110 delivering 200 l/ha water volume at a pressure of 190 kPa to give fine spray quality.

Experiments were of randomised block design with four replications. Plot size was 8 m x 4 m. Sites were in the main green bean production area of the UK at Three Holes (Site 1) and Carters Bridge (site 3, 1992) Cambs. on soils with more than 15% organic matter (site 1); Kirton, South Lincs. (site 2) and Friday Bridge, Cambs. (site 5, 1992) on silt loam soils; Hoveton (site 3, 1990), Swaffham, Norfolk (site 3, 1991), loamy sands and Dilham (site 4, 1992), Norfolk, sandy loam soil. Data from these sites are presented, with a summary for weeds controlled at additional sites.

The beans cvs. Nerina, Groffy, Kent, Labrador, Modus, Provider and Forum were sown at 3 - 4 cm depth with precision drills on 35 - 45 cm row width, at populations of 40 - 45 plants/m^2 between 15th May and 2nd July. Husbandry was according to standard practice for the crop. Broad-leaved weed control was assessed as a score overall (10 = complete control; 7 = acceptable control; 0 = no control), and as counts in 3 x 0.33 m^2 quadrats for each species present. Plots were harvested by hand to determine yield of green bean pods at quick-freezing or canning stage of maturity. Pod maturity was assessed by measuring length of 10 seeds, one from the most mature pod on each of a random sample of 10 plants/plot. Yield and maturity data were statistically analysed.

Cultivar susceptibility experiments were undertaken from 1990 - 92, using the method described by King, 1980. Fomesafen at 675 g AI/ha was applied to a range of 50 commercially grown and new cultivars at growth stages ranging from simple leaf to 1½ trifoliate leaf stage. Observations were also made at 17 sites on any carry-over effect of fomesafen on crops following beans.

RESULTS & DISCUSSION

A summary of results for 1990, 1991 and 1992 for weed control including the main weed species and green bean pod yield are shown in Tables 1, 2 and 3 respectively. Visible crop effects from fomesafen were negligible at most sites and crop scores are only shown at sites where damage was observed.

Crop tolerance of green beans

Fomesafen at rates of up to 448 g AI/ha (twice normal) was highly selective in green beans when applied early post-emergence at simple leaf or 1 - 1½ trifoliate leaf stage. Sprays were applied at temperatures of up to 24°C and in humid conditions. The only visible effects were slight leaf crinkling and a temporary vigour check at site 2 in 1990 and at site 5 in

TABLE 1. Weed scores, species counts & total (including other species), crop score & green bean pod yield: 1990

Material	g AI/ha~	Weed Score				Weed counts main species/m^2															Yield pods as a % of untreated	
						P. annua	V. arvensis	P. rhoeas	M. arvensis	F. convolvulus	C. album	Total	S. media #	U. urens	C. album	P. persica	Total	C. album	U. urens	Total		
	Site:	1	2	2#	3	1							2					3			1	2
	Date:	8/8	13/7	10/8	16/8	16/7							13/7					29/7			8/8	13/8
untreated	-	0	0	0	0	28	24	5	8	8	7	91	61	118	12	6	202	37	22	66	100	100
fomesafen	75	1.0	3.6	4.0	1	25	21	4	8	5	3	72	54	14	6	3	80	24	13	43	155	523
"	125	2.5	4.2	5.5	2	31	11	1	5	3	2	56	52	6	4	1	65	28	8	40	189	609
"	175	3.2	5.0	7.0	3	30	18	1	6	3	2	61	50	3	2	0	55	23	7	35	196	653
"	224	4.5	6.5	8.0	4	28	7	0	3	2	2	43	50	0	0	0	52	27	2	32	215	750
"	448	7.2	6.8	9.0	5	26	0	0	1	0	0	29	41	0	0	0	41	18	2	24	197	743
bentazone	1440	3.0	9.5	6.0	4	32	25	1	0	4	3	65	0	2	4	1	7	22	1	29	182	398
Yield pods untreated t/ha																					6.6	1.7
Significance @ P = 0.05																					SD	SD
LSD @ P = 0.05																					37.6	134.4
CV %																					13.2	17.1

follow-up with bentazone @ 960 g AI/ha on fomesafen treatments killed *S. media*

~ Timing & leaf stage: Site 1, 28/6, beans 1 trifoliate, weeds 2-4 true; Site 2, 25/6, beans simple, weeds 2 true; Site 3, 19/7, beans 1 trifoliate, weeds 8-10 true

TABLE 2. Weed scores, species counts & total (including other species), green bean pod yield: 1991

Material	g AI/ha	Timing	Weed Score			Weed counts main species/m^2																					Yield pods as a % untreated	
						MAT spp.#	L. purpureum	V. persica	F. convolvulus	C. album	M. arvensis	Total	U. urens	S. media	MAT spp.#	C. album	S. vulgaris	P. persicaria	F. officinalis	Total	P. aviculare	U. urens	T. inodorum	V. arvensis	S. vulgaris	Total		
		Site:	1	2	3	1							2								3						1	3
		Date:	4/8	9/8	1/8	28/7							1/8								1/8						15/8	7/8
Untreated	-	-	0	0	0	17	10	3	5	5	2	52	128	15	75	13	11	5	6	254	6	25	57	6	7	103	100	100
fomesafen	75	T_1	2	1	6.6	10	10	1	3	3	2	33	80	12	42	5	8	1	1	150	2	2	3	7	0	16	219	133
"	112	T_1	3	1.6	7.5	10	9	1	3	2	4	30	45	14	37	6	6	4	1	114	3	2	2	3	0	10	247	140
"	175	T_1	4	2	8.5	7	10	0	2	1	2	23	35	12	36	7	7	2	0	100	2	0	2	1	0	6	275	140
"	224	T_1	5.5	2.6	9.5	7	7	0	1	1	2	18	6	11	45	4	3	2	1	72	2	1	1	0	0	4	306	147
"	48	T_1	6.1	4.2	9.9	3	7	0	1	1	2	14	4	11	27	1	1	1	0	46	1	0	0	0	0	1	322	147
	75&75	T_1&T_2	3.8	3.5	6.5	13	8	0	2	3	1	29	2	14	21	1	2	0	0	40	5	2	7	1	0	15	246	128
"	112&112	T_1&T_2	5.4	4.5	9.0	8	6	0	1	1	2	20	0	12	21	0	1	0	0	34	1	0	4	1	0	6	298	148
fomesafen& bentazone	112&960	T_1&T_2	6.4	4.1	8.8	1	1	0	1	2	1	10	4	0	0	6	1	0	2	13	4	1	0	3	0	8	312	132
bentazone	1440	T_2	6	4.8	6.8	1	0	3	1	4	1	12	6	0	0	14	0	0	4	22	3	4	0	5	1	18	320	135
Yield pods untreated t/ha																											5.9	2.6
Significance @ P = 0.05																											SD	SD
LSD @ P = 0.05																											24.1	65.4
CV %																											12.3	17.1

\# MAT spp.: Site 1 mainly *Tripleurospermum inodorum*; Site 2 mainly *M. matricarioides*

Timing & leaf stage T_1: Site 1, 5/7, beans ½ trifoliate, weeds 4 true - small plant; Site 2, 7/7, beans simple - ½ trifoliate, weeds 4-6 true; Site 3, 1/7, beans 1 trifoliate, weeds 4 true - small plant

T_2: Site 1, 17/7, beans 1½ trifoliate; weeds small plant; Site 2, 17/7, beans 1½ trifoliate, weeds large plant; Site 3, 10/7, beans 3 trifoliate, weeds small plant

1992 from the 448 g AI/ha rate. Under hot weather conditions more damage was seen from the standard bentazone even though it was applied at a more advanced bean growth stage. In 1992 where weed populations were low, $57/m^2$ at site 1, and $72/m^2$ at site 2, application of fomesafen to beans at ½ - 1 trifoliate leaf stage caused no statistically significant reduction in yield (Table 3) or effects on maturity and there were no differences between treatments. Fomesafen also appeared safe in programmes with herbicides applied overall: monolinuron pre-emergence at sites 2 and 4 in 1992, trifluralin incorporated pre-sowing at site 3 in 1991 and at other sites not reported in this paper, and with bentazone post-emergence at site 2, 1990, all sites in 1991 and site 5 in 1992. In cultivar sensitivity tests all 50 cultivars, including Provider which is sensitive to monolinuron, and small seeded extra-fine podded types such as Niki and Tavera, were tolerant of fomesafen.

Weed control

In 1990, weather conditions at and following herbicide applications were warmer than the long term average. Table 1 shows that the best control was achieved at site 2 where fomesafen was applied to small weeds (*Chenopodium album* 2 true leaves) when the beans were at simple leaf stage and a follow-up treatment with 960 g AI/ha bentazone removed *Stellaria media*. Control was poor at site 3 for weeds at an advanced stage (*C. album* 8 - 10 true leaves). There was a dose response to fomesafen and rates of less than 224 g AI/ha gave an unacceptable level of control. It was clear that a herbicide programme was needed. Bean yields (Table 1) reflected the level of weed control achieved with fomesafen, and at site 2 weed populations of $202/m^2$ resulted in severe yield reduction. Bentazone, which was applied earlier than the label recommendation caused visible crop damage which appeared to result in yield reduction at site 2. Bean maturity on weedy untreated plots at sites 1 and 2 (data not presented) was later than for treated beans.

In 1991, when temperatures were lower than the long term average after sowing, bean growth was slow in comparison with weeds which were at 4 - 6 true leaf stage or more when the crop was at simple - ½ trifoliate leaf stage. At sites 1, 2 (Table 2), treatment with fomesafen alone gave an unacceptable level of control and 75 g AI/ha was insufficient at all sites. The best control was at site 3 where trifluralin was applied pre-sowing and incorporated, and here fomesafen at 112 g AI/ha or more killed *Urtica urens* at 4 true leaf stage and *Tripleurospermum inodorum* at 6 true leaves, but not *Polygonum aviculare* at small plant stage. The most effective treatments were fomesafen at 224 g AI/ha as a single or split dose. Results for split doses were similar but not much better than for single applications. The follow-up bentazone treatment improved control of *Matricaria matricarioides* and *S. media* at sites 1 and 2. *U. urens* infestations precluded hand-harvesting at site 2. Weeds on untreated plots caused significant and severe yield reduction at sites 1 and 3 (Table 2) and to some extent treatment yields were a reflection of weed control achieved. Maturity was also delayed where weeds shaded the crop on untreated plots.

In 1992, the first fomesafen treatments were applied earlier and in the warm moist conditions weeds were easier to kill than in the previous years. Excellent control was achieved with 112 g AI/ha fomesafen at sites 3 and 4 (Table 3) and at 1 and 2 (data not presented). Fomesafen performed

TABLE 3. Weed score, species counts & total (including other species), crop score & green bean pod yield: 1992

Material g AI/ha		Timing	Weed Score			Weed counts main species/m^2																					Yield pods as % untreated		
						Chenopodium spp.	U. urens	S. nigrum	C. bursa-pastoris	P. annua	S. media	V. persica	Total	V. arvensis	C. album	MAT spp.	Total	Chenopodium spp.	Potato seedlings	U. urens	P. persicaria	C. bursa-pastoris	V. persica	P. rhoeas	Total			
		Site:	3	4	5	3								4				5								1	2	3
		Date:	1/9	21/8	18/9	4/8								24/7				21/8								1/9	26/8	4/9
untreated			0	0	0	50	30	3	5	29	3	5	136	144	95	13	255	120	22	16	10	9	11	5	237	100	100	100
fomesafen	112	T_1	8.4	8.1	5.6	0	0	0	0	10	1	0	11	27	7	0	36	4	2	0	4	1	0	0	15	103	96	194
"	112&	T_1&																										
	112	T_2	9.5	10	8.0	0	0	0	0	2	1	0	3	0	0	0	1	3	0	0	0	0	0	0	7	102	96	187
"	224	T_1	9.5	9.4	8.8	0	0	0	0	8	1	0	10	15	1	0	17	0	0	0	1	0	0	0	3	102	98	194
# "	224	T_2	6.6	10	-	6	0	0	0	5	1	0	13	0	7	0	7	-	-	-	-	-	-	-	-	102	94	191
"	448	T_1	9.6	10	10.0	0	0	0	0	7	0	0	7	0	0	0	1	0	0	0	0	0	0	0	0	96	95	181
bentazone	1440	T_3	3.5	8	3.2	17	0	0	0	25	0	2	44	76	3	0	79	60	19	2	0	0	5	2	92	100	97	142
$fomesafen&	112&	T_1&																										
bentazone	960	T_3			6.3													18	5	0	0	0	0	0	26			
$fomesafen&	224&	T_1&																										
bentazone	960	T_3			9.3													2	1	0	0	0	0	0	7			
Yield pods untreated t/ha																										10.9	17.3	6.6
Significance @ P = 0.05																										NSD	NSD	SD
LSD @ P = 0.05																										-	-	72.8
CV %																										8.6	6.8	28.8

treatment not at site 5; $ site 5 only

Timing & leaf stage T_1: Sites 3, 4 & 5, beans simple leaf; Site 3, 15/7, weeds 2-4 true leaf; Site 4, 6/7, weeds 2-4 leaf; Site 5, 23/7, weeds 2-4 leaf

$T_2 = T_1 + 7$ days

$T_3 = T_1 + 9$ to 13 days, beans 2 trifoliate leaf better than bentazone on the weed spectra at all sites. Fomesafen at 224 g AI/ha and bentazone were less effective at the later timings on more advanced *C. album* (4 - 6 true leaf stage) at sites 3 and 4 than at the earlier one. The second of the split dose applications of fomesafen controlled some late-emerging *Viola arvensis* at site 4. Treated out-yielded untreated plots by up to 94% at the weedy site and maturity was more advanced but there were no statistically significant differences between treatments (Table 3).

Susceptibility of weed species

S. media and *Poa annua* were resistant to fomesafen at 224 g AI/ha. *M. matricarioides* (pineapple mayweed) was not controlled by fomesafen (Table 2) but *T. inodorum* (scentless mayweed) was susceptible. *P. aviculare* at small plant stage was not controlled (Table 2) by fomesafen or bentazone and Kouassi & Pichon, 1993 suggest it is resistant. *Myosotis arvensis* (site 1 1990 and 1991) was moderately resistant, and large *Lamium purpureum* site 1, 1991 was not controlled.

Excellent control of high populations of *U. urens* was achieved by fomesafen at 112 g AI/ha at several sites. *Polygonum persicaria*, *Capsella bursa-pastoris*, *Solanum nigrum* (site 3, 1992), *Senecio vulgaris*, *Sinapis arvensis*, were also susceptible and so were species which were not well controlled by bentazone *Veronica persica*, *Papaver rhoeas*, *Viola arvensis* and *Fumaria officinalis*. Control of *Chenopodium* species was only reliable where the weeds were smaller than the 4 true leaf stage, and *Fallopia convolvulus* only appeared susceptible when small. *Galium aparine* occurred at low populations at several sites and was severely stunted, and was killed by 224 g AI/ha (site 1, 1991).

Fomesafen was effective on potato seedlings (site 5, 1992). There was a random distribution of volunteer potato shoots at some sites and even 112 g AI/ha fomesafen caused severe scorch and stunting. The repeat dose at site 1, 1991 prevented flower and berry formation. In most cases more shoots appeared later. On unreplicated observation plots, fomesafen at 224 g AI/ha completely controlled weed beet at 2 leaf stage, and a population of 51 plants/m^2 oilseed rape volunteers (GS 4 true leaf, a few 6 true leaf) and was more effective than bentazone. The 112 g AI/ha rate did not kill the larger rape and only gave 20% control.

Data on following crops

Crops which followed the green beans at 17 sites in 1990, 1991 and 1992, were monitored for carry-over effects from rates of fomesafen up to and including 448 g AI/ha applied post-emergence of beans from 25th June to the 30th July. After beans the fields were ploughed before sowing the subsequent crops in the rotation, which were winter wheat (9 sites) or spring sown crops of potatoes (7 sites) or sugar beet (1 site). After establishment, crops were assessed for damage, but none was observed.

In three years of experiments, fomesafen, at rates of up to 448 g AI/ha applied post-emergence to green beans from simple leaf - 2 trifoliate leaf stage and at temperatures of up to 24°C was highly selective. At sites with low weed populations, fomesafen did not reduce pod yield. There did not appear to be differences in sensitivity of green bean cultivars and all 50 tested were tolerant of fomesafen. This is in agreement with results from France (Anon., 1991) but there it appears less selective at later growth stages.

Fomesafen controlled a wide spectrum of broad-leaved species commonly found in bean crops, including *S. nigrum*, and in addition volunteer potato foliage was suppressed. These two weeds can cause toxic contaminant problems in the processed crop. It gave excellent control of volunteer oilseed rape. For optimum control of moderately susceptible weeds such as *Chenopodium* spp. application must be made before the 4 true leaf stage.

Although the 224 g AI/ha rate of fomesafen gave more reliable weed control, the 112 g AI/ha dose was sufficient in some situations and where a pre-emergence or pre-sowing of another herbicide was used. A split-dose, 112 g AI/ha followed by 112 g AI/ha, may be necessary to control later weed flushes.

Early applications when weeds are small are the most effective and the high selectivity of fomesafen allows treatment of the crop at simple leaf stage. In France herbicide programmes with fomesafen are recommended (Kouassi & Pichon, 1993), in the UK this appears to be essential because the growth of beans is sometimes retarded in cool weather and the weeds are advanced in comparison. A pre-sowing incorporated application of trifluralin or monolinuron pre-emergence would remove *P. annua* and *S. media*, the weeds resistant to fomesafen; on organic soils a post-emergence treatment with a low dose of bentazone would control *S. media*.

Fomesafen is thus a promising new herbicide with a wide margin of crop safety for early post-emergence use in green beans.

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EVALUATION OF FOMESAFEN AS A RASPBERRY CANE DESICCANT

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ABSTRACT

Fomesafen was evaluated as a potential raspberry cane desiccant at a range of spray concentrations from 0.05 to 0.60 litres of formulated product per 100 litres water. The crop exhibited a high margin of tolerance, with no concentration used showing evidence of translocation up fruiting canes or into second-flush canes produced after desiccation of the first flush. Fruit yields were comparable to those on plots where first-flush canes were cut. Efficacy of desiccation was higher in some experiments than in others, the poorer results being attributed to adverse weather conditions. It was not greatly improved by increases in spray concentration. However, the addition of a non-ionic wetter to the spray solution considerably enhanced performance. Results to date indicate that acceptable levels of desiccation can be obtained with a spray concentration of 0.1 litres of formulated product per 100 litres of water (plus wetter), applied in a spray volume of 1000 litres per treated hectare. There may be scope for reducing this spray concentration in favourable conditions.

INTRODUCTION

Until banned in 1987, dinoseb-in-oil was widely used as a cane desiccant to alter the balance of growth between fruiting and vegetative canes in raspberries. Management techniques such as cane vigour control, biennial cropping and final year primo-cane removal depended on this chemical selectively controlling one or more flushes of young canes in spring (Lawson & Wiseman, 1992). Many alternative chemicals have been assessed at SCRI in recent years (Lawson, 1990), but few have shown the attributes necessary for safe and effective commercial use. One of these has been fomesafen, a herbicide first developed for post-emergence weed control in soya beans (Colby *et al.*, 1983) and more recently evaluated in the United Kingdom in mixture with terbutryn for weed control in peas (Lake & Brennan, 1987) and potatoes (Lawson *et al.*, 1989). This paper summarises progress to date in the evaluation of this chemical as a potential raspberry cane desiccant.

MATERIALS AND METHODS

Five experiments were carried out at Invergowrie in established plantations of raspberry cvs. Glen Clova and Glen Prosen between 1988 and 1992. Plots consisted of single rows, 9 m long and 2 m apart, each comprising 12 stools. Plots were arranged in randomised blocks with three replicates. Untreated and/or hand-cut plots were included as controls. Scores were taken of efficiency of overall desiccation of young canes and records were made of yield of fruit and of vegetative cane production. Plots were assessed regularly for signs of translocation to fruiting laterals or into second-flush canes produced after desiccation.

Fomesafen (250 g a.i./litre, Zeneca Crop Protection) was applied at a range of spray concentrations by Oxford Precision Sprayer to a 30 cm band on either side of the centre of the crop row in May when the first flush of young vegetative canes was 10-20 cm tall. Spray volume was 1500 l/treated ha (using 50-10 nozzles at 160 kPa pressure) in Experiment IV and 1000 l/treated ha (using 50-06 nozzles at 220 kPa pressure) in all other experiments. All young growth below the bottom wire (60 cm) was treated, including any low laterals on fruiting canes. In several experiments the non-ionic wetter Agral (948 g a.i./litre alkyl phenol ethylene oxide, Zeneca Crop Protection) was added at 0.5% V/V to the final spray solution. Details of the individual treatments applied in each experiment are shown in Tables 1 and 2.

RESULTS

<u>Experiment I</u> (Glen Prosen, 1988)

This was the initial field trial to appraise efficacy and safety margin, using rates suggested by the supplier. Treatments were applied to actively growing canes in warm dry conditions. All three spray concentrations of fomesafen gave a high level of cane desiccation (Table 1). Differences in efficacy were very small in relation to the range of concentrations used. Leaves and growing points of sprayed canes turned black within a few days of treatment. This was followed over the next two weeks by the progressive death of stems from the top downwards. There was no visual evidence of translocation up fruiting canes or into replacement canes. Fruit production and end-of-season cane records showed no adverse response to treatment with fomesafen, even at the highest spray concentration, in comparison with untreated or hand-cut controls. Cane removal by either cutting or spraying increased yield above that recorded on untreated plots. The reduction in cane production on sprayed plots, although not as great as on cut plots, was substantial. Vegetative canes present on sprayed plots in December were mainly second-flush canes, although a few first-flush canes had survived.

<u>Experiment II</u> (Glen Clova, 1989)

Following the good results achieved in 1988, spray concentrations were considerably reduced in this experiment. However, although there was a small response to increasing spray concentration, few young cane stems were killed and overall levels of desiccation were completely inadequate (Table 1). First-flush canes had emerged earlier than usual and then encountered a prolonged period of cold weather during which they grew very slowly. The impression was gained during hand-cutting that the young canes were more woody and more mature for their size than normal. Yield results showed little response to hand-cutting, probably due to prolonged dry weather during fruit development. There was no sign of translocation of fomesafen away from treated vegetation. Cane records taken on sprayed plots in December were mainly of first-flush canes which had recovered, hence the lack of difference between sprayed and untreated plots in total cane length produced.

<u>Experiment III</u> (Glen Prosen, 1989)

Spray concentrations were doubled in this experiment, following the poor desiccation achieved in the earlier trial. Possible benefits of adding a wetter to the spray solution were also examined. Young canes emerged much later with Glen Prosen than with Glen Clova and avoided the early cold spell. Spray application was made three weeks after that in Experiment II and canes

TABLE 1. Fomesafen evaluation experiments 1988 and 1989.

Fomesafen spray concentration (V/V product) † ± wetter ‡	Desiccation score after 3 weeks (0-10) ††	Total yield t/ha	Berries /m of fruiting cane length	Mean berry wt (g)	Total cane length produced /plot (m)
Expt I (1988)					
Untreated	-	12.0	39.3	3.87	232***
Cut standard	-	13.2	38.3	4.24	130
0.200 -	8.7	13.1	44.1*	3.60	167
0.400 -	8.8	13.2	39.5	4.17	173
0.600 -	9.0	12.9	40.5	3.95	155
S.E. mean ±	0.24	0.57	1.98	0.239	15.1
Expt II (1989)					
Untreated	-	9.3	52.2	2.50	205**
Cut standard	-	9.3	54.4	2.49	137
S.E. mean ±		0.54	2.48	0.150	14.6
0.048 -	2.0	10.2	53.4	2.74	210**
0.096 -	3.3	9.8	50.8	2.75	190*
0.144 -	4.0	9.1	52.9	2.41	190*
S.E. mean ±	0.52	0.76	3.50	0.212	20.6
Expt III (1989)					
Untreated	-	9.0	59.6	2.93	149***
Cut standard	-	9.5	55.5	3.24	81
S.E. mean ±	-	0.45	3.21	0.110	11.3
0.096 -	7.5	9.2	60.0	2.90	94
+	8.7	10.5	63.2	3.19	112
0.192 -	8.0	10.1	57.6	3.38	129*
+	8.8	10.4	60.8	3.28	137**
0.288 -	7.3	9.3	56.3	3.15	126*
+	-	-	-	-	-
S.E. mean ±	0.36	0.63	4.53	0.155	16.0

*,**,*** - Significantly different from Cut standard at the 5%, 1% or 0.1% level.
† - Litres of formulated fomesafen (250 g a.i./l) per 100 litres water.
†† - 0 = No effect, 10 = Complete kill of leaves and stems.
‡ - All fomesafen treatments ± Agral at 0.5% of the final spray volume.

were growing rapidly when treated. Rain (6 mm) fell during the first 24 h, commencing 4-5 h after treatment. Levels of desiccation were just adequate with fomesafen applied alone, but considerably better with wetter added (Table 1). Spray concentration had little effect. Cane removal by hand-cutting had no significant influence on fruit production, again probably due to a long dry spell during fruit development. There was no evidence of adverse effects of spray treatments on fruiting canes or on yield components. Cane production on sprayed plots was very variable and showed no clear responses to spray concentration or wetter. A proportion of first-flush canes had recovered, so that the reduction in total growth was not as effective as on cut plots, but there were no indications of suppression of replacement canes.

Experiment IV (Glen Clova, 1991)

In this experiment spray volumes were increased to 1500 litres per treated ha to ensure that inadequate spray coverage did not reduce the efficacy of desiccation. Wetter was also added to 50% of the spray treatments. Canes were growing actively at the time of treatment and desiccation levels were acceptable without wetter, but excellent with it (Table 2). All cane removal treatments resulted in an increase in yield in comparison with the untreated control, but there were no significant effects of spray concentration or wetter on yield components. Cane production did show a positive response to the increased efficacy achieved by the addition of wetter, with all canes on these plots being replacement canes and numbers equivalent to those on hand-cut plots.

Experiment V (Glen Clova, 1992)

Wetter was added to every spray treatment in this experiment. All spray concentrations gave rapid and virtually complete desiccation of vegetative canes, which were growing rapidly at the time of treatment. Higher spray concentrations showed the most rapid desiccation, but the final results were very similar (Table 2). Harvest records showed no linear response to increasing spray concentration and no differences between spraying and hand-cutting treatments. Cane production records were very similar across treatments, reflecting the very high levels of desiccation achieved at all spray concentrations. There was no evidence of movement of fomesafen up fruiting canes or into replacement canes.

Subsequent years

No further treatments were applied to plots in Experiments I-IV and yield records in the following year (not presented) closely reflected the amount of cane produced in the previous year. Young canes emerged and grew normally, confirming that there were no residual effects of earlier treatments. Experiment V was designed as a management trial, with one cane removal treatment to be applied every spring for four successive years. The objective was to assess any cumulative adverse effects of spray treatment as compared with hand cutting. In 1993, desiccation scores recorded three weeks after treatment were 8.8, 9.0, 9.5, 9.2 and 9.3 out of 10 for the 0.050, 0.075, 0.100, 0.125 and 0.150% spray concentrations (of product) respectively. Treatments had been applied under good growing conditions. 1993 fruit yields were not available at the time this paper was prepared.

DISCUSSION

The success of the cane desiccation technique depends on achieving a high percentage kill (at least 85%) of first-flush canes, followed by the rapid production of a healthy second flush. Spray treatment never removes young canes as effectively as cutting, so that higher numbers of taller canes are often present on sprayed plots at the end of the growing season. The nearer the cane records resemble those on cut plots, the better the standard of desiccation achieved. If substantially less cane growth were recorded on

TABLE 2. Fomesafen evaluation experiments 1991 and 1992.

Fomesafen spray concentration (V/V product) † ± wetter ‡	Desiccation score after 3 weeks (0-10) ††	Total yield t/ha	Berries /m of fruiting cane length	Mean berry wt (g)	Total cane length produced /plot (m)
Expt IV (1991)					
Cut standard	-	9.6	72.5	2.36	118
S.E. mean ±	-	0.36	3.10	0.060	4.1
Untreated	-	8.1*	61.9	2.37	147***
0.100 -	8.2	8.7	65.2	2.35	136*
+	9.8	8.4	63.2	2.38	114
0.150 -	8.3	8.8	64.8	2.45	129
+	9.9	9.3	72.1	2.39	116
0.200 -	8.7	9.7	74.3	2.36	132
+	9.8	9.6	68.6	2.44	114
S.E. mean ±	0.19	0.50	4.38	0.084	5.8
Expt V (1992)					
Cut standard	-	14.3	67.7	2.65	191
0.050 +	9.6	15.1	69.6	2.71	194
0.075 +	9.6	14.6	63.0	2.89	216
0.100 +	9.8	13.0	66.1	2.44	186
0.125 +	9.9	14.4	64.7	2.83	197
0.150 +	9.9	14.9	64.1	2.94	197
S.E. mean ±	0.15	0.69	2.49	0.170	16.2

*,*** - Significantly different from Cut standard at the 5% or 0.1% level.
† - Litres of formulated fomesafen (250 g a.i./l) per 100 litres water.
†† - 0 = No effect, 10 = Complete kill of leaves and stems.
‡ - All fomesafen treatments ± Agral at 0.5% of the final spray volume.

sprayed than on cut plots, that would indicate injury to the second flush by the desiccant. Similarly, fruit yields lower than those on untreated plots would be evidence of injury to the fruiting canes. These experiments have demonstrated that the raspberry crop has a very high margin of tolerance to fomesafen, no phytotoxic effects having been recorded in non-target areas of either cultivar within the range 0.05 to 0.60% V/V spray concentration (of product). There was also no evidence that an increase in spray volume or the addition of a wetter increased crop sensitivity, as has been recorded (e.g. Lawson & Wiseman, 1991) with several other potential desiccants.

There was relatively little improvement in the final degree of desiccation achieved in individual experiments in response to doubling or trebling the spray concentration of fomesafen, although higher concentrations gave more rapid desiccation. Adverse environmental conditions, such as the prolonged cold spell after cane emergence in early spring in Experiment II or the rainfall within a few hours after spraying in Experiment III, could not be overcome simply by increasing spray concentration. In Experiments III and

IV, the addition of a wetter to the spray solution had much more effect in increasing desiccation scores than a doubling of the spray concentration, even where the spray volume was more than adequate. In a related investigation (Lawson, Wiseman & Wright, unpublished), Agral at 0.5% of the final spray volume was found to be the most effective of a range of commercially available adjuvant treatments in boosting the performance of fomesafen. It was therefore decided that from 1992 onwards all spray treatments with fomesafen would include 0.5% V/V of this adjuvant as standard.

Further evaluation across a wider range of field environmental conditions and cultivars is needed before the selection of the most appropriate spray concentration of fomesafen plus wetter for consistently high levels of cane desiccation can be made. Nevertheless, it seems clear from Experiments III, IV and V that no worthwhile improvement will be gained by exceeding a spray concentration of 0.1 litres of formulated product per 100 litres water. Whether or not a lower spray concentration can give sufficiently reliable results year by year in the same plantation will become more evident as Experiment V continues. Results from our own trials in 1992 and 1993 and those of Zeneca Crop Protection (R. Tucker, personal communication) suggest that the optimum concentration of formulated product lies in the range 0.07-0.10% V/V and that the addition of the wetter has reduced the variability considerably. More detailed information about the influence of environmental factors on the susceptibility of first-flush canes to fomesafen would be of assistance in the compilation of recommendations for field usage. Fomesafen is not currently available as a herbicide or desiccant in the United Kingdom and has no registration for any crop use in this country.

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THE DEVELOPMENT OF ISOXABEN FOR FRUIT AND ORNAMENTAL CROPS

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ABSTRACT

The moderately persistent residual herbicide isoxaben, formulated as a 125 g AI/l suspension concentrate, has recently been granted MAFF approval for use at a rate of 250 g AI/ha for the control of broad leaved weeds in top, bush, cane and soft fruit, vines, hops and field and container grown ornamental crops. When applied alone pre-weed emergence, the herbicide has been shown to give good control of several groups of commercially important weeds, including species of the Cruciferae, Compositae, Polygoniacae, Chenopodiacae, Scrophulariacae and Onagracae families. Where isoxaben applied at 250 g AI/ha has been tank mixed with simazine (1700 or 2250 g AI/ha), propyzamide (1400 or 1700 g AI/ha) or pendimethalin (1980 g AI/ha) the efficacy of the combinations has been found to be enhanced and the length of control extended. Isoxaben exhibited a high level of selectivity when applied alone at 250 g AI/ha to ornamental crops and also in tank mix to fruit crops.

INTRODUCTION

Isoxaben, is a soil acting residual, moderately persistent herbicide which prevents germination and root development of many broad leaved weeds (Huggenberger *et al.*). Formulated in a suspension concentrate as the product 'Flexidor 125', it contains 125 g AI/l. It has been developed as a pre emergence herbicide for use in horticultural crops and has been granted MAFF approval at rates of 250 g AI/ha on top, bush, cane and soft fruit crops, hops, vines and field and container grown hardy ornamentals.

In the UK horticultural industry, the number of newly registered herbicides and existing uses has declined with, for example, the recent commercial withdrawal of diphenamid and the curtailed approvals of diuron, terbacil and simazine. This paper reports efficacy and selectivity trials with isoxaben on fruit and ornamental crops.

MATERIALS AND METHODS

Selectivity trials - fruit

In ten replicated small plot selectivity trials on fruit undertaken in 1991 - 1993, in Scotland and England, isoxaben was applied in one (apples and hops), or in two consecutive seasons (blackcurrants, raspberries, newly planted and established strawberries). Isoxaben was applied at 250 g AI/ha alone and where appropriately approved, tank mixed with simazine (1700 or 2250 g AI/ha), propyzamide (1400 or 1700 g AI/ha), pendimethalin (1980 g AI/ha), diphenamid (6750 g AI/ha) or lenacil (2240 g AI/ha) depending upon the crop.

Treatments in both selectivity and efficacy trials were sprayed between November and April in a minimum 200 l/ha of water using a small plot Azo or modified Oxford precision sprayer fitted with flat fan nozzles. One or more of the following assessments were made in all trials; crop vigour and/or injury, flower number and total yield. Additionally, in apple crops, fruit colour and russet were noted. In raspberry crops, assessments of cane number, height and vigour were made. In strawberry crops, counts of runners were recorded. Except in one blackcurrant trial, results from treated crops were compared to those from untreated plots.

Efficacy trials - fruit

In a series of nineteen replicated small plot efficacy trials on top, bush, cane and soft fruit crops, isoxaben was applied alone at a rate of 250 g AI/ha, or tank mixed with either simazine (1700 or 2250 g AI/ha) and / or propyzamide (1400 or 1700 g AI/ha), pendimethalin (1980 AI/ha), diphenamid (6750 AI/ha) or lenacil (2240 AI/ha). Weed control records were made regularly from one to six months after treatment.

Selectivity trials - field grown ornamentals

Five grower applied selectivity trials, sprayed by conventional tractor mounted equipment, fitted with flat fan nozzles, were undertaken in England on established crops of field grown conifers, deciduous and evergreen broad-leaved trees and shrubs. Six efficacy and selectivity experiments were undertaken on newly planted and established ornamental crops in the UK and France. Oxford precision or Azo sprayers, equipped with flat fan nozzles were used in replicated trials. In both types of test up to 500 g AI/ha isoxaben was applied to "light" soils in a minimum of 200 l/ha water, generally from February to May.

Selectivity trials - container grown ornamentals

Two replicated experiments were undertaken in the UK on container grown hardy ornamental species grown in peat based compost. An application of 250 g AI/ha isoxaben in 600 l/ha water was made in March or April, post planting, using an

Oxford precision sprayer fitted with F80 flat fan nozzles. These tests complemented results from a further five unreplicated trials on container grown ornamentals undertaken in France. In the latter, pots filled with peat + pine bark composts, were treated between May and August with at least 250 g AI/ha isoxaben applied in 800 l/ha water. In all experiments visual observations were made to determine phytotoxicity, crop vigour and/or commercial acceptability of crops during the season.

Efficacy trials - container grown ornamentals

In the two UK based replicated trials described above with container grown species, weed counts and percentage control assessments were made at regular and appropriate intervals after treatment throughout the season.

Statistical analysis

Throughout this paper, significant differences have been analysed using the ANOVA technique and Duncans multiple range test. Letters in common following mean values indicate significant similarity at the P = 0.05 level

RESULTS

Selectivity - ornamentals

Isoxaben applied at dose rates of 250 g AI/ha, caused no damage to any of the following species of established trees, shrubs or ornamental crops when tested in commercial plantations.

TABLE 1. Isoxaben selectivity on container (C) and field grown (F) shrubs, deciduous trees and conifers

Shrubs	Shrubs	Deciduous Trees	Deciduous Trees	Conifers
CF *Berberis*	C *Lonicera*	F *Aesculus*	F *Gleditsia*	F *Larix*
F *Crataegus*	F *Mahonia*	F *Acer*	F *Laburnum*	CF *Pinus*
F *Cornus*	F *Philadelphus*	F *Alnus*	F *Ligustrum*	F *Picea*
F *Cotoneaster*	CF *Potentilla*	F *Amorpha*	F *Populus*	C *Thuja*
F *Deutzia*	CF *Ribes*	F *Betula*	F *Prunus*	C *Chamaecyparis*
F *Euonymus*	F *Rosa*	F *Carpinus*	CF *Quercus*	C *Cupressocyparis*
CF *Escallonia*	F *Sambucus*	F *Caragama*	F *Robinia*	C *Juniperus*
CF *Forsythia*	F *Spiraea*	F *Cassis*	F *Salix*	F *Pseudotsuga*
F *Grosseillier*	F *Sophora*	F *Corylus*	F *Tamarix*	C *Tsuga*
C *Hebe*	C *Skimmia*	F *Fraxinus*	*Tilia*	
F *Hibiscus*	F *Weigela*	F *Fagus*		
F *Hypericum*				

Key: C = container grown, F = field grown

Isoxaben at a rate of 250 g AI/ha was safe to crops. Results of selectivity assessments were similar or superior to the comparative untreated and/or reference plots and no persistent damage was recorded.

Efficacy - fruit and container grown ornamental species

In the relatively non competitive conditions prevailing in top, bush, cane and soft fruit crops, isoxaben applied at 250 g AI/ha alone, gave in excess of 85% control of all the following weeds. Table 2 lists weed species tested including those from trials on container grown hardy ornamentals.

TABLE 2. Weeds controlled with isoxaben applied at 250 g AI/ha.

American willowherb *(Epilobium ciliatum)*	knotgrass *(Polygonum aviculare)*
chickweed *(Stellaria media)*	pineappleweed *(Matricaria matricarioides)*
cleavers (Galium aparine)	red deadnettle *(Lamium purpureum)*
common field-speedwell (Veronica persica)	ribwort *(Plantago lanceolata)*
common orache-Atriplex patula)	rose bay willowherb *(Epilobium angustifolium)*
corn spurrey (Spergula arvensis)	scarlet pimpernel *(Anagallis arvensis)*
dandelion *(Taraxacum officinale)*	scentless mayweed *(Tripleurospermum inodorum)*
fat hen *(Chenopodium album)*	square stemmed willowherb *(Epilobium tetragonum)*
field forget-me-not *(Myosotis arvensis)*	spotted medick *(Medicago arabica)*
groundsel *(Senecio vulgaris)*	
ivy leaved speedwell *(Veronica hederifolia)*	

Results from four fruit trials where isoxaben was applied tank mixed with simazine, confirmed superior weed control with the tank mixture compared with the constituents applied alone (Table 3). In three small plot replicated trials in strawberry and blackcurrant, superior control was achieved where isoxaben was applied mixed with pendimethalin (Table 4). In the reported trials assessments coincided with less than optimal control levels in plots receiving isoxaben alone. Improved activity with tank mixtures of isoxaben have been noted with the partners propyzamide, dichlobenil and lenacil, but results for these are not presented.

TABLE 3. Percentage weed control with isoxaben (250 g AI/ha) applied alone and in tank mix with simazine (2250 g AI/ha)

Crop	Apple	Black-currant	Straw-berry	Straw-berry
Weeds	Knot-grass	Ground-sel	Red-shank	Willow-herb
Treatment				
Isoxaben	77.5 BC	63 AB	53.8 B	70.0 BC
Simazine	75.0 BC	30 BC	60.0 B	56.3 C
Isoxaben + Simazine	98.3 A	100 A	100.0 A	92.0 A
Weeks after treatment	12	18	20	26
Weeds/m^2 (or % cover)	3	20	43	(24%)

TABLE 4. Percentage weed control with isoxaben (250 g AI/ha) applied alone and in tank mix with pendimethalin (1980 g AI/ha).

Crop	Black-currant	Straw-berry	Straw-berry	Straw-berry
Weed	Cleavers	Square stemmed Willow-herb	Scent-less Mayweed	Redshank
Treatment				
isoxaben	73.5 B	70.0 BC	80.0 B	76.0 B
isoxaben + pendimethalin	100.0 A	92.0 A	96.0 A	94.5 A
Weeks after treatment	22	26	4	4
Weeds/m^2 (or % cover)	2	(24%)	15	260

Where isoxaben based tank mixtures have been used at the maximum approved dose rates of both partners on fruit crops, they have been shown to increase persistency of weed control. Initial levels of control achieved with isoxaben against fat hen and orache were marginally but not significantly lower than those obtained from plots treated with tank mixtures (Table 5). However, within 16 - 26 weeks of treatment, the level of control achieved with the tank mix partners were significantly superior to those achieved with isoxaben applied at 250 g ai/ha alone.

TABLE 5. Persistency of weed control with isoxaben in tank mixture with residual herbicides.

Crop		blackcurrant		strawberry	
Weed		fathen		orache	
product	AI/ha				
isoxaben	250	58.8 CD	50.0 C	75.0 A	80.0 B
isoxaben + simazine	250 + 2250	80.0 A-D	75.0 B	100.0 A	98.3 A
isoxaben + propyzamide	250 + 1700	67.5 B-D	81.3 AB	100.0 A	100.0 A
isoxaben + pendimethalin	250 + 1980	100.0 A	90.0 AB	100.0 A	100.0 A
weeks after treatment		8	20	20	26
weeds/m^2 (or % cover)		7.0	2.0	(1.0%)	(5.0%)

DISCUSSION

The development and registration of isoxaben specifically formulated and packaged for horticultural usage, marks a departure from the contemporary trend. This residual herbicide has been developed for application to a comprehensive range of horticultural crops. The moderate soil persistance and the extensive range of weed control is considered advantageous to horticultural growers.

When applied alone in fruit crops, isoxaben has been shown to give levels of control of groundsel, polygonums and speedwells in excess of 85%, weeds which are poorly controlled by the residual herbicide, simazine. Furthermore this tank mixture has been shown to both extend and enhance the level of control achieved. Similar results were obtained where isoxaben was tank mixed with propyzamide, pendimethalin, lenacil and diphenamid.

No persistent reduction of fruit vigour was recorded in crops treated with isoxaben at 250 g AI/ha alone or in tank mixture at any of the rates. Ornamental crops were not damaged by isoxaben applied alone at rates of at least 250 g AI/ha.

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WEED CONTROL IN QUINOA (*CHENOPODIUM QUINOA*) AND CORIANDER (*CORIANDRUM SATIVUM*)

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ABSTRACT

A range of pre- and post-emergence herbicides were evaluated for use in quinoa and coriander. Pre-emergence application of metamitron gave reasonable control of all weeds in quinoa, except *C. album*, with no crop damage. All herbicides applied were crop safe in coriander and several gave good weed control.

INTRODUCTION

In this study, herbicides were evaluated for crop safety and weed control efficacy in two new crop species which are well suited to cultivation in the United Kingdom, quinoa (*Chenopodium quinoa*) and coriander (*Coriandrum sativum*).

Quinoa, traditionally grown by the Incas, is cultivated as a grain crop in the Andes. The protein content of the grain is greater than that of cereals, with a better balance of amino acids. The traditional method of hand weeding is not appropriate for commercial production (Risi & Galwey, 1989; Galwey *et al.*, 1990). The choice of herbicides for use in quinoa is limited since the crop is closely related to the common weed, fat hen (*Chenopodium album*). Metamitron, propachlor and propyzamide have been used with some success (Risi & Galwey, 1989). Observation studies at ADAS Bridgets and ADAS Starcross (Cromack *et al.*, 1993) suggested that metamitron caused minimal crop damage, whilst metazachlor and propachlor resulted in unacceptable crop damage. The herbicides chosen for evaluation here either give poor control of *C. album*, or are used as herbicides in the related crop species, sugar beet.

The seeds of coriander are used as a spice and as a source of oil for the production of cordials and liqueurs (Heath, 1973). There is now considerable interest in this crop for industrial use, as a source of petroselinic acid, a fatty acid present in large quantities in the seed oil (Kleiman & Spencer, 1982; Meier zu Beerentrup & Robbelen, 1987). Germination and emergence of the crop is slow (Cutting & Walsh, 1971), therefore, effective weed control is essential. Prometryn has been used as a herbicide in coriander and several products have off-label recommendations for use in coriander grown as a herb (pentanochlor, propyzamide and trifluralin). Observation studies at ADAS Starcross and ADAS Bridgets suggested that pre-emergence application of linuron, diflufenican and pendimethalin gave good weed control and most compounds were crop safe. The choice of herbicides evaluated was based on these previous observations and on herbicides recommended for use in carrots, a close relative of coriander.

MATERIALS AND METHODS

Herbicide screens were carried out for quinoa and coriander in 1993 at ADAS Bridgets in Hampshire. In each case, plots were sown on 30 April 1993 with 36 kg seed ha^{-1} in 24 cm row widths. Plots were 2.04 x 6 m on 3m centres. Each experiment was of a randomised block design with three blocks. Two untreated controls were included in each block. The herbicides were applied using a Skurray Avocet toolframe at an operating pressure of 2 bar.

Quinoa

Full details of the herbicide treatments for quinoa are shown in Table 1. The pre-emergence herbicides were applied on 3 May and the post-emergence herbicides on 1 June when the crop had 4 to 6 true leaves. The effect of the treatments on % crop cover was assessed on 30 May and 30 June. The populations of the weeds and crop were determined on 30 June using four 0.25 m^2 quadrats per plot.

TABLE 1. Quinoa herbicide treatments. b: pre-emergence, c: post-emergence.

	Active ingredient	Product	Application rate (product ha^{-1})		Water volume (l ha^{-1})	Timing
1	bentazone	Basagran	1.5	l	200	c
2	chloridazon	Pyramin DF	4.7	l	200	b
3	clopyralid / cyanazine	Coupler SC	0.7	l		
	+ fluroxypyr	+ Starane 2	0.75	l	200	c
4	lenacil	Venzar	2.8	kg	200	b
5	metamitron	Goltix	2.5	kg	200	b
6	metamitron	Goltix	2.5	kg	200	c
7	metazachlor	Butisan S	1.5	l	200	b
8	metazachlor	Butisan S	1.5	l	200	c
9	metsulfuron-methyl	Ally	15	g	200	c
10	pendimethalin	Stomp 400	2.5	l	200	b
11	phenmedipham	Betanal E	5	l	200	c
12	propachlor	Ramrod flo	9	kg	450	b
13	sodium monochloroacetate	Croptex steel	28	kg	200	c

Coriander

Full details of the herbicide treatments for coriander are shown in Table 2. The pre-emergence herbicides were applied on 3 May and the post-emergence herbicides on 10 June when the crop had 2 true leaves. The effect of the treatments on % crop cover and on weed populations was assessed on 6 June and 15 July 1993. In the first assessment, two quadrats of 0.25 m^2 were used and in the second assessment, four 0.25 m^2 quadrats per plot were used.

The effect of the herbicides on % crop cover and on the weed populations in both quinoa and coriander was investigated by analysis of variance. Where there was a significant effect of the herbicide treatments, Dunnetts test (Zar, 1984) was used to identify herbicide treatments which were significantly different to the untreated control. Standard errors are not presented since data were log transformed for analysis.

TABLE 2. Coriander herbicide treatments.
a: Pre-sowing with incorporation, b: pre-emergence, c: post-emergence.

	Active ingredient	Product	Application rate (product ha^{-1})		Water volume (l ha^{-1})	Timing
1	chlorpropham	Cambells CIPC	2.8	l	500	b
2	chlorpropham + fenuron	Croptex Chrome	11	l	250	b
3	chlorpropham + pentanochlor	Atlas Brown	5.6	l	200	b
4	chlorpropham + pentanochlor	Atlas Brown	5.6	l	200	c
5	diflufenican + isoproturon	Javelin	1.0	l	200	b
6	isoxaben	Flexidor	0.2	l	200	b
7	linuron	Linuron Flo	1.25	l	200	b
8	linuron	Linuron Flo	1.25	l	200	c
9	pendimethalin	Stomp 400	2.5	l	200	b
10	pentanochlor	Atlas Solan 40	5.6	l	250	b
11	pentanochlor	Atlas Solan 40	5.6	l	250	c
12	phenmedipham	Betanal E	5.0	l	200	c
13	prometryn	Gesagard 5O WP	2.3	kg	200	c
14	propyzamide	Kerb 50	2.2	l	200	b
15	trifluralin	Treflan	2.3	l	200	a
16	trifluralin + linuron	Chandor	4.1	l	200	b

RESULTS

Quinoa

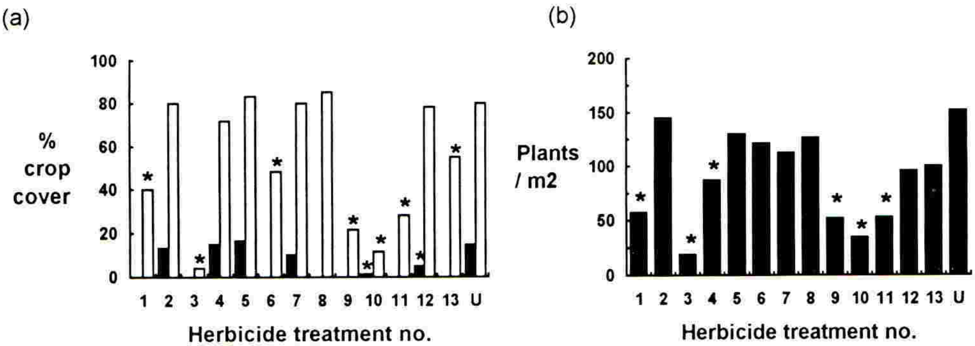

FIGURE 1. (a) The effect on % crop cover of quinoa, of pre-emergence herbicides on 5 May, ■, and of pre- and post-emergence herbicides 30 June 1993, □. (b) The effect on the population (plants m^{-2}) of quinoa, of pre- and post-emergence herbicides on 30 June 1993. Herbicide treatment numbers are shown in Table 1. Untreated controls are shown by 'u'. Treatments marked with * are significantly different to the untreated control (Dunnetts test, P<0.05).

Crop cover was significantly affected by the pre-emergence herbicide treatments on 30 May 1993 (P<0.015) and by both the pre- and post-emergence herbicide treatments on 30 June 1993 (P<0.001) (Figure 1). Pre-emergence application of pendimethalin reduced % crop cover on both assessment dates and decreased the plant population of the crop. Post-emergence applications of bentazone, clopyralid/cyanazine + fluroxypyr, metsulfuron-methyl, and phenmedipham reduced % crop cover and decreased the plant population of the crop.

Propachlor (pre-emergence) reduced % crop cover on 30 May, but had no subsequent affect on % crop cover or crop density. Sodium monochloroacetate and metamitron (post-emergence) reduced % crop cover, but had no effect on the plant population of the crop. Lenacil (pre-emergence) had no effect on % crop cover, but reduced plant population of the crop. Pre-emergence applications of chloridazon, metamitron and metazachlor and post-emergence application of metazachlor had no effect on % crop cover or plant population of the crop.

The main weed species present were *Chenopodium album* (fat hen), *Poa annua* (annual meadow grass), *Stellaria media* (chickweed) and *Papaver rhoeas* (poppy) with some *Cirsium spp.* (thistle) and *Capsella bursa-pastoris* (shepherds purse). The herbicides had significant effects on the populations of *C. album, P. annua, S. media* and *P. rhoeas* ($F = 0.601$, $P<0.001$; $F = 9.92$, $P<0.001$; $F = 2.69$, $P<0.013$; $F = 3.51$, $P<0.002$ for $\log_{10}$ transformed data). All the herbicides reduced the total weed number compared to the control, with the exception of pre-emergence propachlor and post-emergence metazachlor and sodium monochloroacetate (Table 3). *C. album* was controlled by post-emergence applications of clopyralid/cyanazine+fluroxypyr, metamitron and phenmedipham and pre-emergence application of pendimethalin. *P. rhoeas* was controlled by pre-emergence applications of metazachlor, metamitron and lenacil and post-emergence application of metsulfuron-methyl. *S. media* was controlled by pre-emergence applications of metamitron and lenacil and by post-emergence applications of metsulfuron-methyl and bentazone. *P. annua* was controlled by pre-emergence applications of metazachlor, metamitron, chloridazon and lenacil and by post-emergence applications of metazachlor and metamitron.

TABLE 3. The effect of herbicide treatments on the populations of *C. album*, *P. rhoeas*, *S. media*, *P. annua* and total weed number (plants m^{-2}) in quinoa on 30 June 1993. Treatments marked with * are significantly different from the untreated control (Dunnetts test, $P<0.05$).

		Weed population (plants m^{-2})									
	Active ingredient (Timing)	*C. album*		*P. rhoeas*		*S. media*		*P. annua*		Total	
1	bentazone (c)	40		1.7		0.3	*	31		73.3	*
2	chloridazon (b)	51		0.3		1		1	*	53.3	*
3	clopyralid/cyanazine + fluroxypyr (c)	3	*	3.3		0.7		10.7		18.3	*
4	lenacil (b)	34.7		0	*	0	*	0	*	34.7	*
5	metamitron (b)	34.3		0	*	0	*	0.3	*	35	*
6	metamitron (c)	14.7	*	0.3		1		0	*	16.7	*
7	metazachlor (b)	46.3		0	*	0.7		0	*	47.3	*
8	metazachlor (c)	71		2		5.3		0.7	*	80	
9	metsulfuron-methyl (c)	46.3		0	*	0.3	*	10.3		57.7	*
10	pendimethalin (b)	3	*	11.3		1		4.3		20.7	*
11	phenmedipham (c)	12.3	*	1.3		1.3		17.3		34	*
12	propachlor (b)	78.3		8		3.3		2.7		94	
13	sodium monochloroacetate(c)	44		0.7		4.3		33.3		82.7	
	Untreated	142		5		5		17.4		171	

Coriander

None of the herbicide treatments had a significant effect ($P<0.05$) on % crop cover or plant population of the crop. The spectrum of weed species was similar to that in quinoa. On 6 June, there was a significant effect of the pre-emergence herbicide treatments on the populations of *C. album*, *S. media*, *P. annua* and the total weed number. On 15 July, there was a significant effect of pre-emergence and post-emergence herbicides on the populations of *C. album, Cirsium spp.*, *S. media*, and *P. annua*.

All the pre-emergence herbicides, except chlorpropham+pentanochlor, isoxaben and pentanochlor, reduced the total weed number on both assessment dates (Table 4). Pre-emergence application of chlorpropham gave no weed control on 6 June, but gave some control of *S. media* on 15 July. Pre-emergence application of chlorpropham+fenuron gave some initial control of *S. media*, but this effect was lost by 15 July. Pre-emergence application of diflufenican and isoproturon gave some initial control of *S. media* and *P. annua*. Pendimethalin (pre-emergence) gave good control of *C. album* but did not control *S. media* on 6 June. Pre-emergence application of trifluralin gave some initial control of *S. media*, but this effect was lost by 15 July. However, a mixture of trifluralin with linuron improved the control of *S. media* later in the growing season. Pre-emergence propyzamide gave effective control of *S. media* and *P. annua* throughout the growing season.

TABLE 4. The effect of herbicide treatments on weed populations on 6 June on 15 July. Treatments marked * are significantly different less than the untreated control (Dunnetts Test, P<0.05, $\log_{10}$ transformed data). Abbreviations of species: *C. album* (C.a.); Stellaria media (S. m.); *P. annua* (P.a.); *Cirsium spp* (Cir.) Total weed number (Tot.).

Active ingredient	Weed no. (plants m^{-2}) on 6 June				Weed no. (plants m^{-2}) on 15 July				
	C. a.	S. m.	P. a.	Tot.	C. a.	S. m.	P. a.	Cir.	Tot.
Chlorpropham (b)	119	5	5	132	85	5*	6	2	100
Chlorpropham + fenuron (b)	53	1*	10	67*	29	9	5	7	51*
Chlorpropham + pentanochlor (b)	145	7	10	167	95	7	3	4	112
Chlorpropham + pentanochlor (c)	-	-	-	-	0*	18	16	3	38*
Diflufenican + isoproturon (b)	53	2*	1*	57*	42	10	3	0*	58*
Isoxaben (b)	28	33	28	90	36	25	12	1	76
Linuron (b)	41	3*	5	49*	26*	4*	6	0*	38*
Linuron (c)	-	-	-	-	5*	0*	4	1	10*
Pendimethalin (b)	11*	6	10	29*	3*	1*	8	2	17*
Pentanochlor (b)	220	4	26	277	116	15	8	3	147
Pentanochlor (c)	-	-	-	-	0*	30	25	0*	56*
Phenmedipham (c)	-	-	-	-	7*	21	15	0*	44*
Prometryn (c)	-	-	-	-	9*	2*	4	1	18*
Propyzamide (b)	49	1*	0*	55*	37	3*	0*	4	47*
Trifluralin (a)	55	4*	5	63*	31	7	1	<1	43*
Trifluralin + linuron (b)	33	5	1*	42*	26	3*	3	<1	33*
Untreated	178	31	16	236	91	22	6	4	130

Post-emergence application of chlorpropham + pentanochlor controlled *C. album*. Post-emergence application of pentanochlor gave effective control of *C. album*, and *Cirsium spp.*, but with no control of *S. media* and *P. annua*. Linuron gave good weed control after both pre- and post-emergence application. Post-emergence application of phenmedipham gave good control of *C. album* and *Cirsium spp.*, but did not control *S. media*. Post-emergence application of prometryn gave good control of *C. album* and *S. media*.

DISCUSSION

Many herbicides had detrimental effects on quinoa, and thus the choice of herbicides suitable for use in quinoa is very limited. The only herbicides with no adverse effects on crop growth were, pre- or post-emergence metazachlor, pre-emergence chloridazon and pre-emergence metamitron. Of these, pre-emergence application of metamitron gave the best all round weed control as Risi & Galwey (1989) and ADAS have previously reported. None of the herbicides gave any statistically significant control of *C. album* without some detrimental effect on crop growth. Good control of *C. album* cannot be achieved without some damage to quinoa as they are related species. Therefore commercial production of quinoa should be carried out on sites with low natural populations of *C. album*. Contamination of the quinoa grain with *C. album* may present a major problem. Alternative weed control strategies, such as mechanical weeding between the rows may be more effective.

In contrast, none of the herbicides used on coriander adversely effected crop growth, so the choice of herbicides available for use is much wider than in quinoa. Herbicide choice will, of course, depend on the weed flora of the site. For good control of *C. album* and *S. media*, linuron (especially post-emergence), pendimethalin (pre-emergence) and prometryn (post-emergence) are options. The slow establishment of coriander (Cutting & Walsh, 1971) means that pre-emergence herbicides should be used to minimise weed competition during the early growth stages of the crop. Pendimethalin and linuron both gave weed control which lasted until July. A pre-emergence herbicide could be followed by a post-emergence herbicide and this kind of weed control strategy should be examined in future studies.

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Session 8A

Pesticide Regulation in the EC - Future Developments and Probable Impact

Chairman	Mr D OOSTHUIZEN
Session Organiser	Dr B THOMAS
Papers	8A-1 to 8A-4

CONSEQUENCES FOR ENVIRONMENTAL DATA/RISK ASSESSMENT REQUIREMENTS

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ABSTRACT

The EC is recommending methods which have been agreed by International organisations such as OECD, FAO, EC, EPPO and ISO. FAO is issuing new guidelines, particularly in the area of environmental chemistry. In the long-term it is anticipated that OECD will become the major source of guidelines. There is a need for improving methods, eg mathematical modelling, for extrapolating results from one set of conditions to others. Criteria for triggering higher tier tests eg field studies, and decision making criteria are being developed. Some, such as for honeybees, are well validated; while others, such as for aquatic organisms are still being debated. Often, it will not be possible to make decisions based on simple criteria and there will be a continuing need for expert judgement and cooperation between scientists and regulators.

INTRODUCTION

The evaluation of the safety of a pesticide to both man and the environment depends on a knowledge of both the toxicity of the pesticide and the degree of exposure of the organism. This presentation is mainly concerned with information relevant to environmental safety evaluations.

While in some areas, such as for honeybees, testing methods and interpretation are well developed and validated, in others there are no scientifically validated procedures eg for determining the fate of chemicals in air or assessing the safety to beneficial arthropods eg predators of pests.

TEST METHODOLOGY

The broad requirements for environmental fate and ecotoxicity data are listed in the original directive (Council Directive 91/414/EEC); Annex II for active substance and Annex III for Product (Formulation). Subsequently, the European Community hired a consultant, Dr Mark Lynch, to produce a more detailed description of requirements. The Commission of the European Communities then produced a series of Working Documents. At the time of writing (August 1993) new versions of the Fate and Behaviour in the Environment and Ecotoxicological Studies have just been issued. (Commission of the European Communities, 1993a).

Sources of methods

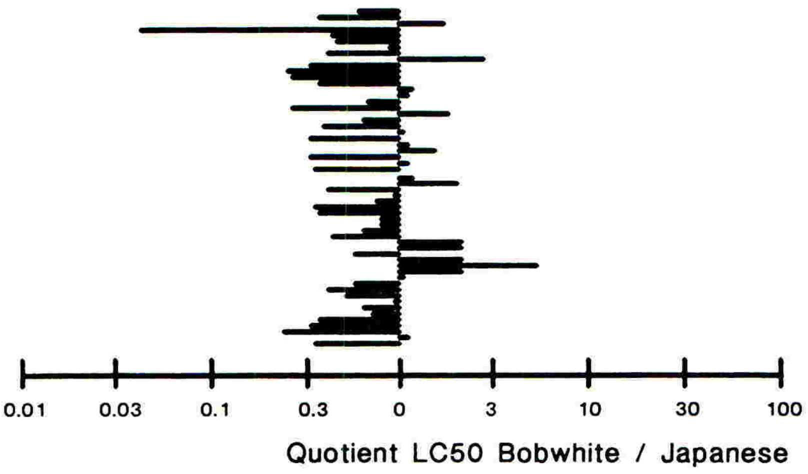
There has been much debate and lobbying on which methods should be recommended. Some people have argued that any scientifically valid method should be accepted, while others have argued for single, detailed rigid protocols. Considering the need for mutual acceptance of data between countries, there is an argument for recommending a particular guideline. However there should be scope for the use of an alternative method where the recommended guideline is inappropriate and to allow the development of improved methods. The degree of flexibility which will be allowed is unclear. For pesticides being re-registered it is essential that scientifically valid tests, carried out previously using alternative methods, should be accepted, to avoid wasting an enormous amount of effort.

Currently, the EC is sensibly only recommending methods which have been agreed by international organisations such as OECD, FAO, EC, EPPO and ISO. FAO is issuing an Annex to their "Revised Guidelines on Environmental Criteria for the Registration of Pesticides published in 1989; this will fill some of the gaps in available international guidelines, particularly in the area of environmental chemistry. OECD is embarking on a major programme for producing test guidelines for pesticides and it is anticipated that these will eventually become the major source of guidelines.

Test species

There is a need for greater harmonisation of test species to avoid unnecessary repeat testing and thus minimise the number of animals used in testing. For example the USA tends to request toxicity data on bobwhite (*Colinus virginianus*) and the EC Japanese quail (*Coturnix coturnix japonica*). Scientifically either is acceptable as they have approximately the same sensitivity to pesticides (Fig.1). It is encouraging that the EC are now moving towards accepting data for either species (Commission of the European Communities (1993a).

Fig.1. Comparison of LC50 values for bobwhite and Japanese Quail



Testing of active substances and formulations

An effective, efficient safety evaluation procedure requires the close integration of information on the active ingredient (ai) and representative formulations, eg evaluation of fate in soil will often require an integration of laboratory data (studies on active ingredient) and field data (studies on formulation). The artificial separation of requirements for ai (Annex II) and formulations (Annex III) could lead to excessive testing requirements. For example, in most situations there is no need to test the toxicity of formulations as well as active substances to fish, Daphnia and birds.

TIER TESTING SEQUENCES

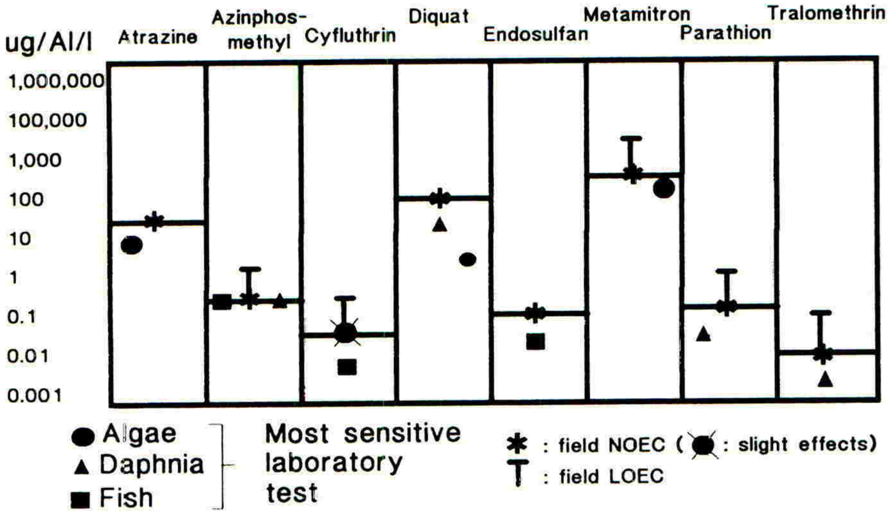
There is general agreement that testing should follow a stepwise testing sequence; starting with standard tests under controlled conditions and only when necessary moving to much more expensive and variable field studies. The main debate is on what criteria should be used to trigger higher tier tests. For example, what should trigger field soil dissipation studies? Currently the EC is proposing a DT90 >100 days at 20° and at a moisture content of the soil related to a pF value of 2-2.5 (suction pressure). Would a review of existing data on laboratory and field persistence show that this is an unnecessarily strict criteria?

The need for field ecological studies is normally based on the ratio of the toxicity of the organism(s) to their level of exposure to the pesticide. For example, a comparison of laboratory and field toxicity data to aquatic organisms has shown that there will be no concern if the predicted environmental concentration (PEC) is <1/10 of LC50, or <chronic NOEL to fish, invertebrates and algae ie there is unlikely to be any significant effect on the aquatic ecosystem (Rijtema *et al*, 1993 and Fig.2). This is in agreement with the US EPA criteria that the level of concern is reached if the estimated environmental concentration exceeds the lowest effect level in the chronic fish and invertebrate tests (Table 1). However, the EC is recommending that field (mesocosm) studies should be considered if the PEC is >1/100 LC50 or >1/10 chronic NOEL. This could result in unnecessary field testing. There will often be a need for expert judgement when deciding if it is necessary to carry out higher tier tests.

Table 1. Evaluation criteria (fish/aquatic invertebrates) There is no concern if predicted environmental concentration (PEC) is less than specified values.

Scientific evidence	USA EPA	EC (Draft Annex III)
< 1/10 LC50	< 1/10 LC50	< 1/100 LC50
< NOEL	< LEL	< 1/10 NOEL

Fig.2. Effects on aquatic organisms, comparison of lowest laboratory results and ecosystem NOEC.



Extrapolation of information

It is impractical to study the fate and ecotoxicity of a pesticide under all sets of conditions. Therefore there is a need for improved methods for extrapolating information eg from laboratory to field or from one set of field conditions to another.

This can be a relatively simple extrapolation of eg soil degradation rates at one temperature to another. Much more complex mathematical models are used to evaluate the environmental fate of residues eg leaching. However, the models have not yet been sufficiently evaluated/validated. There is a need for greater international collaboration on this topic.

DECISION MAKING CRITERIA

The Commission of the European Communities (1993b) has proposed a set of Uniform Principles for evaluation and authorisation of chemical plant protection products. These are a subject of much debate and there is a need for considerable improvement in the defining and validation of these criteria.

An example of a well validated criteria is for honeybees. The best simple measure of exposure for pesticides sprayed onto crops where honeybees are present is the application rate of the active substance. This is used in conjunction with the contact toxicity to calculate a hazard ratio :

$$\text{Hazard Ratio} = \frac{\text{Application rate (g ai/ha)}}{\text{LD50 } (\mu\text{g ai/bee})}$$

Experience with a wide range of pesticides has shown if the ratio is <50 it will be safe to honeybees and if >2500 it is likely to be dangerous if, for example, it is sprayed onto flowering crops (Oomen, 1986). For hazard ratios between these values field testing might be necessary to determine if the pesticide will be safe when sprayed onto flowering crops. Hazard ratios for example insecticides are given in Table 2.

Table 2. Comparison of honeybees toxicity values and application rates of insecticides.

Insecticide	Contact LD50 (μg/bee)	Application Rate g/ha	Ratio
Pirimicarb	50	140	3
Phosalone	8.9	460	52
Cypermethrin	0.056	25	450
Dimethoate	0.12	350	2900
Triazophos	0.055	400	7300

The UK Ministry of Agriculture, Fisheries and Food (MAFF) maintain a honeybee incident investigation scheme. An evaluation of the results from this scheme has confirmed that the pesticide applications classified as low risk (hazard ratio <50) have not caused any bee poisoning incidents. A more detailed analysis of the results of the scheme (A.D.M. Hart, personal communication) has shown that it may be possible to raise the hazard ratio threshold for low risk to 500 and the threshold for high risk could be lowered to 1000. Such changes would reduce the amount of testing required without reducing the accuracy of predictions.

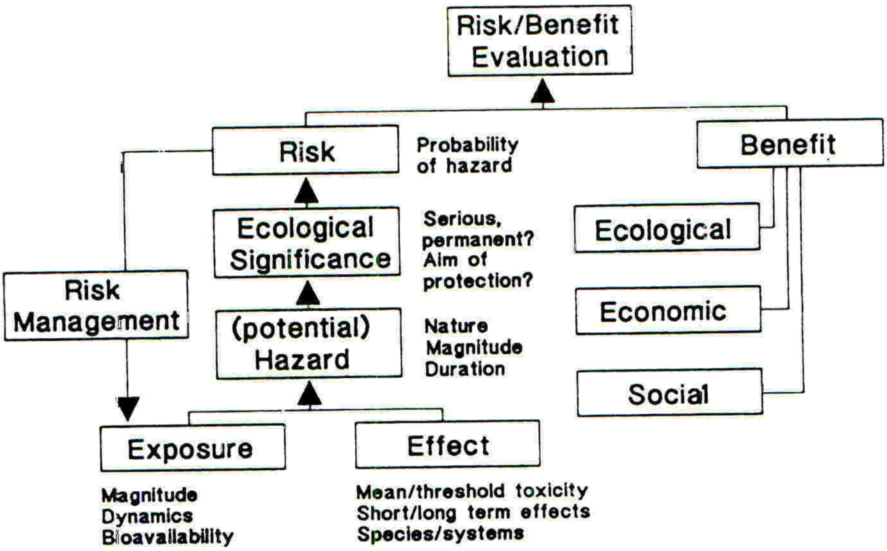
The decision criteria to use in other areas is still under debate, eg aquatics (Table 1).

When the toxicity/exposure ratio does not show a clear safety margin there will be a need to explore options for reducing potential risks; mainly by reducing the exposure of the organisms (Fig.3).

Often it will not be possible to make decisions based on simple criteria and there will be a continuing need for expert judgement. Ultimately decisions should be made on a risk-benefit analysis (Fig.3).

It is essential that scientists and regulators work together to ensure that the safety evaluation procedures are scientifically sound, and to encourage further improvements and validation of test methods and evaluation procedures.

Fig. 3. Environmental Risk Assessment (FAO 1989)



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A REFLECTION OF THE ASSESSMENT OF TOXICOLOGICAL DATA

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ABSTRACT

Registration of pesticides is primarily an estimation of risk. Risk is a function of two parameters : hazard and exposure. In term of hazard, the concept of the No Effect Level (NEL) is fundamental. However with the new tools of biochemistry it is possible to try to understand more accurately the significance of this value. In terms of exposure, an important question, which does not appear in Directive 91/414/EEC and the different Annexes, is the problem of mixtures. We need to reflect on this subject and to try to define a philosophy in the matter.

INTRODUCTION

The registration of pesticides is primarily an estimation of risk. Risk is a function of two parameters, namely hazard and exposure.

To obtain a registration in Europe it is evident that we must now follow Directive 91/414/EEC and more specifically the requirements of Annex II (active substances), Annex III (preparations) and Annex VI (uniform principles).

I would wish however that there will be a place for flexibility and common sense and also for innovation in term of science.

HAZARD

Regarding the safety of active ingredients and more specifically for residues, the key end point is the "no effect level" (NEL) which is established for the most sensitive species. The application of a safety factor, which must be chosen in agreement with the quality and the quantity of data, finally leads to the "acceptable daily intake" (ADI).

In fact, the basic concept of the decision for residues and also for operator safety is the NEL. The concept of "no effect level" is an old concept. The NEL is generally defined following administration of the product by the oral route to laboratory animals and checking the effects through the long term toxicity, the reproductive toxicity and other toxicological studies.

The effects can be more or less numerous because it is possible to use a range of techniques to define these effects. This approach is, so far, the one we have used for many years but we generally do not know why these effects occur. From my point of view, the real problem is not only to note the effects but to try to know why they appear. In this kind of exercise the animal must not simply be regarded as a 'black box'.

It seems to me that we now have the tools to do this. We did not have these tools ten years ago. It is not an easy job, but I think it is certainly the future of toxicology to proceed via this route towards a more precise and understandable "no effect level".

For example, with toxicokinetics it is now possible to study in more depth the effective dose, the tissue levels and the precise doses/effect relationships which are the basis of toxicology. All this information permits an exposure-dose-response assessment which, to me is now indispensable.

Today, when we have no effects even at high dosage, the toxicology studies are not accepted by regulatory bodies. This attitude is an old attitude based on the fact that if you have no effects you can assume that your product was not available in the GI tract. Dosing the product in the blood could provide the proof that the active ingredient reaches the body. So in my view, if you have no effects at a level which largely covers the extent to which consumers could be exposed by ingesting residues, the results must be taken into account. The dosage of the product in blood can validate the negative results obtained.

Using short-term tests and *in vitro* tests we certainly could also approach the mechanisms of toxicity and this is one of the most important questions because knowing the mechanisms of toxicity is certainly the best means to assess the risk. For example, this approach is absolutely needed to make the distinction between genotoxic or not genotoxic carcinogens. Considering the latter you could, for example, obtain an idea of their promoting effects with the Salt Farber System Tests in the rat liver or the Yamasaki models. In doing so we could expect, in the future, a decrease in the weight given to the long-term rodent carcinogenicity tests in decision making, which would also decrease dramatically the cost of expertise, the saving of animal lives and, in fact, increase the value of risk assessment.

Taking into account toxicokinetic data together with a knowledge of the mechanisms of action it is also possible to extrapolate the results obtained in animals to human beings, keeping in mind that the best species for man is, of course, man himself.

EXPOSURE

Exposure is a very important element of risk assessment. Thus data on residues, exposure of workers, exposure in water and the environment must be thoroughly explored. It is not easy to do, but it must be done.

One question which often arises and which does not appear in the Directive is the problem of mixtures. We try to asses the risk on a pesticide by pesticide basis. But what happens when you have different kinds of residues in food or in water?

Conceptually, it is evident that it is not possible to exclude some additive or potentiation effects. This has been very well demonstrated with drugs in humans and in animals. It can be explained by competition of products at different levels (absorption, biotransformation, blood transport, etc...). However, the question is can what is true for drugs given at high doses be also true for traces of pesticides? Water is certainly a good example of this problem : is water a pure product? The answer depends on what is the limit of detection of the analytical techniques which are available to detect contaminants.

At the parts per million level water is quite a pure product. At the level of 0.1 μg/l (limit of EC Drinking Water Directive) it is evident that the answer is "no". At this limit, it has been possible to detect in water more than 1000 products. Most of these are not identified. This is not surprising because water is a powerful solvent and it is very widely distributed on and in our planet. As a result, it can readily dissolve a wide range of substances from any environmental matrix in which they occur and their residues plus the consequences of the various physical and chemical treatments which may be present, at least to some extent, in almost any conventional drinking water supplied to the human consumer.

Under these conditions, is it possible that traces of pesticides can change the impact of the exposure in the body? I have no scientific answer to that, but common sense tells me that if there are any effects, they are certainly negligible in term of risk at the discussed level (0.1 μg/l).

However, we must think of a new scientific approach to try to estimate this risk and perhaps the *in vitro* studies with human cells for example could help us in this difficult job.

CONCLUSIONS

The Directive must be applied. However, we need flexibility to make our judgement and possibly to introduce into the registration process new concepts and new science for the future. Regulation must not be an only administrative process but an evolutionary scientific process as indeed is life itself.

EC AUTHORISATIONS AND MRLS - RESIDUE DATA REQUIREMENTS

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ABSTRACT

Significant progress has been made in developing procedures for evaluating residue data, assessing consumer risk and establishing EC MRLs. This work will form the basis of a harmonised EC approach to residue data requirements in relation to EC 91/414. More work is needed however to ensure that the interface betweeen authorisations and MRLs allows for development of new uses and practices.

INTRODUCTION

Although harmonisation of EC authorisation procedures via implementation of EC 91/414 has yet to be tested in practice work on harmonisation of EC MRLs has been progressing for a number of years. Procedures for the establishment of EC MRLs for plant protection products in food and feedstuffs of plant and animal origin have been developed over the years in a Commission Working Group and detailed guidelines are currently under discussion. This work will be used as the basis for revisions of Annexes II and III of 91/414, for establishing detailed residue data requirements for EC authorisations and for assessing residue data submitted in support of Annex I listing. A Commission proposal for a Council Directive establishing Uniform Principles for Assessment of Annex III Data at the National Level (COM (93)117) has been published recently. This proposal contains little detailed guidance on assessment of residue data but does propose procedures for linking work on authorisations and MRLs.

DATA REQUIREMENTS

The categories of data required are similar to those currently required for UK registration. The broad categories and general requirements are described below with particular emphasis on areas where the EC dimension will impinge.

Metabolism and distribution in plants

Studies are required for all pesticides proposed for use in edible crops to establish the identity of toxicologically significant metabolites. The data must support a decision on the definition and expression of residues.

The guidelines envisage that experiments will be carried out using radiolabelled pesticides in crops representative of those which will be treated. The crop groupings proposed in this context are very broad, for example 'root and tuber vegetables' includes carrots, potatoes and onions and 'fruit' includes oranges, apples, strawberries, nuts and olives. In addition if a similar route of degradation is established for representative crops from three of these groups then no further studies will be required to support use in additional crop groups.

Studies on complete plants treated in accordance with the proposed use pattern are preferred because of their relevance to the real situation, however use of exaggerated treatment rates, cell cultures, isolated enzyme systems and/or parts of plants and plant tissues are recognised as useful methods for preparing metabolites on a scale sufficient for identification. These studies are particularly useful when other studies indicate that in practice total pesticide derived residues in edible portions of the crop will be very low (for example <0.01mg/kg (human food) or <0.05mg/kg (animal feed)). When total terminal residues are of this order of magnitude and characterisation of terminal metabolites is not possible, an assessment of consumer risk can be based on an understanding of the major metabolic pathways.

In situations where total terminal residues are likely to be significant the major components of the residue, that is those which may exceed 0.05 mg/kg in human food or 0.1mg/kg in animal feed should be identified. Components of the residue which are present at lower concentrations may prove impossible to identify; some characterisation of these components is however required. Conventional extraction and partition techniques will establish extractability and solubility. Attempts should be made to release and identify conjugated materials by acid, alkali and enzyme hydrolysis.

Residue trials

Residue trials data requirements are similar to those established in the UK, although the proposed range of climatically similar regions is broader.

The baseline requirement under discussion is for 8 trials per use, including 4 decline trials. Fewer trials are required for minor crops. Trials must cover 2 growing seasons and should be carried out in regions where climatic conditions are 'comparable' to those in the proposed region of use. Two 'climatic zones' have been proposed: Northern and Central Europe; and Southern Europe and the Mediterranean. It has been proposed that for authorisation to be possible throughout a zone, trials data will be needed from sites distributed throughout the region.

EC lists of major crops, based on production statistics, are under discussion in Brussels for the two proposed climatic zones.

The validity of extrapolation of residue data particularly between different crops has been the subject of extensive discussions in the EC. There is a great deal of concern over the position of minor crops and extrapolation is seen as a solution to loss of approvals in these crops due to high registration costs.

Residues in rotational crops

The proposed guidelines are similar to the current UK guidelines. Discussions are at a preliminary stage because consideration of rotational crops has not as yet been necessary when establishing EC MRLs. Studies may be required for pesticides approved for use only in non-edible crops.

Effects of processing

Many data packages for pesticides contain little information on the effects of processing; as a consequence residue levels in processed foods cannot be estimated and intake estimates cannot be refined to take into account the effects of processing. Data requirements in excess of those currently required by individual countries are therefore envisaged. It is proposed that processing data would be required for all crops other than those mostly eaten raw if significant residues (generally >0.1mg/kg) may be present. Data would always be required if theoretical intake estimates based on MRLs and appropriate measures of food consumption amounted to >10% of the ADI. Two types of processing study have been proposed: 'balance' studies (one per crop) establishing a balance sheet and, 'follow up' studies (three per crop) which concentrate on important foods. For example for white cabbage, a balance study would examine inner and outer leaves, cooked white cabbage, cooking liquid, sauerkraut and sauerkraut juice and follow up studies would only examine cooked white cabbage and sauerkraut.

The proposed guidelines do not distinguish between requirements relating to industrial processing and those relating to preparation in the home. There is as yet no requirement for studies on degradation products other than those included in the residue definition.

Metabolism and distribution in livestock

Proposed guidelines for these studies are similar to those used in the UK. Studies are required when residues in total diets may exceed 0.1mg/kg. Maximum likely consumption of individual feed items in various groups (green forage, grains, straws, pulses etc) have been considered on a Community wide basis for chicken, dairy cattle, beef cattle and pigs to allow estimation of highest likely intakes of pesticide.

Livestock feeding studies

If animal diets may contain residues in excess of 0.1mg/kg and metabolism studies show that as a consequence determinable residues may occur in edible animal tissues, feeding studies may be required. Proposed requirements are in line with UK regulatory practice.

Storage stability data

Information on the effects of freezer storage on residue levels is needed to support residue trials and livestock transfer studies. For this purpose crop samples can be considered to be typical of water-, oil-, protein- or starch-containing materials. For livestock studies tissues, milk and eggs should be studied.

The proposed guidelines do not include a requirement to test samples from metabolism studies for changes in the metabolite profile during storage.

DECISION MAKING

Residue definitions

Decisions on residue definitions should be similar to those made by the JMPR since it is proposed that to control analytical costs inclusion of metabolites in the residue definition will be minimised. Decisions on inclusion of metabolites will, of course, take into account their toxicological profile and contribution to the total toxic residue.

Maximum Residue Limits (MRLs)

Statistical methods are used in the EC to identify appropriate MRLs from residue data sets.

The proposed guidelines indicate that figures arrived at using such methods should not be adopted as MRLs without full consideration of the quality, nature and size of the database and the particular characteristics of the chemical and crop concerned.

The method most commonly used is that proposed by Weinmann and Nolting (Weinmann & Nolting, 1981). This method assumes a normal distribution of data and the MRL is calculated from the mean residue (R) and the standard deviation(s) as follows:

$$R + k.s$$

where k is a statistical parameter dependent on the size of the data set (n) and the confidence range chosen. For a 95% confidence range k is 8 when $n = 3$, 3 when $n = 8$ and 2 when $n>30$. For data sets where $n >30$ and R and s are approximately the same the calculation reduces to

$$MRL = 3\ R$$

For normally distributed databases of a reasonable size ($n >8$) statistical outliers can be identified using the method described by Dixon (Dixon, 1953) but the proposed guidelines call for extreme caution when considering ignoring outliers and indicate that calculations should always be carried out with and without them.

It has been proposed that for small data sets, where $n = 3$ or 4, the MRL should be established at 5 times the mean.

An alternative method, developed by the BBA (Wilkening et al, 1990) , based on the 75th percentile of the data distribution has also been proposed as an aid to decision making in the EC.

An important issue requiring resolution is the operation of the interface between authorisations agreed by the Standing Committee on Plant Health and MRLs agreed by the Council. As currently drafted COM (93) 117 precludes authorisation of any use which may lead to residues in excess of established EC MRLs.

Minimising Residues

The current draft of COM (93) 117 requires that residues in crops should reflect the minimum required to reflect use to achieve adequate pest control. One contribution to implementing this is to ensure that PHIs are as long as possible, although it is not clear how this will be achieved in practice. Clearly where an MRL has already been established and a new use is proposed, it will be an attractive proposition to interpolate a complementary PHI from decline data.

Consumer Risk Assessment

The EC has adopted the approach to dietary intake estimation and consumer risk assessment proposed by the WHO (WHO, 1989). In the absence of compatible data on dietary habits for all Member States intake estimates are based on national consumption data generated and expressed in different ways. Theoretical Maximum Daily Intakes and Estimated Maximum Daily Intakes (EMDIs) are calculated as proposed by the WHO, based on MRLs and reduction factors. EMDI calculations are, however, of limited use since on the whole consumption databases available only allow either for the assumption that all of a particular crop is processed or that none is processed. Generation of data on the effect of cooking on residue levels in a crop eaten both raw and cooked, such as carrot, cannot lead to incorporation of a reduction factor in the EMDI calculation.

It is not yet clear how Estimated Daily Intake calculations will be prepared if indeed they will be used at all. It has been proposed that for pesticides without acute toxicological effects, the mean or median residues from trials data should be used as the measure of residue in these calculations. It has also been proposed that, for chemicals which are already established in the marketplace, the proportion of crop treated or residues found in retail produce should be used in intake estimates.

Where the most realistic possible intake estimate fails to fall within the ADI, authorisation will not be granted. Manufacturers will be involved in any decisions on the need to restrict uses to protect consumers.

IMPORT TOLERANCES

Uses outside the Community will need to be reflected in EC MRLs. The residue data requirements and assessment procedures will be as described above for uses inside the Community.

CONCLUSIONS

Residue data requirements and assessment procedures to support authorisations and EC MRLs are being developed and should be agreed shortly. Requirements and assessment procedures are similar to those already established in a number of countries, including the UK. There are a number of areas which appear to require further work. Of these the most significant are: determining the appropriate level of requirements for processing data; developing methodology for preparing more realistic intake estimates; and balancing results of statistical manipulation of data and scientific judgement when fixing MRLs. In addition speedy procedures for varying EC MRLs as appropriate to reflect authorisations are needed to allow growers early access to new uses of pesticides.

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AN INDUSTRIAL EPILOGUE

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ABSTRACT

Despite some apparent views to the contrary the implementation of the EC Registration Directive will result in some major changes in the regulatory control of plant protection products in the European Community. Not least of these, but perhaps the most difficult to achieve, will be the need for Member States to change their 'philosophical' approach established after many years of operating at the 'local' level. The challenges to Member States, Industry and the Commission, in achieving the goal of a harmonised regulatory control system are discussed. Also discussed are some of the key issues which at this stage remain unresolved or are unclear and which require a satisfactory resolution before the full implications of the Directive's implementation can be assessed. The paper concludes by emphasising a theme common to many of the issues discussed, namely the need for Member States and Industry to cooperate during the implementation process.

INTRODUCTION

There can be no doubt or disagreement that the implementation of the 'EC Registration Directive', (91/414/EEC), marks one of the most significant events in the history of the regulatory control of plant protection products within the European Community. Whereas the full impact of this implementation in political, scientific and practical terms are yet to be realized, both Governments and Industry are currently in a position to identify and evaluate at least some of the consequences of the Directive's implementation. Thus, in a sense, we are writing an 'epilogue' to the book on National regulatory control measures whilst, at the same time, drafting the 'prologue' to a new volume on Community control. Clearly however the transition from National to Community systems is neither 'black and white', nor is it likely to occur without the need for considerable ongoing development and rationalisation as we proceed towards the ultimate goal of harmonisation through the Community. In my opinion the practical and procedural issues in achieving this goal can all be solved given sufficient time and on the basis of experience gained during the application of the Directive to real cases. What may not be so easily achievable however is a harmonisation of 'philosophical' approach between Member States. The Directive is after all only a set of 'rules' which Member States must now apply and follow when considering the registration of both new and existing plant protection products. Whereas these new 'rules' are established within the context of regulatory objectives in terms of product safety and efficacy, they are nevertheless required to be implemented against the historical background of well established regulatory control within each of the individual Member States. Some of these control procedures have been developed over decades, for example 1993 sees the 40th anniversary of systems set up in the United Kingdom. It is therefore inevitable that different Regulatory Authorities within the Community have developed different attitudes not only to pesticides registration in particular, but to the use of pesticides in general. Thus, for example, some Regulatory Authorities have adopted an approach based on what might best be described as 'scientific pragmatism' whereas others are renowned for their attention to detail to the point of bureaucratic inflexibility. More significant differences have developed over recent years with the implementation in some Member States, e.g. Denmark and the Netherlands, of specific targets for the overall reduction in the use of plant protection products. Whilst not wishing to suggest that such approaches reflect an overt 'anti-pesticide' policy it is readily apparent that some Member States have a more 'liberal' approach to pesticides than do others.

As the Directive essentially incorporates a two-tiered approach to registration, the final approval for a crop protection product rests with decisions taken at the Member State level. How then will these different, historically developed attitudes referred to above reflect themselves in the practical terms of obtaining new registrations or the renewal of existing registrations? This paper attempts to identify some of the challenges and key issues associated with this question, and discusses the essential role which Industry has to play.

CHALLENGES

Member States

Over recent years the EC Registration Directive, not surprisingly in view of its importance, has been the subject of numerous Symposia and Conferences. From views expressed by Member State representatives during these events it has become apparent that a number of significant conclusions can be drawn regarding the future implementation of the Directive.

Firstly some Member States have expressed the view that the provisions of the Directive can, in broad terms, be readily incorporated into their existing National Laws, with relatively minor amendments. Whilst this may to some extent be true it does possibly imply that full integration into a Community system may be a rather lengthy process. In this context Member States will clearly have to accept that whilst they will contribute to the decision on the acceptability or otherwise of an active ingredient the final decision will, in effect, be a collective one (or at least based on a majority view).

Secondly, despite lengthy and frequent discussions on the Directive, both in the past and currently, there still remain areas where Member States appear to differ on the interpretation of some aspects of the Directive. Amongst these can be included data protection, the extent to which existing National Rules will continue to be applied and the need for full efficacy data packages required under the Review Regulation.

Thirdly, there are areas where Member States (and indeed Industry) remain confused regarding some provisions of the Directive. Thus, for example, how will registration fees be organized, in what languages will dossiers be accepted?

These three areas thus represent a challenge to Member States, a challenge which must be met and resolved if the Directive is to achieve its intended objective.

On a more practical level however it is clear that one other challenge remains which has significant implications for Industry, namely the challenge of resource availability within Member States. Although for both new and existing active ingredients the prime evaluation will be undertaken by the Rapporteur Member State, it seems highly likely that the other Member States will also need to review the dossiers in order to contribute to discussions and decision making at the Community level. Similarly in addition to acting as Rapporteur for those active ingredients allocated to them under the Review Regulation, Member States will also have to act as 'Co-Rapporteur' for other active ingredients. Given these facts and on the basis of past experience, it would seem fairly certain that the overall workload will increase. In the current climate it seems that additional resources are unlikely to be allocated for regulatory purposes and future increases would also seem equally unlikely. The management of these resources and their appropriate balance between the various types of work involved will thus present a significant problem for the future.

Industry

The major challenge to Industry must, in essence, be viewed against the background of the need for planning and investment. It is clearly each company's objective to bring new products to the market in the shortest possible time. In order to do so it must be fully aware of the regulatory procedures and associated constraints which will enable the necessary planning to be undertaken. Such planning not only involves the generation of efficacy and safety data but also the development of formulations and the not inconsiderable investment in the production areas.

The development of a new product is a long-term process and the likelihood of success, both in terms of acceptability and actual registrability of the product must be judged at various stages so as to minimise the risk associated with the phased investment of further capital and manpower resources. This has always been a difficult decision making process where, in the past, the registrability in each of the key markets was a crucial factor. In theory the assessment of future success on a Community-wide basis should in effect, make these decision simpler, and indeed in time this may well prove to be the case. In practice however, and certainly within the context of current knowledge, this is not the case and, in reality, the opposite holds true. The problem can be considered under a number of different scenarios.

Registration dossiers for new active ingredients which will enter into development in 1994 will probably not be completed until 1998 at the earliest. It is hoped that the development of the revised Annexes II and III will have progressed sufficiently quickly for any necessary amendments to be incorporated into the regulatory work programme at an early stage and that the scheduled completion date is not compromised. Similarly during this time sufficient experience will have been gained under the Directive's new procedures to enable registration times to be predicted with at least some degree of confidence.

A second example might relate to a new active ingredient in mid-development, i.e. the long-term toxicity studies have been initiated and other data in the environmental fate, ecotoxicology, resides and efficacy areas are being generated. Completion of the overall data package might therefore be some 18 months to 2 years away. Under these circumstances it is imperative to ensure that the completion date is not delayed and in order to do so full details of Annex II and III data requirements are required as soon as possible. Any additional studies arising from the final requirements of Annexes II and III, and those of Annex VI, must therefore be incorporated into the work programme against the background of a planned development programme for which the time-scale for completion continues to diminish. Prediction of likely registration dates, and the consequential difficulties of production planning, under these circumstances is extremely difficult.

A third class of new active ingredient is that which includes compounds which, in simplistic terms, 'failed' to be registered in a Member State before the 25 July 1993 'deadline'. Clearly some of these must exist and presumably will enter into the Community process sometime in the relatively near future. In the absence of the final revisions of Annexes II and III, it is obviously possible for some of the data bases for some of these compounds (and indeed associated products) to be incomplete. The extent and nature of these data gaps cannot however be fully established until the dossier has been reviewed by the Rapporteur Member State. Additionally, given the uncertainties of the transition period between National and Community procedures and the need to develop further procedures, the prediction of registration dates for these compounds is, in effect, impossible.

This last example also highlights a more general issue which must be recognized and for which some appropriate action must be planned. As previously mentioned above the Directive is at present merely a 'piece of paper'. In one way it has no real substance because as yet it has not been applied to an actual active ingredient and associated plant protection product. As such the Directive's real applicability and the problems, large or small, associated with that applicability will only manifest themselves under the practical conditions of the first few compounds to be evaluated under the new Community procedures. Thus we will inevitably be faced with a situation where 'the rules are made up as we go along'. Without wishing to appear to be over-critical of the United Kingdom, we cannot ignore the fact that following the introduction of the Control of Pesticides Regulations in October 1986, it was some significant period before registration applications were dealt with in anything approaching a reasonable time. This was the fact and must beg the question that if such difficulties were encountered at a National level, what is the potential for even greater difficulties at a Community level?

In this respect Industry clearly has a role to play, both with respect to its own 'in-house' developments and in relation to providing Member States with the benefits of its expertise. Thus Companies must, and this has been agreed in principle, share their practical experience with others. In this way knowledge of the procedures gained by those Companies being amongst the first to progress their compounds through the new system can be used by other Companies to improve their own submissions thereby facilitating the work of not only themselves but also of the Member States. Additionally Industry must closely monitor the process so that, on the basis of collective experience gained, bring to the attention of the Commission and Member States those areas of practical difficulties and proposed means of overcoming these. In this respect Industry's knowledge and experience of procedures adopted by other, non-EC Regulatory Authorities may prove to be of some benefit.

Industry in general, and the author in particular, have on occasions been perceived by some as adopting a pessimistic or negative attitude to the Directive. In response the counter-claim has been made that the attitude is rather one of realism based on experience. Notwithstanding these differences of opinion there is one area of the Directive which, in Industry's opinion, offers the opportunity for major, positive progress. This relates to residues data where the underlying approach of the Directive is towards the generation of fewer data of better quality. Thus the requirement for a 'regional' residues data package of good quality is to be welcomed and will be of advantage to Industry in its overall planning process. The benefits of such a policy however will only occur if Member States accept the 'regional' data package and do not insist on supplementary 'locally derived' data to meet their perceived National needs.

The Commission

It might be argued that to a large extent the Commission's future role in the Directive, or at least in its implementation, is minimal in that this responsibility lies clearly with the Member States. To some extent this is true but clearly the Commission has in addition to those specific duties specified in the Directive and the Review Regulation, an important role to play in ensuring that the Directive's objectives are met and that its provisions are implemented in a harmonious way. Because of the numerous implementation difficulties referred to in the above paragraphs, Industry has requested the Commission on numerous occasions to consider the issue of some Explanatory Notes whereby the Directive's requirements can be further explained and the possibility of different interpretations by Member States minimised. To date the Commission has declined to accede to this request and feels the Directive, its revised Annexes and the Review Regulation will provide both Member States and Industry with sufficient information to meet their immediate needs. The Commission has however acknowledge, at least informally, that in the light of practical experience gained during the actual handling of active ingredients and products within the system, explanatory notes may be needed to address specific issues which have arisen during this practical application. As already mentioned above, Industry will be undertaking a similar exercise and will need to maintain close liaison with the Commission in this and other, areas.

THE KEY ISSUES

The comments made above have identified some of the uncertainties and practical difficulties which can currently be envisaged during the implementation of the Directive. Over and above these and at the time of writing, a number of other key issues which will have a major impact on the future regulatory control of plant protection products remain either unresolved or unclear. Thus:

Drinking water

Much has already been published elsewhere regarding the EC Drinking Water Directive and its link with the decision making criteria embodied in the Commission's Proposed Directive establishing Annex VI, (the Uniform Principles) of the Registration Directive. Essentially the scientific community sees no justification for the current Maximum Allowable Concentration (MAC) of 0.1μg/l for individual pesticides and 0.5 μg/l for total pesticides in drinking water. On the other hand and rather over-simplistically, the 'political' community sees the need to retain these levels as a means of ensuring that there are 'zero' levels of pesticides in drinking water and that the apparent social and public demands are met by adopting the 'precautionary principles'. These conflicting viewpoints are not easily reconciled but clearly the current Proposed Uniform Principles extend the impact of the Drinking Water Directive to the extent that the continued registration of a significant number of existing plant protection products is seriously threatened and the registration of products containing some new active ingredients is put in doubt. Industry continues to express its opposition to quasi-zero, non-toxicologically derived MACs and awaits the outcome of ongoing discussions between the Commission, Member States and interested organizations with a high degree of interest.

Data protection

The topic to data protection is both complex and controversial and much time was devoted to it during Member States' discussions leading to the adoption of the Registration Directive. These discussions were re-opened during the adoption of the Review Regulation when some of the practical implications of the data protection provisions contained in Article 13 of the Directive were examined in more detail, primarily and perhaps not surprisingly, at the instigation of Industry. It became clear during these discussions that some differences in interpretation of Article 13 existed between Member States and Industry took the somewhat unusual step of attempting to consolidate and document the views of Member States.

It became clear during this process that one of the underlying principles in this area is that decisions regarding that inclusion of an active ingredient in Annex I is dependent on the evaluation of all available data, irrespective of source, whereas data protection is an administrative matter to be dealt with by Member States in their consideration of the approval of plant products containing the active ingredient after its inclusion in Annex I. Whereas there now seems to be a degree of consensus between Member States on the interpretation of Article 13, it remains to be seen how such administrative procedures will operate in practice. It would seem to be an area of potential difficulty and confusion where, once again, Industry monitoring and feedback will be essential.

Data requirements and decision making criteria

With the exception of the Introduction to Annex II and Annex III and the Efficacy Data Requirements of Annex III (Section 6) to the Directive, the revision of these Annexes have, at the time of writing, yet to be completed. Similarly the Commission's Proposed Directive establishing the Uniform Principles has yet to be adopted by Council.

Whereas some of Industry's comments have been acted upon during the drafting of these revised Annexes there remain areas of concern regarding the extent of some data requirements and the over conservative nature of some of the decision making criteria, particularly in the environmental fate and ecotoxicology areas. Hopefully the opportunity still exists for Industry's views to be accommodated before these revised Annexes are finally adopted.

CONCLUSIONS

It must not be overlooked that both the Directive and the Review Regulation will assume a significant importance outside the confines of the Community and on to an international regulatory stage. Thus there are clear signs of large parts of the Directive being adopted by other Western European countries such as Switzerland and Austria and, as part of their new political status and ongoing regulatory development, by countries such as Hungary, Poland and Bulgaria. Further afield early signs of harmonisation in some South American countries are being observed and for which the Community system may provide an example. In this context one must also consider the likely influence of inclusion of active ingredients in Annex I as providing potential guidance to those Developing Countries having less sophisticated regulatory control systems. Thus from both a direct Community and an indirect International point of view the successful implementation of the Registration Directive is of prime importance.

Although the responsibility to implement the EC Registration Directive clearly rests with the Member States it must not be overlooked that Industry has a major part to play in achieving a successful and meaningful implementation. The regulatory control of plant protection products is after all a 'partnership' between Regulatory Authorities and Industry, with the latter albeit regarded as a 'junior partner'. Nevertheless Industry is the partner who will discover the new active ingredients, who will generate the enormous amounts of data to prove their safety and efficacy, who will develop the most appropriate formulations and optimum conditions of use and who will undertake their commercial production. Similarly it is Industry who will provide all the information necessary to maintain existing products on the market. This has been the case for many years at the National level and will not change when control systems operate at the Community level. None but the most optimistic can however expect such a transition from National to Community systems to be without its problems and pitfalls. Whereas Member States and Industry may disagree on the extent of these problems everyone must be prepared to recognize the potential issues as they arise and to deal with them expeditiously and in a spirit of cooperation.