SESSION 3C

WEED CONTROL AND PLANT GROWTH REGULATOR USE IN DICOTYLEDONOUS ARABLE CROPS

SESSION ORGANISER MS G. P. WHYTOCK

POSTERS 3C-1 to 3C-12

HERBICIDE TOLERANCE IN WINTER OILSEED RAPE

P.J.W. LUTMAN*, F.L. DIXON

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

ABSTRACT

Pre- and post-emergence applications of metazachlor, particularly at doses higher than those recommended, caused leaf distortion and reduced oilseed rape growth in autumn and winter, but did not significantly affect seed yields. Although cultivars differed slightly in their responses to this herbicide there was no evidence that low glucosinolate cultivars were more sensitive. Pyridate also caused transient foliar effects but did not affect growth after mid-winter. Fluroxypyr was much more damaging and should not be considered for use in this crop.

INTRODUCTION

When herbicides are used to control weeds in a crop, the final crop yield is the resultant of the yield increase due to the removal of the weeds and any yield loss due to any phytotoxic effects of the herbicide. In general, approved herbicides do not have substantial adverse effects on crops, but adverse weather and soil conditions, inappropriate timing, and varietal differences can decrease selectivity and result in crop damage. A number of herbicides used in oilseed rape have been reported to cause foliar damage including, dalapon, TCA, metazachlor, pyridate and cyanazine (Lutman, 1989). Earlier research on dalapon and TCA (Askew, 1984; Lutman, 1985) demonstrated that foliar effects in autumn were followed by reduced seed yields. It is not clear whether the same is true for other herbicides. Metazachlor, one of the more widely used herbicides in rape, is known to cause crop damage under some climatic conditions, when applied pre-emergence as the seed is germinating (Stormonth & Woodroffe, 1982). Foliar damage and checks to growth from applications outside this period have also been reported by the UK advisory services (eg Ward & Turner, 1985; Bowerman, 1989; Davies <u>et al.</u>, 1989). However, it is not clear from these reports whether there was a relationship between the observed symptoms and reductions in yield.

In the early 1980's there were few cultivars of winter rape grown in the UK, so varietal differences in sensitivity to herbicides were of minor significance. The introduction of low glucosinolate varieties over the last 7 years has resulted in the availability of a much wider range of varieties. Glucosinolates are thought to protect the plant against adversity and their levels within the plant are known to increase when plants are stressed. It has been suggested that plants with low levels of glucosinolates may differ in sensitivity to pests and diseases (Chew, 1988) and consequently their ability to withstand herbicides may also be affected.

* Current address: AFRC/IACR Rothamsted Experimental Station, Harpenden, Herts AL5 2JQ

Difficulties with controlling cleavers (Galium aparine) in oilseed rape have led to research into less selective herbicides known to control this weed. Pyridate is recommended for use in rape but can cause appreciable crop damage. Fluroxypyr is the most effective herbicide to control cleavers in cereals and as it is not very active on weed species belonging to the Cruciferae may have potential for use in rape. However, the consequences for crop yield of damage from these two herbicides are not clearly understood.

This paper reports eight field and two pot experiments which investigated: the effects of pre- and post-emergence metazachlor on the growth and yield of oilseed rape, the influence of cultivar on metazachlor's effects and the selectivity of fluroxypyr and pyridate. The field trials were carried out, as far as possible, on sites with low natural weed infestations. In order to attempt to simulate potentially damaging environmental conditions a range of herbicide doses, up to three and four times the recommended rates, were included in all experiments. To simplify the presentation of the results the responses of the crops to the series of doses tested have been plotted using regression analyses. These have provided appropriate data for the presentation of herbicide responses as % damage (loss in dry weight etc) per kilogram of herbicide (a.i.).

MATERIALS AND METHODS

Field experiments

A series of eight field experiments were carried out between 1982 and 1989. Details of the herbicide doses, cultivars used and other agronomic information are given in Table 1. All crops were treated with several doses of metazachlor (500 g/l SC: 0.625 - 5.0 kg/ha a.i.) either pre- or early post-emergence (crop growth stage: cotyledons - 2 leaves). Fluroxypyr (200 g/l EC) and pyridate (45% WP) were also studied in Experiments 3 and 4. In all experiments, except Experiment 8, plots were large, at least 3 x 20m. Data from Experiment 8 are based on $1m^2$ samples, taken in autumn and spring from 2 x 6m plots. All herbicides were applied with a hand held sprayer through Spraying Systems 8002 TeeJets at 200-250 l/ha and at a pressure of 2.1 bar. Each experiment had three replicates. Data from the experiments have been subjected to analysis of variance and subsequently to regression. Herbicide responses are expressed in terms of % loss in yield (eg dry weight) / kg herbicide (a.i.).

In all experiments the effect of the herbicide treatments on the ground cover of the crop was recorded in winter and spring, crop heights were measured in May, and yields from a small plot combine harvester were recorded in all but Experiment 8. This experiment was ended before harvest. Other visual assessments of foliar symptoms etc were made on most trials.

Pot experiments

Both pot experiments were carried out in a heated glasshouse. Eight rape seeds were sown in each pot in the first experiment and five plants were established in every pot in the second. There were three replicates in each experiment. Experiment 1 investigated the response of 6 cultivars to five doses of metazachlor (500 g/l SC: 0.62, 1.25, 2.5, 3.75, 5.0 kg/ha a.i.), applied pre-emergence. The same five doses applied post-emergence, when the rape had 1-2 leaves, were used in the second experiment, which investigated the response of 14 cultivars (Table 5). The metazachlor was applied in a volume of 250 l/ha and at 2.1 bar pressure. Any visual effects were recorded at intervals after spraying and plants were harvested, dried and weighed 34 and 14 days after treatment in Experiments 1 and 2, respectively.

TABLE 1. Details of the 8 field experiments.

	Experiments							
	1	2	3	4	5	6	7	8
Year	82/3	82/3	83/4	83/4	87/8	87/8	87/8	88/9
Cultivars	Jet	Neuf	Jet	Neuf	Bienvenu Liradonna Ariana	Ariana		Bienvenu Cobra Ariana Libravo Liradonna Pasha
Drilling date	18/8	26/8	30/8	1/9	5-7/9	10/9	25/8	6/9
Metazachlor+								
appln dates pre	20/8	1/9	31/8	1/9				
post	3/9	10/9	14/9	23/9	25/9	2/10	8/9	3/10
doses (kg/ha a.i.)	1.25 2.50 5.00*	1.25 2.50	1.25 2.50 3.75	1.25 2.50 3.75	0.62 1.25 1.87 2.50 3.75	as for Expt 5		
Fluroxypyr & Pyridate+								
appln dates			19/10	27/10				
doses (kg/ha a.i.)								
(fluroxypyr)			0.05 0.10 0.20					
(pyridate)			1.00 2.00 3.00					

* only applied pre-emergence
\+ recommended rates (kg/ha a.i.): metazachlor 1.25 , pyridate 0.9 fluroxypyr 0.2 (cereals)

RESULTS

Field experiments

Pre-emergence metazachlor

Reductions in ground cover in winter and early spring (March) were recorded in Experiments 1 and 3, reaching a loss of 5 - 6% / kg a.i. of metazachlor, in March (Table 2). Thus, the higher the dose of metazachlor the greater the reduction in crop growth as estimated by ground cover. Occasional leaf deformity was noticed during the autumn at the high doses, especially in Experiment 3, where following 3.75 kg/ha (3 x recommended rate) leaves were twisted and cup-shaped. Small reductions in crop height were measured in the following May but there appeared to be no relationship between rape yields at harvest and herbicide dose. There were insufficient doses included in Experiment 2 for meaningful regression analysis but the analysis of variance failed to detect any significant effects from doses as high as 2.5 kg/ha, on the growth and yield of the crop. Experiment 4 showed only small effects in the autumn from doses as high as 3.75 kg/ha a.i. (Table 2) and these were no longer evident by the summer. Small reductions in rape plants/m^2 were recorded in all experiments, except 2 but these were only significant in Experiment 3.

TABLE 2. Response of oilseed rape to pre-emergence applications of metazachlor : % reduction in rape growth/kg a.i.

	Experiment					
	1		3		4	
	% Redn	SEM	% Redn	SEM	% Redn	SEM
Plant No/m^2	2.5	1.70	<u>4.1</u>	1.27	1.8	1.09
% Ground Cover Dec/Jan	3.4	1.52	2.5	1.17	1.0	0.88
% Ground Cover March	6.2	3.68	<u>5.4</u>	1.64	1.5	0.62
Crop ht (cm) May	1.6	1.53	<u>1.9</u>	0.51	NR	
Yields (t/ha)	NR (mean 2.20)		NR (mean 3.49)		NR (mean 4.25)	

NR No response
Figures underlined are statistically significant at the 5% level

TABLE 3. Response of oilseed rape to post-emergence applications of metazachlor, fluroxypyr and pyridate : % reduction in rape growth / kg a.i. (except fluroxypyr - see below).

Expt	Cultivar	% Ground Cover Dec/Jan % Redn	SEM	% Ground Cover March % Redn	SEM	Rape Ht (cm) May % Redn	SEM	Yields (t/ha) % Redn	SEM	Mean
Metazachlor										
3	Jet Neuf	<u>4.8</u>	0.62	<u>5.6</u>	0.52	<u>2.6</u>	0.43	2.6	1.74	3.59
4	"	1.9	1.05	2.0	1.08	0.8	0.40	NR		4.25
5i	Bienvenu	1.2	0.52					1.6	1.95	3.22
5ii	Liradonna	1.5	0.86					NR		2.42
5iii	Ariana	<u>2.1</u>	0.57					3.7	1.49	3.30
6	Ariana	NR		NR				NR		2.24
7	Ariana	NR		NR				2.4	1.42	2.47
Fluroxypyr (% reduction / 0.1 kg a.i.)										
3	Jet Neuf	<u>3.9</u>	0.94	NR		<u>3.1</u>	0.71	NR		3.40
4	"	<u>4.0</u>	1.29	<u>4.7</u>	1.46	<u>5.5</u>	1.43	3.2	2.18	4.15
Pyridate										
3	"	<u>5.4</u>	1.17	NR		NR		NR		3.56
4	"	<u>6.9</u>	2.62	NR		NR		NR		4.38

NR = no response
Figures underlined are statistically significant at the 5% level

Post-emergence metazachlor

The early post-emergence treatments did not affect rape plant numbers but caused more obvious symptoms than the pre-emergence treatments. Leaf deformation (twisting, cupping and leaf fusion) was particularly evident, during the autumn, after the 3.75 kg/ha dose in Experiments 3 and 4. The regression analyses failed to show statistically significant effects on rape growth in winter in Experiments 4, 5i, 5ii, 6 and 7, although in the first three there appeared to be a small decline in ground cover, with increasing herbicide dose (Table 3). In Experiments 3 and 5iii there were significant effects on growth, March crop ground cover decreasing by 5.6% / kg a.i. in Experiment 3. Seed yields were not significantly affected although in several experiments, particularly Experiment 5iii, there were indications of a reduction with increasing dose.

Results from the final experiment (8) failed to demonstrate a statistically significant effect on crop dry weight/m^2 in November for all cultivars (Table 4), although some plants treated with 1.87 kg/ha, or greater, had deformed twisted leaves. The data were rather variable due to uneven establishment of the crops and consequent greater weed growth. Pasha's response approached significance. The analysis of variance showed a highly significant overall decline in rape dry weight with increasing dose, although the responses of the individual cultivars were not significant. Ground cover assessments also carried out in November were less variable and again showed effects of the herbicide on Pasha (Table 4). The following spring there were no differences in crop vigour.

TABLE 4. Response of six cultivars of oilseed rape to post-emergence applications of metazachlor : % reduction in growth in November / kg a.i.

	Dry Wt (g/m^2)		% Ground Cover	
Cultivar	% Redn	SEM	% Redn	SEM
Bienvenu	5.6	8.47	5.8	3.40
Ariana	6.3	6.95	2.2	1.09
Cobra	4.0	2.64	3.7	1.29
Libravo	3.6	4.32	3.7	2.08
Pasha	7.9	3.17	<u>4.9</u>	0.92

Figures underlined are statistically significant at the 5% level

Post-emergence fluroxypyr

Severe leaf curling followed treatment with all doses (0.05, 0.1, 0.2 kg/ha a.i.) in late October in both Experiments 3 and 4. This resulted in appreciable reductions in crop growth throughout the following 6 months, affecting both ground cover and crop height (Table 3). A dose of 0.1 kg/ha caused up to a 5.5% reduction in crop growth in Experiment 4. Effects were less marked on Experiment 3. However, reductions in seed yield were not statistically significant in either experiment.

Post-emergence pyridate

Applications of pyridate at the end of October in Experiments 3 and 4, caused some chlorosis and necrosis to the largest leaves present when the herbicide was applied. As a consequence, crop ground cover in

December/January was reduced by 5.4 - 6.9% / kg pyridate (Table 3). This effect had disappeared by the following March and no further responses to this herbicide were recorded. There were no detectable effects on yields.

Pot experiments

Experiment 1: pre-emergence metazachlor

Doses of 3.75 kg/ha metazachlor and higher, caused leaf curling and stunted some plants on all six cultivars. Symptoms were not uniform, as some plants in a pot were affected whilst others were not, but tended to increase in severity with increases in dose. Pasha and Libravo appeared least affected. In contrast the dry weights showed that the growth of Cobra and Pasha had been reduced most severely and Bienvenu the least (Table 5).

Experiment 2: post-emergence metazachlor

Most of the cultivars, with the exception of Pasha, showed few symptoms from the post-emergence treatments of metazachlor, even from doses as high as 5 kg/ha. Leaves of Pasha tended to be curled and fused, especially at doses above 2.5 kg/ha. Leaves of some plants of Bienvenu and Tapidor also showed symptoms, but only a minority of plants were affected. The dry weights of the majority of the 14 cultivars were not greatly reduced by the herbicide treatments (Table 5). Only Liradonna, Doublol and Payrol showed statistically significant reductions, declining by 9.7, 4.2 and 7.7% / kg herbicide, respectively.

TABLE 5. Response of 14 rape cultivars to increasing doses of metazachlor (% reduction in dry wt / kg a.i.

Cultivar		Expt 1 % Redn	Expt 1 SEM	Expt 2 % Redn	Expt 2 SEM	Cultivar		Expt. 2 % Redn	Expt. 2 SEM
Ariana	**	5.8	2.78	2.3	2.42	Ceres	**	4.9	1.94
Bienvenu	*	3.4	2.90	4.1	2.83	Lictor	**	2.4	2.30
Cobra	**	<u>10.6</u>	3.27	3.6	2.36	Liquanta	**	3.9	2.56
Libravo	**	5.4	2.10	1.0	3.10	Capricorn	**	2.2	1.73
Liradonna	**	9.6	3.92	<u>9.7</u>	1.76	Tapidor	**	1.9	2.17
Pasha	*	<u>8.2</u>	1.32	0	2.35	Doublol	**	<u>4.2</u>	1.25
						Payrol	**	<u>7.7</u>	1.37
						Score	**	4.6	2.45

* - single 'low' - high glucosinolate cv

** - double 'low' - low glucosinolate cv

Figures underlined are statistically significant at the 5% level

DISCUSSION

The results of all the experiments showed that metazachlor, particularly at rates higher than those recommended, can cause leaf distortion and stunt the early growth of rape. There was considerable variation in the level of damage between experiments, with Experiment 3 showing particularly clear symptoms from both pre- and post-emergence treatments and Experiments 6 and 7 showing no detectable effects.

Practical experiences indicate that the risk of serious crop loss is greater with the pre-emergence treatments, particularly if heavy rain occurs after application, but these conditions did not arise in our experiments. The pre-emergence treatments had a small effect on rape plant numbers but the post-emergence treatments seemed to cause greater foliar damage. It is possible that differences in varietal sensitivity were the cause of the differing responses in the eight field experiments but the results of those with several cultivars do not support this. For example, Ariana was most susceptible in Experiment 5 but not in Experiment 8 and, in contrast, Pasha was most severely affected in Experiment 8 and Pot Experiment 1 but was little affected in Pot Experiment 2. The varietal comparisons do not support the thesis that low glucosinolate cultivars are more sensitive to herbicides, as there was no consistent response of the single and double low cultivars. Further work is needed to confirm whether the results of the second pot experiment, indicating that some cultivars are slightly more sensitive to metazachlor than others, are repeatable.

Although foliar symptoms, mainly from high doses, and reductions in growth in autumn and winter were recorded in several of the experiments these were not translated into reductions in yield. Even in Experiment 3, where post-emergence metazachlor caused a 5.6% reduction in ground cover / kg a.i., in March, it failed to cause a significant reduction in yield. In eight of the nine experiments taken to yield there was either no response to herbicide dose or the yield response was the lowest of the values recorded during the life of the crop. This ability of the crop to compensate for herbicide induced reductions in growth in the autumn, winter and early spring is mirrored by its ability to recover from weed competition and late control of weeds (Lutman, 1989; Lutman & Dixon, 1990). Earlier work reported by Askew (1984) also found that rape herbicides, with the exception of dalapon, did not cause significant reductions in yield. However, Askew's paper gives only limited information on the severity of foliar symptoms.

The responses of the crop to pyridate were similar to those of metazachlor, though more transient. The leaf scorch caused by the herbicide affected crop growth in the early winter but the crops had fully recovered by March. Fluroxypyr, even at only 0.05 kg/ha had a devastating effect on the appearance of the crop and as a consequence vigour was reduced throughout the growing season. Again, because of the crop's ability to compensate, there was no significant effect on yields. However it would in our opinion be very risky to use this herbicide in rape, despite the need to control cleavers. Considerably more work would be needed to confirm that the crop was always able to recover from the severe foliar damage caused by this herbicide. Pyridate, despite its variable efficacy must be preferred.

The use of regression analyses to identify trends in the data was of considerable benefit to the understanding of the results. As with weed density/competition experiments and other investigations involving studies of the effects of treatments with a series of increasing values, analysis of variance is not the most appropriate technique (Cousens, 1988). Regression analyses are more appropriate for the identification of trends. In herbicide dose response experiments it is suggested that plant responses follow a curvilinear relationship, with little response at low doses and increasing effects at high ones. However, in the experiments reported in this paper, where responses were significant, a linear model fitted the data best and there were no indications of curved responses. Similarly, the use of higher than recommended rates of herbicide can be criticised on the basis that these would never be used in practice. However, the use of high doses provides information relevant to the potential damaging effects of the herbicide under adverse crop or environmental conditions; conditions which cannot be reliably recreated in field conditions.

ACKNOWLEDGEMENTS

We would like to thank Andy Lovegrove for his help with the earlier experiments and the staff of Experimental Husbandry at Long Ashton for their assistance with the more recent ones.

REFERENCES

Askew, M.F. (1984) The effects of several post-emergence herbicides on the seed and oil yield of winter oilseed rape. Aspects of Applied Biology **6**, Agronomy, Physiology, Plant Breeding and Crop Protection of Oilseed Rape, 251-256.

Bowerman, P. (1989) Weed control in winter oilseed rape - a review of ADAS trials 1985-87. Aspects of Applied Biology 23, Production and Protection of Oilseed Rape and other Brassica Crops, 219-226.

Chew, F.S. (1988) Biological effects of glucosinolates. In: Biologically Active Natural Products: Potential Uses in Agriculture. H.G. Cutler (Ed), Washington, American Chemical Society, pp 155-181.

Cousens, R.D. (1988) Misinterpretations of results in weed research through inappropriate use of statistics. Weed Research, **28**, 281-289.

Davies, D.H.K.; Walker, K.C.; Whytock, G.P. (1989) Herbicide use and yield response in winter oilseed rape in Scotland. Aspects of Applied Biology 23, Production and Protection of Oilseed Rape and other Brassica Crops, 227-236.

Lutman, P.J.W. (1985) Effects of dalapon and TCA on the growth and yield of oilseed rape (Brassica napus). Annals of Applied Biology, **107**, 515-527.

Lutman, P.J.W. (1989) Objectives of weed control in oilseed rape. Aspects of Applied Biology 23, Production and Protection of Oilseed Rape and other Brassica Crops, 199-210.

Lutman, P.J.W.; Dixon, F.L. (1990) The competitive effect of volunteer barley (Hordeum vulgare) on the growth of oilseed rape (Brassica napus). Annals of Applied Biology, **117**, 633-644.

Stormonth, D.A.; Woodroffe, R. (1982) The use of metazachlor for the control of weeds in winter oilseed rape. Proceedings 1982 British Crop Protection Conference - Weeds, 103-108.

Ward, J.T.; Turner E.W. (1985) Annual grass and broad-leaved weed control in winter oilseed rape. Proceedings 1985 British Crop Protection Conference - Weeds), 223-230.

BENEFICIAL EFFECTS OF THE PLANT GROWTH REGULATOR CGA 163'935 IN OILSEED RAPE UNDER UK CONDITIONS.

E.J.C. HENDERSON, W. MAURER, D.W.CORNES, P.J. RYAN.

Ciba-Geigy Agrochemicals, Whittlesford, Cambridge, U.K.

ABSTRACT

CGA 163'935 is a growth regulator which is active in a wide range of arable crops including cereals and oilseed rape. In winter oilseed rape a spring application of 400g ai/ha CGA 163'935 was found to give effective height reduction and control of lodging. Height reduction was dependent on the timing of application and CGA 163'935 was found to be most effective when applied prior to flowering. Effective lodging control was achieved irrespective of the time of application or the degree of height reduction obtained. Seed yield was increased by CGA 163'935, particularly in those trials where lodging was controlled.

INTRODUCTION

Oilseed rape (*Brassica napus*) has increased in prominence in UK farming systems during the last two decades and is now the most extensively grown combinable break crop. In the UK the area grown has expanded from approximately 10,000 hectares in 1970 to over 390,000 hectares in 1990 (Anon., 1970, 1990). The oilseed rape crop is tall and top heavy due to the presence of a dominant terminal raceme, and hence it often lodges extensively during pod development, especially after periods of heavy rainfall (Scarisbrick *et al.*, 1985). Baylis & Wright (1990) showed that lodging can incur serious yield and quality penalties. In their work, natural lodging significantly reduced yield by 0.39 t/ha (13%) compared with a supported control and severe, induced lodging caused a 48% reduction in yield. A growth regulator which shortens crops and prevents lodging could therefore improve recoverable yield. Hence the search for chemicals which inhibit or retard the growth of oilseed rape is an active field of research (Child *et al.*, 1987).

Kerber *et al.* (1989) reported the chemical and physical properties of CGA 163'935, a new plant growth regulator discovered by Ciba-Geigy Ltd., Basle. It is currently being developed for use in a wide range of arable crops including cereals and oilseed rape (Amrein *et al.*, 1989). CGA 163'935 is a cyclohexanedione compound which is taken up by the foliage and translocated to the growing shoot where it reduces internode length. Hence the activity of CGA 163'935 is not influenced by soil moisture content unlike the triazole compounds such as paclobutrazol, which are mainly taken up through the root system (Scarisbrick *et al.*, 1985). CGA 163'935 appears to have little action on photosynthesis or root growth and development. The mode of action of CGA 163'935 has been reported by Adams *et al.* (1991a, 1991b).

Extensive testing of CGA 163'935 has been conducted in France and has been reported by Szabo & Roy, (1991). This paper reports on a similar series of trials designed to evaluate the effects of CGA 163'935 in winter oilseed rape under UK growing conditions.

MATERIALS AND METHODS

CGA 163'935 has been field tested in the UK for six consecutive seasons (1986-1991). Twenty-three small plot trials were conducted on commercial crops of winter oilseed rape in the south-east of England, on the 'single low' cultivars Bienvenu (3 trials) and Rafal (1) and the 'double low' cultivars Ariana (4), Capricorn (1), Cobra (1), Falcon (3), Libravo (5), Lictor (2) and Score (1). Trials were of a complete randomized block design with four replicates and a plot size of 36-50m^2. Programmes for fertilizer application and disease, pest and weed control were carried out by the farmers and were appropriate for each site with regard to soil type, variety and good agricultural practice. Growth regulator applications were made using a CO_2 - pressurised small plot sprayer fitted with 6 Lurmark 02-F110 nozzles calibrated to deliver a spray volume of 200 l/ha at 207 kPa pressure.

CGA 163'935 was formulated as an emulsifiable concentrate in 1986-89 and as a micro-emulsion in 1990 and 1991. Formulation type was not found to affect activity. Rates of between 200 and 800 g ai/ha were evaluated from which 400g ai/ha was selected for optimum activity. The results presented in this paper are therefore from applications of 400g ai/ha with the exception of 1986 when 500g ai/ha was applied.

Treatments were applied at four timings in the spring as detailed below :-

Timing 1 (T1) : prior to stem elongation (at the development stage 1,9 - 3,1)
Timing 2 (T2) : during early stem extension (2,03 - 3,3)
Timing 3 (T3) : during flower bud development (3,3 - 3,9)
Timing 4 (T4) : during early flowering (4,0 - 4,2)

Development stages are from the growth stage key by Sylvester-Bradley and Makepeace, 1984.

Growth regulation was monitored by *in situ* measurement of crop height at fortnightly intervals from application to the end of flowering. Six measurements per plot were taken from ground level to the highest point of the canopy. More detailed assessment of plant structure, including total plant length, length of vegetative stem, and depth of pod canopy, was carried out on samples of 5 plants per plot taken from one trial in 1987 and from both trials in 1989, approximately 3 weeks before harvest. Crop lodging was assessed visually by estimating the percent plot area affected. The degree of lodging was assessed on a 0 - 100 scale where 0 = stems erect (no lodging) and 100 = stems horizontal (completely lodged). The lodging index was calculated according to Bolton & Adam (1987) :

$$\text{Lodging Index} = (\text{\% area lodged} \times \text{degree of lodging}) / 100$$

Trials were yielded with a small plot combine harvester and were combined either directly or after desiccation depending on field practice. Seed yields were corrected to 9% moisture content. Statistical analyses of variance were performed on crop height and seed yield using Tukey's T-test.

RESULTS

Plant height was reduced by 400g ai/ha CGA 163'935 in each of the six years of testing. This effect was consistent, with only small variations observed at individual timings from year to year (Table 1).

TABLE 1. The effect of year on crop height reduction by CGA 163'935. Final crop height expressed as a percentage of the untreated, mean of (x) trials.

Year	Crop height, % of untreated			
	T1	T2	T3	T4
1986		89(1)	90(2)	
1987	86(1)	86(2)		
1988				90(1)
1989			92(2)	
1990		94(2)	95(4)	96(7)
1991	88(3)	88(3)	88(3)	95(7)

Where application timing was compared within the same trial, treatments applied prior to flowering, at timings T1 - T3, were consistently more effective than those applied during early flowering, at timing T4 (Table 2). The activity of CGA 163'935 was not affected by variety, effective height reduction being demonstrated on a range of varieties (Table 3).

Results from three trials carried out in 1987, where applications of 200 - 800g ai/ha were made prior to or during stem extension, showed that the rate of growth was similar for both the untreated and treated crop, although the treated crop did not reach the same final height (Figure 1). Height reduction was observed to be dose-dependent in these trials and persisted through to harvest. Plant structure assessments suggested that height reduction was mainly due to a shortening of the vegetative stem and not to a reduction in pod canopy depth.

Lodging occurred in 17 of the 23 trials and was particularly severe in 1991. CGA 163'935 reduced lodging in all trials (Table 4). Where application timings were compared, lodging control was found to be independent of both application timing and degree of height reduction obtained (Figure 2). Lodging control was less effective in trials 001,91, 004,91, 005,91, and 008,91 (Table 4). Treated plots at these sites were observed to lodge later than the untreated plots and were lodged in a uniform manner with the pods held approximately 50 cm above ground level. Untreated plots were in parts completely lodged, with pods lying at ground level, and in other parts were forced into clumps of upright plants.

TABLE 2. The effect of application timing of CGA 163'935 on crop height, expressed as a percentage of the untreated.

Site	Untreated crop height (cm)	Crop height, % of untreated T1	T2	T3	T4
002,91	157	92			98
003,91	154	82*			90*
007,90	121		95		97
008,90	147		93		95
005,91	124		82*		96
006,91	162		89		90
008,91	180		97		99
001,90	132			92	94
004,90	114			97	98
005,90	128			99	100
006,90	141			92	95
004,91	162			87*	99
007,91	159			85*	92*

* significantly different from the untreated at P = 0.05 (Tukey's)

TABLE 3. The effect of variety on crop height reduction by CGA 163'935. Final crop height expressed as a percentage of the untreated, data expressed as the mean of (x) trials where more than one trial.

Variety	Crop height, % of untreated T1	T2	T3	T4
Ariana	86		91(3)	94(2)
Bienvenu		87(2)	90(2)	
Capricorn		82		96
Cobra		93		95
Falcon	87(2)	88	95	90(2)
Libravo			93(5)	96(5)
Lictor	92	93(2)		98(3)
Rafal		86		
Score				93

FIGURE 1. The effect of CGA 163'935 on crop growth rate (mean of 3 trials).

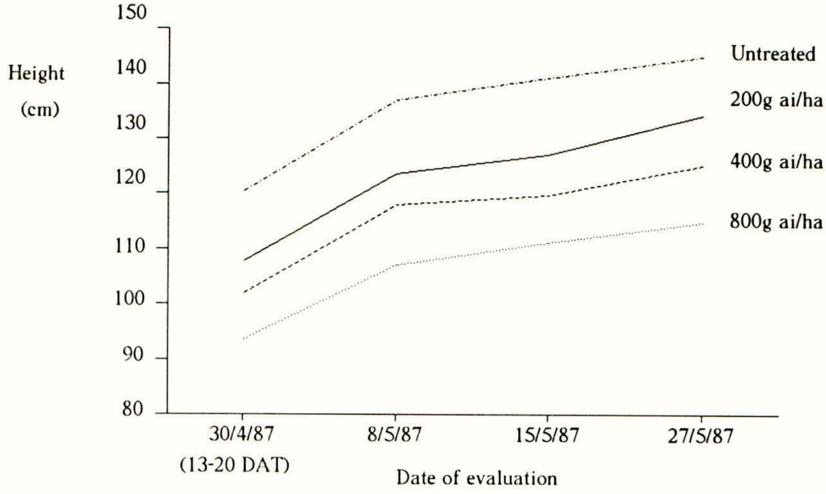


TABLE 4. The effect of 400g ai/ha CGA 163'935 on Lodging Index.

Site	Untreated	Lodging Index T1	T2	T3	T4
002,91	40	27			15
003,91	43	4			10
008,90	36		11		9
005,91	72		52		40
006,91	70		7		7
008,91	77		55		62
001,90	5		0		4
004,90	40			16	14
005,90	38			15	18
006,90	19			6	4
004,91	65			34	42
007,91	52			0	1
001,91	58	50		36	
002,87	22	8			
003,87	25		1		
002,89	10			2	
001,88	35				1

The effect of 400g ai/ha CGA 163'935 on seed yield, in the presence and absence of lodging, is presented in Table 5. Yield increases over the untreated were recorded both from trials where lodging was controlled and from trials where lodging did not occur.

Seed harvested from treated plots has been observed to have a higher moisture content than that from untreated plots. This delay in maturity may be a consequence of the 4 - 5 day delay in the start of flowering recorded in treated plots.

FIGURE 2. The effect of time of application of CGA 163'935 on crop height and Lodging Index.

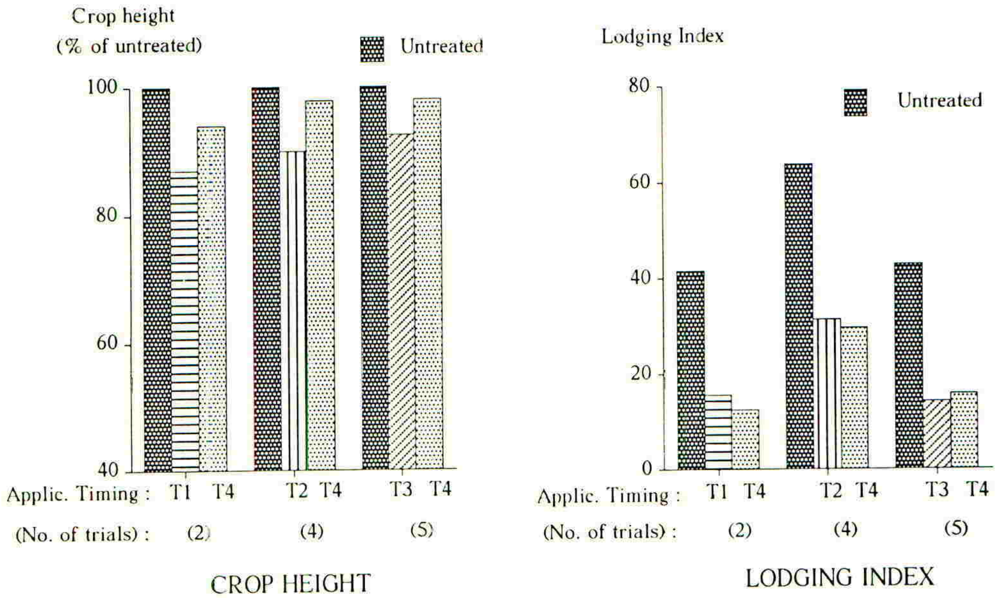


TABLE 5. The effect of CGA 163'935 on yield in trials with or without lodging, expressed as a percentage of the untreated.

	No. of observations	Mean yield of treatments (%)
Presence of lodging (Untreated L.I. > 20)	21	107.2
Absence of lodging (Untreated L.I. < 20)	12	105.7

DISCUSSION

Spring applications of 400g ai/ha CGA 163'935 reduced the height of a range of cultivars of winter oilseed rape. Height reduction, from treatments applied prior to or during stem extension, was mainly due to a reduction in vegetative stem length and this effect persisted through to harvest. Triazole growth regulators applied at early stem extension have also been found to reduce stem and total crop height without affecting canopy depth (Child *et al*, 1988). CGA 163'935 is taken up through the foliage and its activity is therefore independent of soil moisture content. This may explain the consistency of results obtained over the six years of testing despite varying environmental conditions. The degree of height reduction was influenced by the timing of application and CGA 163'935 was most effective when applied prior to flowering. From a practical point of view a growth regulator with the capacity to reduce crop height could be a valuable management aid. A short standing crop would allow easier post-anthesis crop management perhaps negating the need for specialist high clearance spraying machinery. Reducing the amount of vegetative material passing through the combine may further improve the efficiency of harvesting operations (Almond & Dawkins,1985).

Lodging control was observed to be independent of application timing, and there appears to be little correlation between height reduction and lodging control. Hence there is a wide application window in the spring when CGA 163'935 will provide effective control of lodging. Good control of lodging was obtained from treatments providing relatively small reductions in height. Baylis & Wright (1990) observed this effect when working with a paclobutrazol - chlormequat chloride mixture. They suggested that delayed flowering and consequently less heavy racemes at the start of lodging, as well as shorter or thicker stems acting to reduce bending movements, may have contributed to the lodging control achieved. CGA 163'935 has been found to delay flowering by 4 - 5 days, however stem thickness has not been measured. In 1991 CGA 163'935 did not give complete control of severe lodging and some late lodging occurred in treated plots. However, unlike untreated plots, those treated with CGA 163'935 were lodged in a uniform manner with pods held well above ground level.

This trial series indicates that applications of CGA 163'935 can result in improved recoverable yield and confirms the results of trials in France (Szabo *et al*, 1991). Yield increases over the untreated have been associated with control of lodging and may be due to reduced seed loss before and during harvest. Yield increases have also been recorded from trials where lodging did not occur. However no correlation has been found between the degree of lodging and subsequent yield obtained from CGA 163'935 application. The inherent variation present in the oilseed rape crop, along with the delay in ripening following CGA 163'935 treatment, make yield results from small plot trials difficult to interpret. Therefore larger plot trials will be conducted to further quantify the yield benefits resulting from control of lodging by CGA 163'935.

REFERENCES

Adams, R.; Kerber, E.; Pfister, K.; Weiler, E.W. (1991a) Studies on the action of the new growth retardant CGA 163'935. *11TH International Conference on Plant Growth Substances, Amsterdam.* (In Press).

Adams, R.; Weiler E.W.; Kerber, E.; Pfister, K.; Schaer, H-P. (1991b) Studies on the action of the new growth retardant CGA 163'935. *Brighton Crop Protection Conference - Weeds 1991.* (In Press).

Almond, J.A.; Dawkins, T.C.K. (1985) Investigations into the use of flurprimidol (EL500) as a plant growth regulator for winter oilseed rape (*Brassica napus* L.) *British Crop Protection Conference - Weeds 1985*, 2 , 481 - 488.

Amrein, J.; Rufener, J.; Quadranti, M. (1989) The use of CGA 163'935 as a growth regulator in cereals and oilseed rape. *Brighton Crop Protection Conference - Weeds 1989*, 1, 89 - 94.

Anon. (1970) Ministry of Agriculture, Fisheries and Food, *1970 Agricultural Returns for England and Wales - June, Press Notice 521.*

Anon. (1990) Ministry of Agriculture, Fisheries and Food, *1990 Agricultural Returns for the UK and England - June, No. 169/90.*

Baylis, A.D.; Wright I.T.J. (1990) The effects of lodging and a paclobutrazol - chlormequat chloride mixture on the yield and quality of oilseed rape. *Annals of Applied Biology*, 116, 287 - 295.

Bolton B.J.G.; Adam N.M. (1987) Growth regulation of winter oilseed rape with RSW 0411. *Proceedings of Crop Protection in Northern Britain 1987*, 214 - 219.

Child, R.D.; Butler, D.R.; Sims, I.M.; Johnson, W.; Thorn, M. (1987) Control of canopy structure in oilseed rape with growth retardants and consequences for yield. In : *Plant Growth Regulators for Agricultural and Amenity Use*, A.F. Hawkins (Ed) *BCPC Monograph No. 36*, Thornton Heath : BCPC Publications, 21 - 35.

Child, R.D.; Evans, D.E.; Hutcheon, J.A.; Jordan, V.W.; Stinchcombe, G.R. (1988) Influence of time of application of growth retardants on canopy structure, disease and yield in oilseed rape. *Brighton Crop Protection Conference - Pests and Diseases 1988*, 3, 881 - 886.

Kerber, E.; Leypoldt, G.; Seiler, A. (1989) CGA 163'935, a new plant growth regulator for small grain cereals, rape and turf. *Brighton Crop Protection Conference - Weeds 1989*, 1, 83 - 88.

Scarisbrick, D.H.; Addo-Quaye, A.A.; Daniels, R.W.; Mahamud, S. (1985) The effect of paclobutrazol on plant height and seed yield of oilseed rape (*Brassica napus* L.). *Journal of Agricultural Science, Cambridge* 105, 605 - 612.

Sylvester-Bradley, R.; Makepeace, R.J. (1984) A code of stages of development in oilseed rape (*Brassica napus* L.). *Aspects of Applied Biology 6, Agronomy, physiology plant breeding and crop protection of oilseed rape*, 399 - 419.

Szabo, J.; Roy C. (1991) CGA 163'935, new plant growth regulator for winter wheat, winter barley and winter oilseed rape, lodging prevention. *3ème Colloque sur les Substances de Croissance et leurs Utilisations dans les Productions Vegetales*. ANNP No. 01, 1, 63-73.

CONTROL OF LODGING IN OILSEED RAPE BY A MIXTURE OF PACLOBUTRAZOL AND CHLORMEQUAT CHLORIDE PLANT GROWTH REGULATORS

A D BAYLIS

ICI Agrochemicals, Jealott's Hill Research Station, Bracknell, Berks., RG12 6EY, UK.

C H VOON

ICI Agrochemicals, Fernhurst, Haslemere, Surrey, GU27 3JE, UK.

I DELPEUCH

ICI Protection de l'Agriculture, 1 Avenue Newton, BP208, 92142 Clamart Cedex, France.

ABSTRACT

JF10405, a 1:8 mixture of paclobutrazol and chlormequat chloride, is a recently commercialised plant growth regulator for oilseed rape, sold in France since 1989. Three series of trials were conducted in the UK and France in two seasons. Applications of JF10405 in autumn and spring significantly reduced the severity of lodging. Spring applications at the green bud stage were especially effective. Some significant increases in yield, and, in one trial, significant reductions in glucosinolate levels were recorded. Lower application rates appeared more appropriate in autumn to avoid excessive retardation in spring. Significant increases in yield in the absence of lodging were also recorded in one experiment.

INTRODUCTION

JF10405 ('Parlay C') is a mixture of paclobutrazol and chlormequat chloride plant growth regulators developed to control lodging and facilitate the management of oilseed rape (*Brassica napus*) crops. The two components of JF10405 are complementary in their precise modes of action and absorption by plants (Dicks, 1980; Lord & Wheeler, 1981; Dalziel & Lawrence, 1984). Paclobutrazol is more potent on oilseed rape than chlormequat chloride (Scarisbrick *et al*, 1982; Scarisbrick *et al*, 1985), but when mixed together they show synergistic growth retardant activity (ICI, unpublished).

The 'double low' varieties currently grown in Europe produce high quality seed, low in erucic acid and glucosinolates, but are, generally, tall and susceptible to lodging. Lodging in oilseed rape can reduce yields by up to 50%, early lodging being particularly damaging (Baylis & Wright, 1990). It can also encourage infection by splash-borne diseases, impair seed quality, and increase harvesting time (Baylis & Wright, 1990; Baylis & Hutley-Bull, 1991).

Inherent weaknesses in standing power can be exacerbated by early drilling leading to greater shoot growth and higher yield potential (Mendham *et al*, 1981). Late sown crops can yield as well as, and sometimes better than, those sown early due to better realisation of yield potential (Jenkins & Leitch, 1986; Lutman & Dixon, 1987). However, good yields from later sown crops may depend on early spring weather conducive to the development of a canopy capable of intercepting, and receiving, high levels of radiation (Mendham *et al*, 1981; Jenkins & Leitch, 1986). Furthermore, there are good practical reasons for drilling oilseed rape before mid-September. A drilling period of late August to mid-September occupies a niche between wheat harvest and winter cereal drilling in arable areas of England and France.

In the more southerly oilseed rape growing areas of Europe, early drilled crops can make substantial growth before the onset of winter. Such advanced, vigorous crops can be susceptible to damage by frost, resulting in a reduction in ground cover as radiation receipts increase in early spring and the potential for growth returns. Autumn treatments of JF10405 have been applied to prevent excessive growth before winter and to improve winter hardiness.

MATERIALS AND METHODS

JF10405 is a plant growth regulator comprising 50 g/l paclobutrazol, 400 g/l chlormequat chloride and 50 g/l Tween 20. Three series of field trials were carried out in the UK and France in 1988/89 and 1989/90. Series 1 comprised three experiments conducted in southern England in 1988/89, coded UK89/1, UK89/2, and UK89/3. Varieties were Libravo, Ariana and Libravo, respectively. JF10405 treatments were applied at late green bud (GB) or late yellow bud (YB),(later treatments were not applied in UK89/1) in late March and April. Rates of 1.25 and 2.50 l/ha were used.

Series 2 consisted of three experiments conducted in the Tours area of France in 1988/89, designated F89/1, F89/2, and F89/3. Varieties were DCH1 (F89/1 and F89/2) and S002 (F89/3). JF10405 was applied at 1.25 l/ha to F89/1 on 14 October, and to the other two experiments on 28 October, when all crops had 4-6 leaves. Spring applications were made either as single sprays of 1.25 l/ha at early green bud, or as a split application of 0.75 l/ha followed by 0.5 l/ha, at early green bud and early yellow bud.

Series 3 comprised three experiments conducted in the Reims area of France in 1989/90, coded F90/1, F90/2 and F90/3. The variety was Samourai. JF10405 was applied at 0.75 l/ha or 1.25 l/ha. Application dates were 7 November, 23 October and 11 October to F90/1-3, respectively. Treatments were applied at the 6 leaf stage, except for F90/2 which was at 4-5 leaves.

All experiments were laid down in well-established commercial crops of winter oilseed rape, drilled between late August and early September on medium soils. In each case a fully randomised block design with four replicates was used. Plots were all 4m wide, but lengths varied between 10 and 20 m. JF10405 treatments all included the addition of 0.1% v/v non-ionic wetter, usually Agral 90, but Renex 36 in experiments UK89/1 and UK89/3, and were applied at spray volumes between 200 and 300 l/ha using a two-man boom hydraulic sprayer with flat fan nozzles operating at 2.5 bar. Crops were fertilized and maintained free of pests and diseases by normal agricultural practices and harvested by small-plot combines after desiccation with diquat.

Crop canopy height was determined by taking ten measurements per plot of the visually assessed mean height of the canopy across the plot. Lodging was visually assessed using an index accounting for the severity of lodging and the proportion of the plot affected (Caldicott & Nuttall, 1979). In Series 1, the concentration of glucosinolates in harvested seed was measured by X-ray fluoresence.

Two-way analysis of variance was performed on all data and least significant differences (P = 0.05) were calculated. In the tables of results, treatment means followed by a common letter are not significantly different at the 5% probability level.

RESULTS

Series 1

In two of the three trials (both cv Libravo) lodging began in May while the crops were still flowering. The third trial with cv Ariana did not lodge. Crop canopy heights close to the onset of lodging are shown in Table 1.

TABLE 1. Series 1. Effects of JF10405 on canopy height in mid-May as % of untreated.

	UK89/1 (10 May)	UK89/2 (17 May)	UK89/3 (22 May)
Untreated	100 a (158 cm)	100 a (159 cm)	100 a (136 cm)
1.25 l/ha GB	82 b	98 ab	99 ab
2.50 l/ha GB	76 c	85 c	97 b
1.25 l/ha YB	-	97 abc	98 ab
2.50 l/ha YB	-	91 bc	99 ab

The progress of lodging and the effects of the lower rate of JF10405 are shown in Figs. 1a and 1b. There was little difference between the higher rate of JF10405 and the 1.25 l/ha rate. Earlier applications were significantly more effective at controlling early lodging, but there were no differences between timings at harvest (Fig. 1b). Yields of JF10405 treatments tended to be greater than those of the control (Table 2). Increases were significant from both rates at the later application timing in UK89/2 and from the higher rate at the early timing in UK89/3. There were, however, no significant differences in yield between the various JF10405 treatments.

TABLE 2. Series 1. Effects of JF10405 on seed yields (t/ha at 91% d.m.).

	UK89/1	UK89/2	UK89/3
Untreated	3.93 a	3.43 c	2.77 b
1.25 l/ha GB	4.10 a	3.72 abc	2.93 ab
2.50 l/ha GB	3.93 a	3.69 abc	3.18 a
1.25 l/ha YB	-	3.80 ab	3.00 ab
2.50 l/ha YB	-	3.97 a	2.93 ab

Glucosinolate levels in the harvested seed from control plots and those treated at green bud are presented in Table 3. Levels of glucosinolates significantly lower than the control were recorded in UK89/1.

FIGURE 1. Series 1. Effects of 1.25 l/ha JF10405 on lodging.

FIG. 1a. UK89/1.

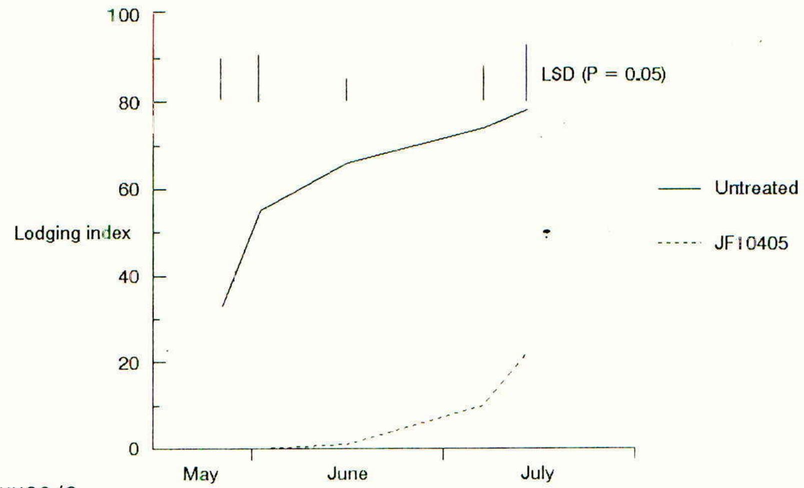


FIG. 1b.UK89/3.

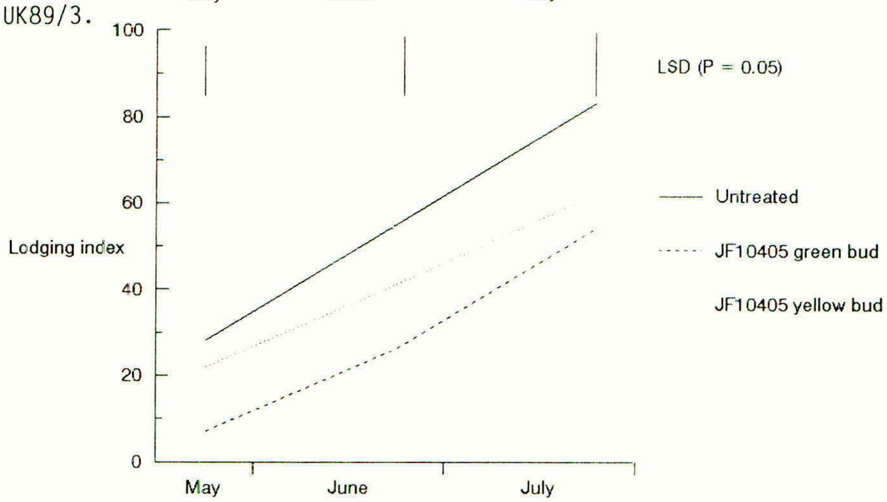


TABLE 3. Series 1. Effects of JF10405 applied at green bud on glucosinolate levels (μmol/g seed at 91 % d.m.).

	UK89/1	UK89/2	UK89/3
Untreated	23.7 a	29.4 a	33.2 a
1.25 l/ha GB	19.8 b	28.7 a	31.1 a
2.50 l/ha GB	18.9 c	32.0 a	31.4 a

Series 2

Moderate to severe lodging occurred in all three trials in mid-May. This was significantly reduced by all JF10405 treatments, and particularly so by those applied in spring in F89/1 (Table 4). Lodging was so severe in F89/2 that the trial was abandoned.

TABLE 4. Series 2. Comparison of effects of autumn (A) and spring (S) applications of JF10405 on early lodging. Data are shown as lodging index, where 0 = fully standing, 100 = completely flat.

	F89/1	F89/2	F89/3
Untreated	68 a	100 a	25 a
1.25 l/ha A	22 b	85 b	0 b
1.25 l/ha S	1 c	88 b	0 b
0.75 + 0.5 l/ha S	0 c	89 b	0 b

Effects on seed yield are shown in Table 5. In the experiment suffering the more severe early lodging, applications of JF10405 increased yield by up to 67% from the split spring treatment.

TABLE 5. Series 2. Comparison of effects of autumn and spring applications of JF10405 on seed yield (t/ha at 91% d.m.).

	F89/1	F89/3
Untreated	1.92 c	3.12 a
1.25 l/ha A	2.58 b	3.28 a
1.25 l/ha S	3.04 ab	3.13 a
0.75 + 0.5 l/ha S	3.21 a	3.20 a

Series 3

In early to mid-November all experiments were at approximately the 6 leaf stage, and the effects of JF10405 treatments applied two weeks previously on the height of the crop canopy and leaf expansion were clearly evident (Table 6). The retardation caused by the lower rate of JF10405 soon disappeared as rapid growth recommenced in spring, but the effects of the higher rate were rather more persistent. In experiments F90/1 and F90/3 a 10% reduction in canopy height was still present at the end of flowering. Lodging was negligable in all experiments in this series. There were no significant differences in yields between treatments in all experiments, except in F90/3 where the higher rate of JF10405 resulted in a significant ($P < 0.05$) depression in yield.

TABLE 6. Series 3. Effects of autumn applications of JF10405 on crop stand at the start of winter: visual assessment of composite of height and leaf area as % of untreated control (14 days after treatment).

	F90/1	F90/2	F90/3
Untreated	100 a	100 a	100 a
0.75 l/ha	69 b	76 b	82 b
1.25 l/ha	61 c	59 c	75 c

DISCUSSION

Baylis & Wright, (1990) and Baylis & Hutley-Bull, (1991) showed that good control of lodging by JF10405 may be associated with only small reductions in plant height at harvest. However, retardation from JF10405 is proportionately greater soon after application and declines thereafter (Baylis & Wright, 1990). In Series 1, much better control of lodging was apparent in UK89/1, where retardation from JF10405 was greater at the time of the onset of lodging, than in UK89/3 (Table 1, Figs 1a, 1b). In the latter experiment, however, although at the time of first lodging plots treated with JF10405 at 1.25 l/ha were not significantly shorter than the untreated control, marked reductions in lodging occurred. Except at harvest, this application rate was significantly more effective when applied at green bud than at yellow bud (Fig. 1b). It is conceivable that treatment with JF10405 may have helped to control lodging by increasing stem strength (Scarisbrick *et al*, (1985) noted increases in stem diameter from paclobutrazol treatment) or by stabilising the canopy through effects on branching (Baylis & Hutley-Bull, 1991).

In Series 2, the three trials provided a contrast in terms of the severity of the first lodging events (Table 4). In F89/1, although substantially reducing the degree of lodging, the autumn JF10405 treatment was significantly less effective than either the single or the split spring applications. However, in the other two trials where the lodging was milder or extremely severe, all treatment regimes gave similar levels of control. An absence of lodging in Series 3 made it impossible to judge the efficacy of its control by autumn applications of JF10405. It was clear, however, that when applied in October or early November substantial retardation was evident over winter.

Five experiments had substantial lodging (one was not harvested). Significant increases in yield were recorded in three trials. In F89/1, where early lodging was fairly severe (Table 4) a split spring application increased yield by 67% (Table 5). However, in the two Series 1 trials which lodged in a similar pattern (Figs. 1a, 1b), yields were only increased by JF10405 treatments in the trial in which there was, in fact, less effective control of lodging. Furthermore, in the other trial in this series, which did not lodge, yield was increased by both rates applied at the later timing, by up to 16% (Table 2). In Series 3, crops did not lodge, but in F90/3, where plots treated with the higher rate on 11 October still showed retardation at flowering, this treatment significantly reduced yield (P = 0.05).

Two things are, therefore, suggested in relation to the control of lodging and yield effects. Firstly, that yield increases may be obtained in the absence of lodging by favourably altering canopy structure and source-sink relationships. There are several reports of paclobutrazol and similar triazole retardants having such effects (Scarisbrick *et al*, 1985; Child *et al*, 1987; Luib *et al*, 1987). Secondly, as yield losses have clearly been shown to result from early lodging (Baylis & Wright, 1990), where this has not occurred following the control of such lodging by JF10405, some physiological depression of yield resulting from excessive retardation may have negated the physical benefits of a standing crop. Similarly, excessive or persistent retardation as observed from some autumn treatments may also depress yield.

Such excessive retardation may be avoided by selecting rates appropriate to specific application timings. Effective rates will be lower for autumn sprays due to the greater susceptibility of smaller plants. Similarly, applications of higher rates in late autumn, as temperatures decrease and the metabolism of residues of active ingredients in plants and soil presumably slows, may result in excessive retardation as growth recommences in spring. Autumn applications of JF10405 are, therefore, best regarded as discrete treatments aimed to improve the state of crops, particularly early drilled or rapidly developing ones, as they enter winter. The winters of 1988/89 and 1989/90 were extremely mild, so it was not possible to determine the effect of JF10405 on winter hardiness. Paclobutrazol has been observed to increase the cold tolerance of several species (eg. Fletcher, 1989) and chlormequat chloride has been reported to improve the winter hardiness of oilseed rape (Voskerusa, 1972) and other crops including winter wheat (Gusta *et al*, 1990).

Controlling lodging with JF10405 can result in improved seed quality by reducing levels of glucosinolates (Baylis & Hutley-Bull, 1991). Glucosinolate levels were only measured in selected treatments in Series 1, but significant reductions were recorded from both rates of JF10405 applied at green bud in UK89/1 (Table 3). Controlling lodging may have prevented the increased biosynthesis of glucosinolates. This may be associated with the stress of lodging in an analogous way to which it appears to be linked to attack by pests and diseases (Doughty *et al*, 1991).

Improvements in the yield and quality of oilseed rape are important benefits of controlling lodging. Also important, however, are the general aspects of crop management, eg. ease of pesticide application and harvesting operations, which can be seriously impaired by tall or lodged crops.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the help and expertise of ICI fields trials staff in the UK and France, and to thank Imperial Chemical Industries plc for allowing this work to be published.

REFERENCES

Baylis, A.D.; Wright, I.J.T. (1990) The effects of lodging and a paclobutrazol-chlormequat chloride mixture on the yield and quality of oilseed rape. *Annals of Applied Biology*, 116, 287-295.

Baylis, A.D.; Hutley-Bull, P.D. (1991) The effects of a paclobutrazol-based growth regulator on the yield, quality and ease of management of oilseed rape. *Annals of Applied Biology*, 118, 445-452.

Caldicott, J.J.B.; Nuttall, A.M. (1979) A method for the assessment of lodging in cereal crops. *Journal of the National Institute of Agricultural Botany*, 15, 88-91.

Child, R.D.; Butler, D.R.; Sims, I.M.; Johnson, W.; Thorn, M. (1987) Control of canopy structure in oilseed rape with growth retardants and consequences for yield. In: *Plant Growth Regulators for Agricultural and Amenity Use*, A.F. Hawkins (Ed.), *BCPC Monograph No. 36*, Thornton Heath : BCBC Publications, pp 21-35.

Dalziel, J.; Lawrence, D.K. (1984). Biochemical and biological effects of kaurene oxidase inhibitors such as paclobutrazol. In: *Biochemical Aspects of Synthetic and Naturally Occurring Plant Growth Regulators*, R. Menhenett and D.K. Lawrence (Eds), *British Plant Growth Regulator Group Monograph No. 11*, Wantage : BPGRG, pp 43-57.

Dicks, J.W. (1980). Modes of action of growth retardants. In: *Recent Developments in the Use of Plant Growth Retardants*, D.R. Clifford and J.R. Lenton (Eds.), *Joint Society for Chemical Industry/British Plant Growth Regulator Group Monograph No.4*, Wantage : BPGRG, pp 1-14.

Doughty, K.J.; Porter, A.R.J.; Morton, A.M.; Kiddle, G.; Bock, C.H.; Wallsgrove, R. (1991) Variation in the glucosinolate content of oilseed rape (*Brassica napus*, L.) leaves. II. Response to infection by *Alternaria brassicae* (Berk.) Sacc. *Annals of Applied Biology*, 118, 469-477.

Fletcher, R.A. (1989) Strategies for improvement of triazole induced stress protection in wheat seedlings. *Plant Physiology*, 89, supplement 2, 42.

Gusta, L.V.; O'Connor, B.J.; Reaney M.J.T. (1990) The effects of growth regulators on the winter survival of winter wheat. In: *Plant Growth Substances 1988*, R.P. Pharis & S.B. Rood (Eds), Springer-Verlag: Berlin, pp 531-536.

Jenkins, P.D.; Leitch, M.H. (1986) Effects of sowing date on the growth and yield of winter oil-seed rape. *Journal of Agricultural Science, Cambridge*, 107, 405-420.

Lord, K.A.; Wheeler, A.W. (1981) Uptake and movement of ^{14}C-chlormequat chloride applied to leaves of barley and wheat. *Journal of Experimental Botany*, 32, 599-603.

Luib, M.; Kohle, H.; Hoppner, P.; Rademacher, W. (1987). Further results with BAS 111 04W, a new growth regulator for use in oilseed rape. In: *Plant Growth Regulators for Agricultural and Amenity Use*, A.F. Hawkins (Ed.), *BCPC Monograph No. 36*, Thornton Heath : BCBC Publications, pp 37-43.

Lutman, P.J.W.; Dixon, F.L. (1987) The effect of drilling date on the growth and yield of oil-seed rape. *Journal of Agricultural Science, Cambridge*, 108, 195-200.

Mendham, N.J.; Shipway, P.A.; Scott, R.K. (1981) The effects of delayed sowing and weather on growth development and yield of winter oil-seed rape (*Brassica napus*). *Journal of Agricultural Science, Cambridge*, 96, 389-416.

Scarisbrick, D.H.; Daniels, R.W.; Noor Rawi, A.B. (1982) The effect of chlormequat on the yield and yield components of oil-seed rape. *Journal of Agricultural Science, Cambridge*, 99, 453-456.

Scarisbrick, D.H.; Addo-Quaye, A.; Daniels, R.W. & Mahamud, B.S. (1985) The effect of paclobutrazol on plant height and yield of oil-seed rape (*Brassica napus*). *Journal of Agricultural Science, Cambridge*, 105, 605-612.

Voskerusa, J. (1972) The influence of CCC on the DM production, overwintering, yield and quality of winter rape. *Zeitschrift fur Acker- und Pflanzenbau*, 135, 169-177.

THE BIO-DYNAMICS OF VOLUNTEER POTATO POPULATIONS.

MELVYN F ASKEW

Agricultural Development & Advisory Service, Woodthorne, Wolverhampton, WV6 8TQ, UK.

ABSTRACT

Volunteer potatoes can arise from field leavings after potato harvest and/or seedlings from true potato seed, according to cultivar. They have become an increasing problem associated with close potato cropping and unusually mild winters in recent years. Many different crops are contaminated by volunteer potatoes and yield and quality losses accrue. Such volunteers also increase pest and disease risks for planted potato crops. Whilst frost can kill volunteer potatoes the high numbers that remain after potato harvest and the cultivation techniques used to establish subsequent crops frequently cause populations to persist at quite high level. Multiplication of volunteer potatoes is significantly affected by the crop in which the volunteers occur; vigorous, early established winter cereals minimise multiplication. In the absence of agro-chemicals cultural techniques alone are unlikely to control volunteer potatoes given the mild climatic conditions of recent winters. Agro-chemicals vary in their efficacy, frequently only producing limited control but in good conditions linked with good cultural techniques provide the best option to give effective volunteer control.

INTRODUCTION

The precise incidence of volunteer potatoes (Solanum tuberosum) is not formally recorded in published literature although it is agreed in most European Community countries, amongst acknowledged potato experts, that volunteer potatoes are an increasing problem in potato crops themselves and in a wide range of other crops. Consensus view report these latter to include sugar beet; dried and vining peas; Faba and Phaseolus beans; oilseed rape; cereals; herbage seed crops; carrots; onions and a number of high value vegetable crops, especially horticultural brassicas.

The reason for this increase in volunteer potato problems is composite, involving intensified potato production on a reduced number of holdings; increased use of mechanical harvesting systems; a series of relatively mild winters, and, probably, in some countries like the United Kingdom, the popularity of cultivars with the potential to produce copious amounts of true potato seed (TPS) (Lawson, 1983).

WHY ARE VOLUNTEER POTATOES A PROBLEM?

It has generally been accepted that significant populations of any other plant species in a cultivated crop stand are undesirable since yield losses are likely to result from plant competition and quality losses can be caused by them.

Clearly volunteer potatoes have this capability too but in addition have several other detrimental effects:

i) Disease carry over: Volunteer potatoes act as a source of potato viruses and of late blight. They may also act as a carryover for soil-borne disease.

ii) Pest carry over: In Europe potato cyst nematode populations (PCN) are at least maintained and probably multiplied 2-3 fold by PCN-susceptible volunteers (Ouden, 1967). In countries where Colorado Beetle (Leptinotarsa decemlineata) is endemic unsprayed potato volunteers act as a pest reservoir.

iii) They cause problems associated with harvesting, where green haulm from potato volunteers adversely affects mechanical harvesters of various crops.

iv) Increased costs: Farmers in The Netherlands are thought to have spent up to 50 hours per ha in mechanically weeding some crops to remove volunteer potatoes. Alternatively herbicides used specifically to control volunteer potatoes are an additional cost, albeit variable according to crop. Similarly, increased costs accrue from extra roguing required in potato seed crops.

SOURCE OF VOLUNTEER POTATOES

Lutman (1977) reported that up to 370,000 tubers per ha may remain after potato crop harvest in the United Kingdom, but Lumkes (1974) reported up to 460,000 tubers per ha in The Netherlands. Also Lawson (1983, 1986) indicated that many popular potato cultivars grown in the United Kingdom produced viable TPS, this in turn producing tuber-bearing seedlings. TPS numbers vary but could reach 249×10^6 per ha. Lawson (1983) and Lawson and Wiseman (1983) showed this TPS to be viable for at least 8 years in field conditions; its lifetime viability has not been reported.

POPULATION DYNAMICS OF VOLUNTEER POTATOES

Natural losses of volunteer potatoes occur because of freezing, mechanical damage caused by farm machinery, and pests or wild animals which eat or destroy potato tubers. Lumkes and Sijtsma (1972) found potato tubers to be killed by 50 accumulated degree centigrade frosts below -2°C. Lumkes also reported temperatures between 0°C and -2°C had no freezing effect upon tubers. Hence numbers of volunteers were unaffected by, for example, 50 hours exposure to -1°C.

There is obviously advantage therefore in leaving volunteer potatoes untouched after harvest of the crop, presuming this to be a practical proposition in any area where frost occurs. In the United Kingdom the trend towards growing potatoes on lighter soils does not necessarily aid leaving potatoes to be frosted since evidence shows that early establishment of cereals, the usual sequel to potatoes, is generally advantageous on such soils (unpublished data, ADAS).

Evidence in United Kingdom (Minhinick, 1990) at 3 different sites characteristic of large areas of maincrop potato production, showed that in the period 1959 to 1988 soil temperatures at 30cm deep never reached 0°C and at 10cm deep there were only 9 occasions in toto over all sites where temperatures reached -4°C or less for 48 hours. This represents approximately 0.03% of days; freezing alone is unreliable as a control measure. This conflicts slightly with data reported by Perombelon (1975) and Lutman (1977).

ESTIMATES OF POPULATION CHANGES OVER A ROTATION

Potatoes in the United Kingdom and northern Europe are frequently grown on a 5 year rotation or even less. Estimates of population change given below are calculated on the basis of 5 years using initial populations of tubers remaining after harvest as quoted by authors above.

Year 1

Initial population per ha

370,000 (Lutman) 460,000 (Lumkes)

Frost free: no cultivation post-harvest

370,000 460,000

Severe frost: no cultivation post-harvest

Virtually nil

Frost: ploughing post-harvest (frost losses only)

247,900 306,667

Estimates of residual potato volunteer populations after the first winter are therefore nil to 460,000 tubers per ha but in years without severe frost or when ploughing post-potato harvest has occurred are likely to be approximately 248,000 to 460,000 at maximum. Whilst critical data cannot be found this level of volunteer potatoes does not appear to be found in agricultural practice. Clearly therefore further losses are therefore occurring. It has been reported that mechanical damage to tubers caused either deliberately or by accident during seed bed preparations has caused up to 30% of tubers to become infected with fungi or bacteria and to rot thereafter. If this damage scenario were to be repeated on the above figures populations would be reduced to at minimum 166,160 and at maximum 308,200.

Year 2

Volunteer potatoes vary in their degree of reproductive ability according to the host crop in which they are growing. Personal experience has indicated that vigorous, early-established crops with a long growing season (eg winter wheat) have a much greater effect in reducing populations than do less competitive spring established crops (eg dried peas; sugar beet). This is supported by both British and Dutch reports (Lumkes, 1974; Perombelon, 1975; Sijtsma, 1977). Precise data vary but generally multiplication rates of volunteer potatoes are in the order of two-fold in winter wheat to approximately four-fold in sugar beet.

On that basis the volunteer population that would arise from year 1 figures above, discounting the immeasurable effects of potato pests or diseases on volunteers, but allowing for damage caused by cultivations for crop establishment is likely to be between 332,320 and 1,232,800. Since sugar beet is unlikely to be the first successor crop after potatoes it is more realistic to work on the former figure.

Years 3 and 4

In the absence of severe frosts and presuming a cereal as vigorous as wheat to be grown in these years, volunteer potato populations could increase to 178,272 tubers per ha just prior to the next potato crop, presuming 30% loss per annum caused by cultivation. This is approximately 4 times a normal planted potato population.

Agro-chemicals to control volunteer potatoes

Choice of active ingredient and conditions of use affect success of volunteer potato control with agro-chemicals. The highest level of volunteer control reported in the literature occurred where maleic hydrazide was used pre-potato harvest (Peddie et al, 1986). However, frequently, herbicides alone have only given limited control of volunteer potatoes (eg Ogilvy et al, 1989). In the case reported by Peddie et al a combination of maleic hydrazide and cultural techniques could have resulted in a population of only 36,000 volunteer potato tubers per ha remaining when the next potato crop was planted. This again presumes no severe frost and only one agrochemical used on volunteers. If 30% control of volunteers was achieved in each of years 2, 3 and 4 by use of other agrochemical whilst multiplication of volunteers was minimised and reductions in initial populations in each season made by cultivations for crop establishment, approximately 6,000 tubers per ha would remain at planting of the next potato crop. Such a population is much lower than would actually be planted in potato production but is still significant.

A STRATEGY FOR REDUCTION OF VOLUNTEER POTATO POPULATIONS

i) Minimise field leavings after potato harvest.

ii) Minimise use of ploughing post-potato harvest and maximise use of tined cultivations to keep volunteer potatoes in the surface soil, preferably at depths of less than 10cm if this is practicable. This will expose volunteer tubers to any frost and cause maximum mechanical damage to them.

iii) Maximise the planting/sowing of early vigorous crops like winter wheat after potatoes.

iv) Choose agrochemicals for weed control in crops carefully to minimise cost and maximise potato control. Do not overlook the possibility of using materials in the original potato crop itself which would reduce germination or emergence of volunteer potatoes.

REFERENCES

Lawson, H.M. (1983) True potato seeds as arable weeds. Potato Research, 26, 237-246.

Lawson, H.M. (1986) Potato seedlings: a review of the current situation. Aspects of Applied Biology, 13, 187-194.

Lawson, H.M.; Wiseman, J.S. (1983) Weed control in crop rotations. Report of Scottish Crop Research Institute for 1982, 157.

Lumkes, L.M. (1974) Research on control of volunteer potatoes in The Netherlands. Proceedings of 12th British Weed Control Conference, 1031-1040.

Lumkes, L.M.; Sijtsma, R. (1972) Mogelijkhaden aardappelen als onkruid in volgewassen te voorkomen en/of te bestridgen. Landbouw en Plantenziekten, Number 1, 17-36.

Lutman, P.J.W. (1977) Investigations into some aspects of the biology of potatoes as weeds. Weed Research, 17, 123-132.

Minhinick, J. (1990) Unpublished data calculated from the archives of The Met Office, 1959-1988.

Ogilvy, S.E.; Cleal, R.A.E.; Rogers-Lewis, D.S. (1989) The control of potato volunteers in cereal crops. Proceedings of the British Crop Protection Conference - Weeds - 1989, 205-207.

Ouden, H. dem. (1967) The influence of volunteer potato plants in oats on populations of *Heterodera rostochiensis*. Nematologica, 13, 325-335.

Peddie, S.A.; Bartlett, D.H.; Tavener, P.B. (1986) Preharvest application of potassium maleic hydrazide to potatoes to suppress volunteers in succeeding crops. Aspects of Applied Biology, 13, 219-225.

Perombelon, M.C.M. (1975) Observations on the survival of potato groundkeepers in Scotland. Potato Research, 18, 205-215.

Sijtsma, R. (1977) Competition by the crop. Proceedings of European Association for Potato Research Symposium "Control of volunteer potato plants", Paper 15.

GLUFOSINATE-AMMONIUM - A NEW HERBICIDE AND DESICCANT FOR POTATOES

R.T. HEWSON, I.A. BLACK

Hoechst UK Limited, Agriculture Division, East Winch Hall, East Winch, King's Lynn, Norfolk, PE32 1HN

ABSTRACT

Glufosinate-ammonium is a new total herbicide and desiccant, and as such is well-suited to use in the potato crop. A high level of weed control was obtained with the product applied at 10-40% crop emergence either alone or, where subsequent weed emergence occurred, in tank mixture with a residual herbicide. Following scorch to potato shoots present at application, new ones quickly emerged and the plants grew away normally. The yield, storage and growth of daughter tubers was unaffected by treatment. Glufosinate-ammonium, applied as a single spray around the onset of senescence, was also effective as a desiccant of both the leaves and stems of potatoes. This included late-maturing varieties where diquat often gave only partial desiccation, due to regrowth. No differences were observed between the 150 and 200 g/l formulations of glufosinate-ammonium either as a herbicide or desiccant.

INTRODUCTION

Glufosinate-ammonium is a non-selective, post-emergence herbicide and desiccant developed under the code number Hoe 39866 by Hoechst AG (Schwerdtle et al, 1981). The free acid of this compound was discovered earlier as a microbial metabolite and given the name phosphinothricin (Bayer et al, 1972). This chemical, and the monoammonium salt, glufosinate-ammonium, are potent inhibitors of glutamine synthetase in higher plants. This inhibition results in rapid accumulation of ammonia, a strong phytotoxin, which leads to the death of plant cells (Wild & Manderscheid, 1983). Glufosinate-ammonium has a short half-life in soil and is rapidly degraded to carbon dioxide, ammonia, methane and phosphate (Götz et al, 1983). There is no uptake by plants from the soil. Glufosinate-ammonium has many potential uses and results are presented in this paper on the product (®Challenge) applied as an early post-emergence herbicide and also as a desiccant in potatoes.

MATERIALS AND METHODS

General

Trials were carried out over a ten-year period between 1980 and 1990 on commercial crops located in the main potato-growing areas of England and Scotland. They covered a wide range of agronomic and climatic conditions, and crop varieties. The trial design was a randomised block with three (efficacy trials) or four (crop tolerance studies) replicates. Plot size was three or four crop rows by 7.5-10 m in length.

Applications were made, using a Van der Weij 'AZO' precision plot sprayer at a pressure of 250 kPa and water volume of 200 l/ha (weed control) or 300-400 l/ha (desiccation), through eight F800 or F110/040/3 (BCPC nozzle code) flat fan nozzles spaced 25 cm apart on a 2m spray boom.

Glufosinate-ammonium was applied either as a 150 or 200 g/l soluble concentrate formulation. In 1988 and 1989 both formulations were included in the same trials. All trials received standard fungicide and insecticide treatments according to the rest of the field.

Weed control

Glufosinate-ammonium was applied in comparison to paraquat (Gramoxone 100, 200 g/l aqueous concentrate), both at 3.0 l/ha from 10-40% emergence of the potatoes. In fifty-seven trials the products were applied alone and in fifty-nine trials in tank mixture with monolinuron (Arresin, 200 g/l EC) at the recommended rate according to the soil type. In nine of these trials tank mixtures with linuron (Afalon, 450 g/l SC), metribuzin (Sencorex, 70% WP) and terbuthylazine + terbutryn (Opogard 500 FW, 500 g/l SC) were also included and compared with the formulated product containing monolinuron and paraquat (Gramonol 5, 154 + 110 g/l SC).

In crop tolerance studies, conducted in weed-free situations, double rates of glufosinate-ammonium were also included. Crop yield was assessed by hand lifting tubers from the middle two rows of each plot. One hundred seed-size tubers per plot from some of these trials were stored over winter at 5°C in the dark until February and then chitted at 15°C until April, when they were grown on after sprout length measurements had been carried out. Assessments of the grown-on crops were also made.

In all trials crop vigour assessments were made at regular intervals after treatment using a percentage scale (0 = as untreated, 100 = total kill). Weed control was assessed by counting individual species in a number of random quadrats in each plot 1-2 and 3-5 weeks after application.

Desiccation

Glufosinate-ammoniunm was applied at 3.0 l/ha in comparision to diquat (Reglone 200 g/l soluble concentrate) at 4.0 l/ha, around the onset of senescence of the potatoes. A total of forty trials was carried out of which eight were on late-maturing varieties (Cara and Drayton). In a further five trials, the effect of tank-mixing blight fungicides (fentin acetate + maneb, Brestan 60 70% WP; mancozeb, Dithane 945, 80% WP; fentin hydroxide, Du-Ter 50 47.5% WP) with glufosinate-ammonium was investigated.

Visual assessments of leaf and stem senescence were made separately on a percentage scale. Samples of 100 tubers per plot were saved and assessed for internal vascular browning and skin set.

RESULTS

Weed control

Both glufosinate-ammonium and paraquat applied alone gave very good control of a range of weeds in potatoes when assessed 1-2 weeks after

TABLE 1. Percentage control of weeds in potatoes with glufosinate-ammonium, paraquat and tank-mixes with monolinuron.

Species	1-2 weeks after application						3-5 weeks after application					
	G	P	(No.)	G+M	P+M	(No.)	G	P	(No.)	G+M	P+M	(No.)
Capsella bursa-pastoris	100	100	(1)	100	100	(1)	90	80	(5)	100	100	(4)
Chenopodium album	98	99	(10)	99	99	(12)	90	88	(24)	98	98	(24)
Galeopsis tetrahit	-	-	(-)	100	100	(2)	97	88	(5)	100	99	(7)
Lamium purpureum	-	-	(-)	99	100	(2)	92	91	(6)	98	98	(4)
Polygonum aviculare	100	100	(3)	100	100	(7)	80	81	(8)	96	97	(14)
Polygonum convolvulus	100	100	(1)	100	100	(3)	98	97	(8)	99	98	(11)
Polygonum persicaria	92	93	(4)	100	100	(4)	94	87	(14)	97	97	(16)
Stellaria media	97	98	(6)	100	100	(7)	97	95	(20)	99	98	(25)
Tripleurospermum maritimum spp. inodorum	100	100	(3)	100	100	(6)	80	81	(9)	99	99	(21)
Urtica urens	-	-	(-)	96	99	(2)	80	82	(7)	95	96	(12)
Veronica persica	100	100	(3)	100	100	(5)	88	90	(13)	96	97	(10)
All dicot spp.	97	98	(23)	99	99	(29)	90	88	(57)	98	98	(59)
Poa annua	100	100	(3)	100	100	(4)	88	87	(8)	98	99	(13)

G = glufosinate P = paraquat M = monolinuron - = no data (No.) = No. of trials

TABLE 2. Weed control and crop tolerance of tank-mixtures of glufosinate-ammonium with residual herbicides (mean of 9 trials).

Treatment	Mean (range) % crop vigour (days after application) 6-10	23-30	% Weed control 23-30 days after application
glufosinate-ammonium + monolinuron	4 (0-8)	1 (0-5)	99
" + linuron	5 (0-15)	1 (0-5)	98
" + terbuthylazine + terbutryn	5 (0-15)	1 (0-7)	98
" + metribuzin	4 (0-12)	2 (0-11)	98
monolinuron + paraquat formulated product	6 (0-13)	1 (0-4)	98

TABLE 3. Effect of time of application of glufosinate-ammonium and paraquat (from 10-60% crop emergence) on crop tolerance (mean of 10 trials).

		% Crop vigour (days after application)																Relative yield (untreated = 100)			
		2-4				5-8				9-18				19-29							
Treatment	l/ha	10	20	40	60	10	20	40	60	10	20	40	60	10	20	40	60	10	20	40	60
glufosinate)	3.0	1	1	5	8	2	4	7	-	2	4	5	9	1	2	5	-	100	97	99	99
-ammonium)	6.0	2	1	6	11	3	5	10	-	3	5	6	8	1	3	7	-	100	97	100	91
paraquat	3.0	4	4	14	16	6	13	21	-	4	6	7	11	1	4	7	-	98	90	93	93

- = No data

application (Table 1). By 3-5 weeks the overall level of control was lower. This was due to late emergence of weeds in some of the trials.

With paraquat there was also regrowth of some treated weeds, notably Polygonum persicaria. The addition of monolinuron as a tank-mix with glufosinate-ammonium, or paraquat, maintained a high level of control of all species. Other residual herbicides applied in tank mixtures with glufosinate-ammonium were also safe and effective (Table 2).

When the two formulations of glufosinate-ammonium were compared identical levels of 97% weed control were obtained 3-5 weeks after application and no differences in crop vigour were seen.

In the crop tolerance studies plants took longer to recover from the scorch or kill of emerged shoots the later the application was delayed (Table 3). Also, paraquat had a noticeably greater effect on the crop than did glufosinate-ammonium. When the latter was applied up to 40% crop emergence there was rapid emergence of new potato shoots, the plants grew away normally and yield was unaffected. With later applications recovery was delayed and with the double rate of glufosinate-ammonium applied at 60% crop emergence there was a slight reduction in yield.

No differences in sprout length prior to planting, emergence or growth were obtained when tubers from potatoes treated at 35-45% emergence, with glufosinate-ammonium or paraquat, in one season were retained and grown on the next.

Desiccation

On varieties which matured normally, glufosinate-ammonium gave very good desiccation of the leaves and stems by about two and three weeks after application, respectively. Initially, diquat desiccated the crop more rapidly but the end result was very similar to that obtained with glufosinate-ammonium (Table 4).

On late maturing varieties, desiccation with glufosinate-ammonium was slightly slower than on 'normal' varieties but a single spray still achieved an effective result on both leaves and stems. Diquat, however, gave only partial desiccation, particularly of the stems, since regrowth occurred in some of the trials.

The addition of a blight spray in tank mix with glufosinate-ammonium did not adversely affect the speed or completeness of desiccation (Table 5).

There were no differences in the speed or overall level of desiccation between the 200 and 150 g/l formulations, both giving 87% and 100% leaf desiccation after 1 and 2 weeks, respectively, and 47%, 83% and 98% stem desiccation after 1, 2 and 3 weeks, respectively.

In most of the trials vascular browning did not occur or could only be detected at trace levels. Where it did occur in appreciable amounts it often tended to be greater in tubers from diquat-treated plots than from the glufosinate-ammonium treatment or untreated control (Table 6). No differences in skin set between the different treatments were observed.

TABLE 4. Progress of desiccation of potato haulm with glufosinate-ammonium and diquat.

Treatment	% Desiccation (days after application) Leaf 3-5	6-9	13-17	20-25	Stem 3-5	6-9	13-17	20-25
Normal varieties (mean of 32 trials)								
glufosinate-ammonium	51	91	99	100	9	44	85	98
diquat	77	96	98	99	23	53	89	98
untreated	7	16	35	56	2	6	18	26
Late-maturing varieties (mean of 8 trials)								
glufosinate-ammonium	22	84	96	99	3	18	55	94
diquat	49	88	88	89	6	34	55	79
untreated	4	13	24	28	0	3	11	19

TABLE 5. Effect of tank mixtures of potato blight fungicides with glufosinate-ammonium on desiccation of potato haulm. (Mean of 5 trials).

Treatment	% Desiccation (days after application) Leaf 5-7	13-14	18-21	Stem 5-7	13-14	18-21
glufosinate-ammonium	93	97	100	67	93	98
+ fentin acetate + maneb	96	99	100	70	95	98
+ mancozeb	96	96	100	69	94	98
+ fentin hydroxide	95	98	100	70	95	98
Untreated control	33	52	58	20	23	36

TABLE 6. Effect of glufosinate-ammonium and diquat on vascular browning

Variety and Location	% brown ring glufosinate-ammonium	diquat	untreated	L.S.D. (P<0.05)
Desiree, Lincs.	3	18	9	7.7
Desiree, Cambs.	3	7	2	4.5
Estima, Norfolk	0	8	0	4.7
Desiree, Suffolk	2	15	5	5.3
Maris Piper, Cambs.	0	3	0	1.3
Cara, Cambs.	5	4	7	6.2
Drayton, Cambs.	7	23	6	2.4
Desiree, Lincs.	17	20	18	5.5

DISCUSSION

When applied as a herbicide early post-emergence of potatoes, glufosinate-ammonium gave a high level of control of a wide range of annual grass and broad-leaf weeds. Although Viola arvensis did not occur frequently, or at high densities, in these trials it appeared to be the only species which was not effectively controlled. This was also the conclusion from trials carried out in West Germany (Stübler, 1988).

Glufosinate-ammonium has no residual activity and so weeds emerging after application will not be controlled. Where this pattern of emergence is expected a tank mixture with a residual herbicide can be made, ensuring longer-term control. In Swedish trials, Hallgren (1989) also found that mixtures with linuron and other residual herbicides were very effective, giving yield increases up to 41%. In many situations, however, because application can be delayed up to 40% crop emergence, treatment with glufosinate-ammonium alone will be effective.

In common with other total herbicides, glufosinate-ammonium will adversely affect any emerged potato shoots present at application. However, new ones quickly emerge and, provided application is not delayed beyond 40% crop emergence, the subsequent crop growth and yield are unaffected. Lawson et al (1985) also reported that yield was not affected when application was made at 20-35% emergence but a significant yield loss occurred when treatment was delayed until 80% emergence.

In the present trials and in those reported by Stübler (1988) paraquat had a greater and more prolonged effect on the potato shoots than did glufosinate-ammonium. Although Lawson et al (1985) reported the opposite effect, haulm weights taken from the glufosinate-ammonium and paraquat treatments when the tubers were of seed size generally did not show any difference. As in the present trials, Lawson et al (1985) confirmed that yield, and also the performance of daughter tubers in store and grown on in the field, were unaffected. Applied as a herbicide glufosinate-ammonium clearly does not affect tuber sprouting.

Glufosinate-ammonium was also effective as a potato desiccant. Beckerson et al (1985) in Canada and Stübler (1988) in West Germany also achieved high levels of desiccation, with similar rates of active ingredient, within 2-3 weeks of application. As in the present work, Stübler (1988) noted that the speed of action of glufosinate-ammonium was initially slower compared to diquat, but that desiccation was thereafter maintained at a high level, whereas regrowth often occurred with diquat, particularly on late-maturing varieties. He also mentioned that there were no negative influences on storage quality, yield or taste of potatoes desiccated with glufosinate-ammonium. Although diquat tended to increase the incidence of brown ring in these trials, this did not occur with glufosinate-ammonium, even under dry conditions.

In tank mixtures glufosinate-ammonium was compatible with blight fungicides and it is sound practice to include a blight spray with the final desiccant to prevent blight spores infecting the tubers while the haulm is senescing.

No differences were observed between the two formulations of glufosinate-ammonium when used either as a herbicide or as a desiccant.

ACKNOWLEDGEMENTS

The authors thank the many farmers who kindly provided trials sites and their colleagues within the Technical Department of Hoechst Agriculture Division for technical assistance.

REFERENCES

Beckerson, D.W.; Townsend, D.; Hay, G. (1985) Potato top growth desiccation using Hoe 39866. Research Report of the Expert Committee on Weeds Eastern Canada Section Meeting October 29-31, 1985, 412.

Bayer, E.; Gugel, K.H.; Hägele, K.; Hagenmaier, H.; Jessipow, S.; König, W.A.; Zähner, H. (1972) Phosphinothricin und Phosphinothricyl-Alanyl-Alanin. Helvetica Chimica Acta, **55**, 224-239.

Hallgren, E. (1989) Official evaluations of new herbicides for control of dicot weeds in cereals and oilseeds and for control of dicots and grassweeds in potatoes, peas and field beans. Experimental Report of the Swedish Department of Crop Production Science.

Lawson, H.M.; Wiseman, J.S.; Davies, D.H.K.; Richards, M.C. (1985) Tolerance of potato crops to glufosinate-ammonium applied as an early post-emergence herbicide. British Crop Protection Conference - Weeds 1985, **3**, 811-817.

Götz, W.; Dorn, E.; Ebert, E.; Leist, K-H.; Köcher, H. (1983). Hoe 39866, a new non-selective herbicide: chemical and toxicological properties - mode of action and metabolism. Asian Pacific Weed Science Society, 9th Conference, Manila, 1983, 401-404.

Schwerdtle, F.; Bieringer, H.; Finke, M. (1981) Hoe 39866 - ein neues nicht selektives Blattherbizid. Zeitschrift für Pflanzenkraukheiten und Pflanzenschutz, Souderheft **IX** 1981, 431-440.

Stübler, H. (1988) Herbicidal systems for potato cultivation in West Germany under the special consideration of glufosinate. Weed Science Society of Japan, 27th meeting 1988, 29-30.

Wild, A.; Manderscheid, R. (1983) The effect of phosphinothricin on assimilation of ammonia in plants. Presentation at the International Workshop on Mode of Action of Herbicides in Photosynthesis, Wageningen, August 7-9, 1983.

EVALUATION OF GLUFOSINATE-AMMONIUM AS A HAULM DESICCANT FOR SEED POTATO CROPS

H. M. LAWSON, J. S. WISEMAN

Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA

ABSTRACT

Glufosinate-ammonium at 0.6 or 1.2 kg a.i./ha desiccated foliage of potato cv. Maris Piper effectively, more rapidly than metoxuron but more slowly than diquat. Desiccant treatments had no adverse effect on tuber yield in comparison with that on hand-cut plots. Daughter tubers from plants treated with glufosinate-ammonium at either rate showed severe sprout suppression when chitted in store and considerable mortality when planted in the field. No such effects followed haulm treatment with recommended rates of diquat or metoxuron. The recently-approved rate of glufosinate-ammonium for use as a potato desiccant in the United Kingdom is only 0.45 kg a.i./ha, but the results of these experiments emphasise the need to restrict this use to ware crops.

INTRODUCTION

New potato haulm desiccants which are safe and pleasant to handle, work rapidly, have a minimum of weather-related restrictions and do not translocate to daughter tubers are required by growers of seed potato crops. All the currently available products have one or more drawbacks which restrict their usage. Results of an examination of the tolerance of the potato crop to glufosinate-ammonium applied as an early post-emergence herbicide were reported previously (Lawson & Wiseman, 1985). In another series of experiments its potential as a desiccant for seed potato crops was evaluated.

MATERIALS AND METHODS

Experiments were carried out on crops of cv. Maris Piper at Invergowrie. Plots consisted of two rows each of 27 tubers, plus shared guard rows. Tubers (35-45 mm diameter) were planted at 30 cm spacing in rows 71 cm apart on 20 April 1982 (Experiment I) or 25 April 1983 (Experiment II). Treatments were arranged in randomised blocks and replicated three times. There were two hand-cut plots in each block. Applications of insecticides and fungicides were made for protection against aphids and potato blight. The desiccant treatments used were diquat (200 g/l e.c.; Reglone; ICI Agrochemicals) at 0.8 kg a.i./ha, metoxuron (800 g/kg w.p.; Deftor; PBI Ltd) at 2.0 kg a.i./ha and glufosinate-ammonium (200 g/l a.c.; HOE 39866; Hoechst UK Ltd) at 0.6 or 1.2 kg a.i./ha. They were applied in fine sunny weather, with no rain for at least 48 hours. Application was by Oxford Precision Sprayer at 250 kPa pressure in 300 litres water/ha.

Desiccation and cutting treatments were imposed when the majority of daughter tubers were of seed size (16 August 1982 and 24 August 1983), i.e. before the onset of natural senescence. The crops were harvested on 25 September (Experiment I) and 18 October (Experiment II), graded for size and assessed for injury and disease incidence. Seed-size tubers (20/plot) were stored in trays until mid February in the dark at 2°C and then submitted to a chitting regime of 12 hours light and 12 hours dark, both at 15°C, until mid-April. Records were taken of sprout numbers, growth and weight. Ten chitted and ten unchitted daughter tubers from Experiment I were replanted on 25 April 1983, 30 cm apart in single row plots. With Experiment II, replanted in the same way on 27 April 1984, a further ten tubers from which the chitted sprouts had been removed were included. In both experiments the chitting sub-treatments were randomised within main plots. All plots were given standard management and were harvested in mid-August.

RESULTS

In both experiments diquat gave the most rapid desiccation of haulm, followed by the two rates of glufosinate-ammonium, between which there was little to choose (Tables 1 and 2). Metoxuron was very much slower-acting. All treatments eventually gave virtually complete desiccation, with the exception of metoxuron in Experiment II. There was no regrowth.

Harvest records showed no adverse effects of spray treatments on yield or size grade distribution in comparison with hand-cut plots. Disease and internal vascular browning were not a problem in either crop. Dry matter percentages were always higher on desiccated plots than on hand-cut plots, sometimes significantly so, but there were no consistent differences between the desiccant treatments.

A high proportion of the sprouts produced by daughter tubers from plots treated with glufosinate-ammonium showed delayed growth and malformation. The worst affected eyes produced cauliflower-like rosettes rather than shoots and had not recovered by the time of replanting. Others did eventually manage to produce normal shoots. These effects occurred with both rates, although slightly more severely at the higher rate, and were reflected in chitting records (Tables 3 and 4). The other desiccants showed no adverse effects in comparison with the hand-cut standard.

Although replanted daughter tubers grew differently according to whether they had been planted with sprouts on or off, or without chitting, there was no interaction with the original haulm removal treatments. Accordingly, for brevity, the replant records are presented as the means across sprout preparation sub-treatments. There were no differences in emergence, growth or yield between tubers from plots originally treated with diquat or metoxuron and those from hand-cut plots. However, 13% and 37% of the tubers from plots treated with glufosinate-ammonium at 0.6 and 1.2 kg a.i./ha respectively failed to produce above-ground shoots in Experiment I. The corresponding figures for Experiment II were 34% and 80%. With plots treated at the lower rate of this chemical, the numbers and weights of tubers produced by emerged plants were not significantly different from those on hand-cut plots, despite delayed emergence and early growth. At the higher rate, tuber yield per plant was increased in Experiment I, while tuber numbers were greatly increased in Experiment II.

DISCUSSION

Glufosinate-ammonium at either rate was slower-acting than diquat, but all three treatments gave very effective desiccation of dense, actively-

TABLE 1. Experiment I First year records

Treatment of haulm	Dose kg a.i. /ha	Desiccation scores (0-10)≠			Harvest records (F. wt tubers t/ha)			Tuber % dry matter
		18 Aug	31 Aug	14 Sept	Total	Seed 35-55 mm	Ware >55 mm	
Cut					45.3	28.5	14.0	22.9
S.E. mean ±					1.98	0.99	2.36	
Diquat	0.8	5.2	9.7	9.9	46.4	30.4	13.8	23.7*
Metoxuron	2.0	1.8	6.7	9.5	50.2	30.3	17.2	23.6
Glufosinate-ammonium	0.6	1.0	9.0	9.8	46.8	27.8	16.7	23.7*
Glufosinate-ammonium	1.2	0.8	9.6	9.9	46.4	29.4	14.7	23.3
S.E. mean ±					2.80	1.40	3.34	0.29

TABLE 2. Experiment II First year records

Treatment of haulm	Dose kg a.i. /ha	Desiccation scores (0-10)≠			Harvest records (F. wt tubers t/ha)			Tuber % dry matter
		26 Aug	9 Sept	13 Oct	Total	Seed 35-55 mm	Ware >55 mm	
Cut					31.1	24.3	1.8	23.4
S.E. mean ±					1.99	1.61	0.94	0.43
Diquat	0.8	7.7	9.0	9.0	30.2	23.8	0.8	24.6
Metoxuron	2.0	0	1.5	5.2	34.0	27.3	2.3	24.1
Glufosinate-ammonium	0.6	1.5	9.6	9.8	28.1	22.0	0.6	25.0*
Glufosinate-ammonium	1.2	1.8	9.9	9.9	28.8	22.4	0.6	25.6**
S.E. mean ±					2.81	2.28	1.33	0.60

*,** - Significantly different from Cut at the 5% or 1% level
≠ - 0 - unaffected, 10 = 100% desiccation

TABLE 3. Experiment I Chitting and second year records

Treatment of parent crop haulm		Chitting records 15 April		Harvest records/ 20 plant unit 11 August		
	Dose kg a.i. /ha	Mean length mm/ longest sprout	Wt. sprouts g/20 tubers	No. plants surviving	No. tubers /live plant	Wt. tubers g/live plant
Cut		13.8	44.7	20.0	24.1	602
S.E. mean ±		0.67	2.33	0.64	1.13	42.9
Diquat	0.8	13.3	44.1	20.0	24.5	562
Metoxuron	2.0	13.7	44.7	20.0	25.4	644
Glufosinate-ammonium	0.6	8.3***	19.2***	17.4*	24.4	547
Glufosinate-ammonium	1.2	7.4***	17.3***	12.6***	22.7	766*
S.E. mean ±		0.95	3.29	0.90	1.60	60.6

TABLE 4. Experiment II Chitting and second year records

Treatment of parent crop haulm		Chitting records 27 April		Harvest records/ 30 plant unit 13 August		
	Dose kg a.i. /ha	Mean length mm/ longest sprout	Wt. sprouts g/20 tubers	No. plants surviving	No. tubers /live plant	Wt. tubers g/live plant
Cut		33.2	30.7	30.0	18.6	887
S.E. mean ±		1.48	1.51	1.26	1.26	78.5
Diquat	0.8	29.5	29.4	30.0	18.6	833
Metoxuron	2.0	33.6	29.5	30.0	19.1	968
Glufosinate-ammonium	0.6	7.9***	8.9***	20.0***	20.4	624
Glufosinate-ammonium	1.2	6.2***	6.4***	6.0***	27.6***	1012
S.E. mean ±		2.10	2.13	1.80	1.80	111.0

*,**,*** - significantly different from Cut at the 5%, 1% or 0.1% level

growing haulm, without regrowth. Metoxuron normally desiccates very slowly (Jeffrey, 1981); in commercial practice it is recommended only for use on ware crops and applied when the crop is already senescing. No desiccant treatment had any adverse effect on tuber yield. Diquat and metoxuron did not influence the behaviour of daughter tubers in store or when replanted, but glufosinate-ammonium had major adverse effects on sprout development during chitting and on field performance thereafter. This was due to inhibition of normal shoot development, tissue proliferation and failure of injured shoots to emerge from the soil. Some plants emerged and grew normally, while others emerged late with numerous stems and made relatively poor growth. On plots with many gaps, healthy plants showed greater productivity in the absence of competition.

Tests on stored tubers from trials by the Scottish Agricultural College, Aberdeen (W. Addison, personal communication) and by ADAS, Cambridge (D. T. Eagle, personal communication) produced similar results. The malformed sprouts, shoot proliferation and poor subsequent field performance are similar to the reported effects of contamination of seed potato crops with glyphosate (Eagle, 1984).

Haas & Muller (1987) studied pathways of translocation of glufosinate-ammonium in a number of weed species. They found that while there was translocation of the active ingredient within leaves and shoots, relatively little was transported unchanged to the root system. The metabolites are apparently non-phytotoxic and it was suggested that differences in species susceptibility to the chemical were related to its speed of breakdown within the plant. It is clear, however, that glufosinate-ammonium can translocate rapidly and extensively from potato haulm into daughter tubers in late summer, in sufficient quantity to have severe consequences for their future productivity as seed tubers. It also translocates to the fruiting part of the potato plant, as was demonstrated in a subsidiary trial on potato berries harvested from Experiment I (Lawson & Wiseman, 1991) where the higher rate reduced the viability of true seeds.

Glufosinate-ammonium has no residual activity and breaks down rapidly in the soil (Goetz et al., 1983). The density of haulm present at the time of treatment would in any case have severely restricted the amount of chemical reaching the soil. It is therefore highly unlikely that uptake from the soil would have been a major source of contamination of the tubers. The reason for the more severe effects of glufosinate-ammonium on daughter tubers in the second experiment than in the first is not known, but it suggests a degree of seasonal variability which reduces the safety margin for any given dose.

The formulation of glufosinate-ammonium marketed in the United Kingdom in 1991 is recommended for use as a potato haulm desiccant at 0.45 kg a.i./ha (Anon., 1991), i.e. three-quarters of the lower rate examined in these trials. Usage on seed potato crops is excluded. Despite the lower dose, our experiments indicate that this is a very necessary restriction. Growers should be made aware of the reasons for the restriction so that they are not tempted to treat seed crops or to retain seed-size tubers from a ware crop for replanting.

Finally, it would be worth examining the potential of the various uses of glufosinate-ammonium between crops and in crops, including the potato, to contribute to the control of volunteer potatoes in the rotation.

ACKNOWLEDGEMENTS

This work was funded by the Scottish Office Agricultural and Fisheries Department. Hoechst UK Ltd supplied experimental samples of HOE 39866.

REFERENCES

Anon., (1991) Challenge: Desiccation. Technical leaflet Hoechst UK Ltd, King's Lynn, Norfolk, 10 pp.

Eagle, D.T. (1984) Beware of seed contamination with herbicides. Arable Farming, 11, 47-48.

Goetz, W.; Dorn, E.; Ebert, E.; Leist, K-H.; Kocher, H. (1983) HOE 39866 - a new non-selective herbicide : chemical and toxicological properties - mode of action and metabolism. Asian Pacific Weed Science Society, 9th Conference, Manila, 401-404.

Haas, P.; Muller, F. (1987) Behaviour of glufosinate-ammonium in weeds. Proceedings 1987 British Crop Protection Conference - Weeds, 3, 1075-1082.

Jeffrey, R.A. (1981) Deftor - a new haulm desiccant. Proceedings Crop Protection in Northern Britain 1981, Dundee, 143-148.

Lawson, H.M.; Wiseman, J.S. (1985) Tolerance of potato crops to glufosinate-ammonium applied as an early post-emergence herbicide. Proceedings 1985 British Crop Protection Conference - Weeds, 3, 811-817.

Lawson, H.M.; Wiseman, J.S. (1991) Effects of potato haulm desiccants on the viability of true potato seeds. Tests of Agrochemicals and Cultivars No. 12 (Annals of Applied Biology 118 Supplement), 128-129.

THE EFFECTS OF CONTAMINATION OF A POTATO CROP WITH A THIFENSULFURON-METHYL/ METSULFURON-METHYL HERBICIDE

H.M. LAWSON, J.S. WISEMAN

Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA

ABSTRACT

A potato crop, cv. Maris Piper, was sprayed with a thifensulfuron-methyl/metsulfuron-methyl cereal herbicide to simulate contamination by spray drift or by spray tank residues. Rates from 12% to 0.5% of the spring barley dose were applied to foliage at tuber initiation (Date I) or at the onset of tuber bulking (Date II). The earlier treatment applied at 9 or 12% of the field dose delayed canopy development, but otherwise foliar symptoms were transient. Rates of 6% and above applied at Date I reduced total yield, but a major effect of treatment at both dates, particularly the later one, was cracking and malformation of tubers, which severely reduced saleable yield. The 10% threshold for saleable yield loss for both dates of application was 2.1% of the barley dose. The response was very steep thereafter, reaching 75% loss at a 3.9% (Date I) or a 5.9% (Date II) dose. Stored tubers chitted normally, but sprout weights were reduced in tubers from some higher rate plots.

INTRODUCTION

Accidental contamination of potato crops by cereal herbicides, due either to spray drift or to inadequately cleaned spray tanks, has become an increasing problem in recent years. Modern herbicides can be applied safely to cereal crops at relatively late stages of growth, which increases the risk of drift to emerged potato shoots. They are also biologically active at much lower rates of active ingredient than their predecessors. This demands very rigorous spray tank hygiene if damage to subsequently-treated sensitive crops is to be avoided. A preliminary trial at SCRI (Lawson et al., 1990) showed that simulated contamination of a potato crop with a thifensulfuron-methyl/ metsulfuron-methyl herbicide formulation caused severe cracking and malformation of daughter tubers. This experiment was carried out a) to quantify the effects of dose on foliage and yield and on storage and chitting of daughter tubers, b) to estimate the threshold for economic effect on the crop.

MATERIALS AND METHODS

The experiment was carried out at Invergowrie on a crop of cv. Maris Piper. Plots consisted of two rows each of 30 tubers, plus shared guard rows. Tubers (35-45 mm grade) were planted on 12 April 1990 at 30 cm spacing in rows 75 cm apart. Treatments were arranged in randomised blocks and replicated three times. The cereal herbicide formulation Harmony M (a water-dispersable granule containing 68% w/w thifensulfuron-methyl + 7% w/w metsulfuron-methyl, Dupont UK Ltd) was applied at rates of 12, 9, 6, 3, 1.5, 0.5 and 0% of the field dose for weed control in spring barley (45 g a.i./ha). Application was

TABLE 1. Contamination of a potato crop with thifensulfuron-methyl + metsulfuron-methyl - 1990 field and harvest records

% of spring cereal field dose (45 g a.i. total/ha) applied	% crop canopy cover 9 July		Tuber production records: Total yield t/ha		Total no. /plot		Saleable# yield t/ha		Saleable# no./plot	
	I##	II##	I	II	I	II	I	II	I	II
12	75.4***	87.0	44.4***	59.1	496**	735***	8.4***	8.2***	112***	106***
9	75.4***	85.3	46.2***	55.0	458***	596	11.1***	8.2***	126***	100***
6	87.4	90.5	53.0*	55.2	495***	601	10.8***	14.9***	115***	169***
3	90.7	91.9	55.7	56.3	467***	549	29.7***	42.4***	248***	402***
1.5	88.4	90.1	57.0	58.8	497**	538	52.8	56.9	439**	491
0.5	88.3	91.6	56.1	56.6	508**	557	54.4	54.0	476	502
0	92.2		57.9		573		54.0		509	
S.E. mean ±	2.82		1.43		14.6		1.87		16.5	
Sig. of effect										
Dose (linear)	+++		+++		+++		+++		+++	
Date	++		+++		+++		+		+++	
Interaction	+		+++		+++		NS		++	

*,**,*** - Significantly different from Untreated (0) at the 5%, 1% or 0.1% level.
+,++,+++ - Effect significant at the 5%, 1% or 0.1% level. NS - Not significant.
- Free from cracking or malformation and >34 mm diameter.
- Application dates I (14 June, 35% canopy) and II (26 June, 75% canopy).

by Oxford Precision Sprayer at 300 kPa pressure and a volume of 500 litres of water/ha. Treatment was made at tuber initiation (14 June, 35% crop canopy cover - Date I) or at the onset of tuber bulking (26 June, 75% crop canopy cover - Date II).

Terbutryn + terbuthylazine (Opogard 500FW) and paraquat (Gramoxone 100) were applied to all plots for weed control pre-emergence of the crop at standard commercial rates. Neither treatment had any visible adverse effect on emergence or early growth of the crop. Routine applications of insecticides and fungicides were made when necessary for protection against aphids and potato blight. The crop was not irrigated.

Effects on crop foliage were recorded and potato haulm was cut and weighed on 23 August. Tubers were harvested on 11 October, graded for size and assessed for injury and disease incidence. Twenty 35-55 mm tubers were stored in trays until mid-February in the dark at 2°C and then submitted to a chitting regime of 12 hours light and 12 hours dark, both at 15°C, until late May. Records were taken of sprout numbers, growth and weight.

RESULTS

All treatments caused transient yellowing and slight incurving of young foliage. The symptoms were not severe and declined with dose. They were much less evident in plots treated at Date II. Within two weeks after application they had effectively disappeared from all plots. A visible check to growth occurred on plots treated at Date I at 9 and 12% of the barley dose; on all other plots canopy cover development was slightly, but only temporarily delayed (Table 1). By the date of haulm removal, there were no differences in the fresh weights of foliage recorded across the experiment.

Total yield of tubers indicated no adverse effect of treatment at Date II, but reduced yields on plots treated on Date I at the 6, 9 and 12% rates. Total numbers of tubers were significantly reduced on all plots treated at Date I in comparison with untreated plots, with little evidence of a negative dose response. In contrast, plots treated at Date II showed a significant positive response to dose, particularly at the highest application rate, where numbers were 28% greater than on untreated plots (Table 1).

Mechanical injury during lifting was minor. However, cracking and malformation of tubers was recorded on all treated plots, other than at the lowest (0.5%) dose. The severity of effect and the proportion of tubers affected increased with dose, but were worse on plots treated at the higher rates on Date II than on Date I. Injury was recorded in tubers of all sizes. The cracks had virtually all healed by harvest time and there was no evidence of rotting or of disease incidence in affected tubers in the field or during storage. All tubers were assessed for injury on a 1-5 scale (1 = undamaged; 5 = severely cracked or misshapen). Tubers scored 2 or above on the scale were considered unsuitable for sale for ware or seed purposes. Yield of saleable tubers was determined for each plot, i.e. tubers free from chemical or mechanical injury and over 34 mm in diameter. Results showed major reductions in total yield in comparison with untreated plots at rates of 3% of the barley dose and above, for both dates of application (Table 1). The response to the 3% dose was much less severe on plots treated at Date II than at Date I, but differences between the two dates were not significant at higher doses.

TABLE 2. Contamination of seed potatoes with thifensulfuron-methyl + metsulfuron-methyl - 1991 chitting records on daughter tubers (20/plot)

% of spring cereal field dose (45 g a.i. total/ha) applied	Mean score for tuber damage (1-5)#		Mean no. sprouts/tuber 13 March		Mean length longest sprout mm/tuber 13 March		Mean length longest sprout mm/tuber 30 May		Wt. sprouts g/20 tubers 1 June	
	I##	II##	I	II	I	II	I	II	I	II
12	1.68**	3.33***	5.33	5.75	10.2*	11.9	118	139	80.8*	95.7
9	1.70**	3.13***	5.45	5.42	10.7	11.6	121	103*	78.4*	86.3*
6	1.85**	2.30***	5.73	5.26	10.3*	11.8	128	126	84.4*	92.5
3	1.60*	1.43	6.03	5.52	10.6	11.7	161	152	103.3	96.7
1.5	1.13	1.18	5.68	5.68	11.8	12.1	146	145	102.1	99.8
0.5	1.08	1.05	5.62	5.62	11.5	11.3	134	122	97.1	87.7
0	1.03		5.65		11.5		158		109.2	
S.E. mean ±	0.145		0.253		0.33		13.2		7.19	
Sig. of effect										
Dose (linear)	+++		NS		NS		NS		NS	
Date	+++		NS		+++		NS		NS	
Interaction	+++		NS		++		NS		NS	

*,**,*** - Significantly different from Untreated (0) at the 5%, 1% or 0.1% level.
+,++,+++ - Effect significant at the 5%, 1% or 0.1% level. NS - Not significant.
- 1 = undamaged, 5 = severely cracked and misshapen.
- Application dates I (14 June, 35% canopy) and II (26 June, 75% canopy).

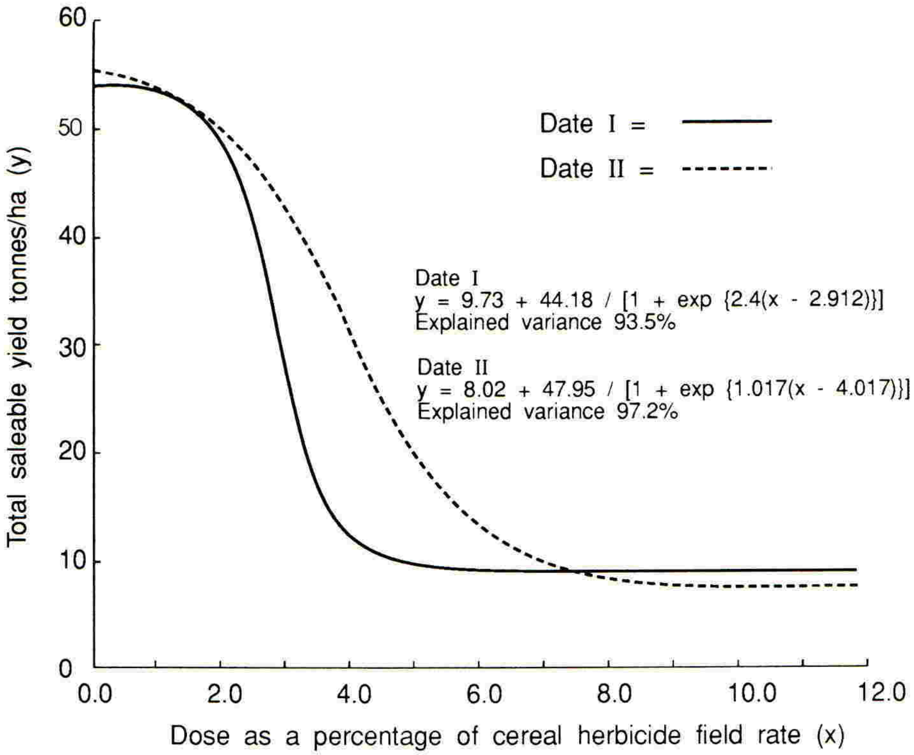


Fig. 1 The relationship between saleable yield of tubers and herbicide dose at the two dates of application (fitted curves).

Saleable numbers of potatoes showed very similar results to those for tuber weights; the additional total numbers produced at high rates at Date II were mostly excluded due to cracking and malformation. Effects on saleable numbers at Date I extended lower down the dose scale than in equivalent yield records. With both saleable yield and saleable numbers the major factor identified in treatment effects in the analysis of variance was a linear response to dose. However, further examination disclosed that sigmoid curves gave by far the best fit to both sets of data for each application date. These curves allowed more precise estimation of the effects of particular rates of application. Fig.1 shows the response curve for saleable yield.

Twenty tubers in the 35-55 mm size grade, selected at random from each plot for storage and chitting, were scored for injury and numbered so that subsequent records could be traced back to individual tubers. Tubers from the Date I application showed significant injury scores from the 3% rate upwards, in comparison with untreated plots; for Date II the equivalent rate was 6% (Table 2). However, the severity of symptoms was considerably greater at the higher rates from Date II application. Sprout numbers recorded on 13 March showed no effects of experimental treatment. There was no visible evidence of stunting, discoloration, or malformation of sprouts, even on the most severely injured tubers. However, mean length of the longest sprout per tuber was slightly less on tubers from plots treated on Date I at the higher rates of application than on those from untreated plots. There was no such effect on tubers from equivalent plots treated at Date II.

Replanting of daughter tubers was not within the remit of this project, but the tubers were kept growing in store until early June, to allow any potential problems to develop. Lengths of longest sprouts on 30 May were very variable and there was no clear evidence of differences related to experimental treatments. However, when all sprouts were rubbed off and weighed, it was found that the adverse effects of higher doses at Date I noted on 13 March were still present. Using data from individual tubers, attempts were made to relate differences in sprout records to tuber injury scores. No significant correlations were found, although malformed tubers weighed less than unaffected tubers within the 35-55 mm grade, due largely to the effects of the cracks.

DISCUSSION

The sulfonylurea herbicides stop cell division by inhibiting biosynthesis of the essential amino-acids valine and isoleucine (Sionis et al., 1985). They are rapidly absorbed by plant foliage and roots and translocated throughout the plant. There is ample published data on their activity on annual weed species and their tolerance by cereal crops (e.g. Espir, 1987; Palm et al., 1980), but very little on the sensitivity of the potato crop to accidental uptake.

In the earlier experiment (Lawson et al., 1990) application of this herbicide formulation at 10% of the barley field dose to cv. Maris Piper at 40% crop canopy cover caused only transient foliar symptoms, slightly delayed canopy development, increased tuber numbers, reduced overall yield of ware size potatoes and caused cracking and malformation of nearly 50% of the harvested tubers. A 1% dose produced results no different from those on untreated control plots. These findings match those for similar rates in the current experiment, given the slightly different timings of application.

It appears unlikely that the presence or severity of foliar symptoms can be used to predict yield loss. The foliar effects were transient and, especially at the lower rates, would be difficult to detect in a commercial crop in the absence of adjacent untreated rows. Leaf yellowing and incurving can also be caused by other agents. Furthermore, foliar effects were more severe following the earlier application than the later one, while tuber malformation showed the opposite trend.

Overall yield was more affected by the earlier application, while cracking and malformation of tubers was more severe following the later application. The combination of these factors resulted in similar dose response curves for yield of saleable tubers, despite variations in tuber numbers and degree of injury. However the adverse response to doses between 2 and 7 % of the barley dose was more severe for Date I than for Date II application (Fig. 1). Taking a 5% reduction in saleable yield as the threshold for crop injury, the fitted curves indicate that this point would have been reached in the current experiment at doses of 1.8 and 1.5% of the barley rate of the herbicide applied at Date I and Date II respectively. For both dates a 10% reduction would have been recorded at a 2.1% dose. Possibly more important, however, is the steepness of the slopes thereafter, indicating the severe penalties to be incurred for relatively small increases in levels of contamination. A 50% loss of yield would have been recorded at either 3.1 or 4.4% of the field dose, depending on the date of treatment, while the relevant values for a 75% loss were 3.9 and 5.9%.

Reasons for the differing effects of application date and dose on tuber development require more detailed investigation. However, the dates of application were very close and the overall effects of contamination were not markedly different other than in the slope of the response in the middle dose range. Of more immediate interest is the identification of a reliable threshold above which unacceptable yield loss may be expected. The results indicate that this threshold, at least for cv. Maris Piper, lies between 1 and 2% of the field dose for weed control in barley. Both spray drift and inadequately cleaned spray tanks could deliver this level of contamination, equivalent to only 0.45-0.90 g a.i./ha, to a potato crop. Further work may be needed to establish similar information for other cultivars.

Cracked and malformed tubers produced similar numbers of sprouts to those on tubers from untreated plots, regardless of dose. Sprouts emerged at the same time and showed no growth abnormalities. Early differences in sprout lengths at the higher application rates at Date I were reflected in lower weights of sprouts removed at the end of the trial, but were not related to intensity of tuber malformation. These tubers were not replanted, but some of those from the earlier experiment were (Lawson et al., 1990). Tubers from plots treated at 10% of the barley rate were softer and more wrinkled at planting time than those from untreated plots, but they produced foliage without malformation, which grew normally. Daughter tubers were unblemished, but yield was only 87% of that of tubers from untreated plots, due mainly to a reduction in numbers. It seems likely that the reduced sprout weights recorded at higher rates in the current trial indicated similar potential yield loss. Poorer performance by these tubers in both experiments is thought to have been due more to lower tuber weight than to continued presence of the herbicide, although the relationship between dose, timing and sprout behaviour is not clear.

Overall, the results demonstrate very clearly the need for every possible precaution to be taken to prevent accidental contamination of potato crops by this herbicide formulation. Potential risks associated with the other sulfonylurea herbicide formulations currently marketed in the United Kingdom need similar assessment.

The imidazolinones, a herbicide group with similar properties to the sulfonylureas, are reported from the United States to be even more phytotoxic to potatoes (Eberlein & Schaffers, 1990). Thus, formulations of this group available in Europe as cereal herbicides should also be investigated.

ACKNOWLEDGEMENTS

This work was funded by a grant from the Potato Marketing Board. Thanks are due to Mrs G. Wright and to Gina Macphail for technical assistance.

REFERENCES

Eberlein, C.V.; Schaffers, W.C. (1990) Potato response to simulated drift of imidazolinone herbicides. Abstracts 11th Triennial Conference of the European Association for Potato Research, Edinburgh, 412-413.

Espir, A.F. (1987) Weed control in spring barley in Scotland with thiameturon-methyl plus metsulfuron-methyl. Proceedings Crop Protection in Northern Britain 1987, Dundee, 31-34.

Lawson H.M.; Wiseman J.S.; Wright, G.McN. (1990) Tolerance of seed potato to contamination with two sulfonylurea herbicides. Tests of Agrochemicals and Cultivars, No.11. (Annals of Applied Biology 116 Supplement), 76-77.

Palm H.L.; Riggleman J.D.; Allison, D.A. (1980) Worldwide review of the new cereal herbicide - DPX 4189. Proceedings 1980 British Crop Protection Conference - Weeds, **1**, 1-6.

Sionis, S.D.; Drobny, H.G.; Lefebvre, P.; Upstone, M.E. (1985) DPX-M6316- A new sulfonylurea cereal herbicide. Proceedings 1985 British Crop Protection Conference - Weeds, **1**, 49-54.

EVALUATION OF MONOCARBAMIDE DIHYDROGENSULPHATE FOR CANE VIGOUR CONTROL IN RASPBERRY

H. M. LAWSON, J. S. WISEMAN

Scottish Crop Research Institute, Invergowrie, Dundee, DD2 5DA

ABSTRACT

Monocarbamide dihydrogensulphate was evaluated as a potential raspberry cane desiccant at a range of dilutions with water in a total spray volume of 1000 l/treated ha. Effective desiccation of young canes was not possible without adverse effects on fruit yield, due to direct injury to fruiting cane bases. The addition of a wetter and/or a doubling of spray volume to achieve better spray coverage increased both the efficiency of desiccation and the incidence of injury to fruiting canes. Under UK conditions this chemical is not sufficiently selective for cane vigour control in raspberries.

INTRODUCTION

Until banned in 1987, dinoseb-in-oil was widely used in the United Kingdom to remove first-flush vegetative canes in vigorous raspberry cultivars, e.g. Glen Clova. Since then, an evaluation programme for potential alternative treatments has been under way at SCRI (Lawson & Wiseman, 1989). Screening trials in Washington, USA in 1987 and 1988 (R. Norton, personal communication) indicated that monocarbamide dihydrogensulphate (MCDS) could desiccate raspberry canes and that the manufacturer was interested in further development. Thus, this material was included in our 1989 trial series.

MATERIALS AND METHODS

The experiments were carried out at Invergowrie in established plantations of Glen Clova (Experiment I) and Glen Moy (Experiment II). Plots consisted of single rows, 9 m long and 2 m apart, each comprising 12 raspberry stools. Plots were arranged in randomised blocks with three replicates, each containing two untreated and two hand-cut plots as controls. Records were taken of cane and fruit production, efficiency of desiccation and injury to fruiting canes. The plantation was managed without soil cultivation; alley suckers were removed mechanically twice between April and July.

MCDS (as Enquik, an 81.6% a.i. liquid formulation, Unocal Chemicals Inc.) 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 when the young canes were 10-20 cm tall. In Experiment I treatments were made with the formulated product either neat, 50:50 with water, or 25:75 with water, all at 1000 l/sprayed ha (220 kPa pressure). In Experiment II the 50:50 and 25:75 concentrations were applied either alone or with the addition of a non-ionic wetter (Agral, ICI Agrochemicals) at 0.125% v/v of the final solution. Spray volume was either 1000 or 2000 l/treated ha (220 or 400 kPa pressure). Treatments were applied to Experiment I on 3 May and to Experiment II on 19 May in calm, cool conditions, with no rain for 72 hours thereafter.

TABLE 1. Experiment I - Glen Clova. Desiccation and cane injury records

Treatments applied 3 May to canes 10-20 cm tall		First flush canes Desiccation scores (0-10)#		Fruiting canes Post-harvest records (2 peeled stems/stool)	
Concentration of product in water###	Spray volume l/ha	5 May	18 May	% surface area necrotic##	% cane no. dead
Cut by hand		-	-	22.7	12.5
Untreated		-	-	-	-
S.E. mean ±		-	-	4.58	6.79
25% v/v	1000	5.0	5.2	52.7**	25.0
50% v/v	1000	5.0	6.0	71.0***	45.8**
100% v/v	1000	7.7	9.3	90.2***	79.2***
S.E. mean ±		0.31	0.41	6.47	9.63

TABLE 2. Experiment I - Glen Clova. Fruiting cane records

Treatment applied 3 May to canes 10-20 cm tall		Yield of fruit			
Concentration of product in water###	Spray volume l/ha	Total yield t/ha	Berries /metre of fruiting cane (g)	Overall mean berry wt (g)	Fruiting lateral wilt score/plot 2 June (0-10)
Cut by hand		9.32	54.4	2.49	0
Untreated		9.30	52.2	2.50	0
S.E. mean ±		0.540	2.48	0.150	-
25% v/v	1000	7.82	51.6	2.20	0
50% v/v	1000	8.66	50.6	2.51	1.7
100% v/v	1000	4.84***	37.4***	2.17	4.7
S.E. mean ±		0.764	3.50	0.212	-

,* - Significantly different from Cut by hand at the 1% or 0.1% level.
\# - 0 = no effect, 10 = leaves and stems completely desiccated.
\## - Assessed in zone 15-30 cm above ground level.
\### - 81.6% a.i. monocarbamide dihydrogensulphate.

RESULTS

Experiment I

The 100% concentration of MCDS gave very rapid and comprehensive desiccation of leaves and stems of young vegetative canes (Table 1). The lower concentrations were effective on leaves, but not stems and failed to reach an acceptable score for overall control (at least 7 out of 10). Wilting of laterals occurred at the top of fruiting canes 2-3 weeks after treatment at the 100% and 50% concentrations, especially on relatively weak fruiting canes. The effects was particularly severe on plots treated with the 100% concentration (Table 2). The loss in yield of fruit compared with hand-cut plots was due mainly to fewer berries. Diluted concentrations did not produce significant yield reductions, nor were there any differences between untreated and hand-cut plots.

However, fruiting canes senesced early on sprayed plots, particularly those treated at the 100% concentration, where many canes had died before the completion of fruit harvest. An assessment of direct injury to the basal areas of fruiting canes was made a few weeks after the end of harvest. Canes (24/plot) were cut out, peeled and scored for surface necrosis in the sprayed zone. Completely dead canes were also recorded. The results showed increasing necrosis and early cane death as the concentration of chemical increased (Table 1). This contrasted with the much lower incidence of injury and slower speed of senescence on unsprayed plots.

Plots treated with the 100% concentration produced a healthy second flush of canes which grew at a similar rate to those on hand-cut plots (Table 3). Most first-flush canes on plots treated at the 25% concentration recovered, while with the 50% concentration there was a mixture of both types. End-of-year records reflected these responses, but there were more canes on plots treated at the 25% concentration than on any other plots.

Experiment II

As in Experiment I, desiccation by either spray concentration at 1000 litres/treated ha without wetter was inadequate (Table 4). The addition of wetter improved performance, boosting the desiccation score for the 50% concentration to above the acceptable threshold. Doubling the spray volume improved the performance of both concentrations in the absence of wetter, but desiccation on these plots was still inadequate. The combination of wetter and higher volume produced a very high level of desiccation with both concentrations. Treatment with the 50% concentration at high volume plus wetter resulted in subsequent injury to fruiting laterals (Table 5). Some lateral wilting was also noted with the 25% concentration plus wetter at 2000 l/ha and with the 50% concentration at this volume without wetter.

Yield results showed that doubling the spray volume increased phytotoxicity to the fruiting canes with both concentrations. The addition of wetter also increased the likelihood of yield loss, which was due to reductions in both size and numbers of berries. Hand-cut plots produced bigger but slightly fewer berries than untreated plots, but overall yield was not significantly improved.

Basal cane injury and cane death were again substantial in fruiting canes from plots treated with the more effective spray combinations (Table 5),

TABLE 3. Experiment I - Glen Clova. Vegetative cane records

Treatments applied 3 May to canes 10-20 cm tall		Young cane records /plot 12 June		Total production /plot, December	
Concentration of product in water#	Spray volume l/ha	No. live canes	Mean ht (cm)	No. canes	Mean ht (cm)
Cut by hand		159	41.9	131	104
Untreated		199**	78.0***	154	132***
S.E. mean ±		9.7	2.93	10.6	3.8
25% v/v	1000	208**	73.3***	175*	121*
50% v/v	1000	206**	57.3**	146	116
100% v/v	1000	153	37.7	147	107
S. E. mean ±		13.7	4.15	15.0	5.3

*,**,*** - Significantly different from Cut by hand at the 5%, 1% or 0.1% level.
- 81.6% a.i. monocarbamide dihydrogensulphate.

although less severe than in Experiment I for comparable treatments.

On plots showing effective desiccation, most of the canes present at the end of the year were second-flush canes and production was comparable to that on hand-cut plots (Table 4). On other sprayed plots there was a mixture of first and second-flush canes. On those plots treated with the 25% concentration at the lower volume without wetter, there was again evidence of increased cane numbers at the end of the year.

DISCUSSION

The success of the cane vigour control technique as practised in the United Kingdom depends on a high percentage kill of first-flush canes and the rapid production of a healthy second flush, which provides the following year's fruiting canes. Only one such treatment is possible per year. There must also be no adverse effect on the current season's fruiting canes. Our experiments suggest that treatment of young canes with MCDS at any dilution in a spray volume of 1000 l/treated ha is unable to give adequate desiccation at a concentration which is not also phytotoxic to the fruiting canes. This spray volume was the one recommended commercially for use with dinoseb-in-oil and ensures thorough spray coverage (Lawson & Wiseman, 1981). Increasing the spray volume and/or adding a wetter enhanced desiccation, but only at the expense of crop safety. It seems unlikely, therefore, that a suitable recommendation can be developed for UK conditions.

In Oregon, DeFrancesco et al., (1989) found that MCDS (plus wetter) applied to young canes 10-15 cm tall at a range of dilutions gave less than

TABLE 4. Experiment II - Glen Moy. Vegetative cane records

Treatments applied 19 May to canes 10-20 cm tall		Desiccation scores (0-10)#		Young cane records/plot 7 June		Total production /plot, December	
Concentration of product in water###	Spray volume l/ha##	23 May	7 June	No. live canes	Mean ht (cm)	No. canes	Mean ht (cm)
Cut by hand		-	-	53	7.5	114	97
Untreated		-	-	168***	34.8***	132	110**
S.E. mean ±		-	-	10.0	1.27	7.6	2.8
25% v/v	1000+	4.3	5.3	137***	22.6***	146*	106
	1000-	3.7	3.8	186***	29.6***	174***	112**
	2000+	7.5	8.7	63	14.1**	106	102
	2000-	5.2	6.0	150***	22.7***	152**	100
50% v/v	1000+	6.8	7.7	124***	18.7***	147*	98
	1000-	5.0	6.0	120***	20.3***	136	118***
	2000+	8.0	8.8	42	11.6	98	90
	2000-	5.7	6.8	106**	17.8***	152**	102
S.E. mean ±		0.52	0.42	14.2	1.79	10.7	3.9
Sig. of effect							
Concentration		++	+++	+++	+++	NS	NS
Volume		+++	+++	+++	+++	++	+++
Adjuvant		+++	+++	+++	+++	+++	++

*,**,*** - Significantly different from Cut by hand at the 5%, 1% or 0.1% level.
+,++,+++ - Effect significant at the 5%, 1% or 0.1% level.
- 0 = no effect, 10 = leaves and stems completely desiccated. ## = ± adjuvant.
- 81.6% a.i. monocarbamide dihydrogensulphate.

TABLE 5. Experiment II - Glen Moy. Fruiting cane records

Treatment applied 19 May to canes 10-20 cm tall		Yield of fruit			Cane injury		
						Post harvest records on peeled stems (2/stool)	
Concentration of product in water###	Spray volume l/ha##	Total yield t/ha	Berries /metre of fruiting cane (g)	Overall mean berry wt (g)	Fruiting lateral wilt score /plot 16 June (0-10)	% surface area necrotic#	% cane no. dead
Cut by hand		10.9	42.5	3.91	0	37.0	13.8
Untreated		9.9	45.2	3.45*	0	-	-
S.E. mean ±		0.40	2.33	0.123	-	4.54	5.13
25% v/v	1000+	9.8	40.6	3.76	0	43.3	19.6
	1000-	10.8	45.5	3.63	0	36.8	7.1
	2000+	8.5**	34.1*	3.74	0.8	67.5***	37.5*
	2000-	8.7**	42.8	3.23**	0	41.7	17.9
50% v/v	1000+	9.3*	44.6	3.21**	0	55.8*	23.8
	1000-	10.4	42.0	3.78	0	37.2	11.3
	2000+	6.7***	30.6**	2.99***	2.8	82.2***	63.8***
	2000-	8.4***	39.5	3.88**	0.4	61.1**	32.1*
S.E. mean ±		0.57	3.30	0.173	-	6.42	7.25
Sig. of effect							
Concentration		NS	NS	+		+	+
Volume		+++	++	+		+++	+++
Adjuvant		+	+	NS		+++	+++

*,**,*** - Significantly different from Cut by hand at the 5%, 1% or 0.1% level. ## = ± adjuvant.
+,++,+++ - Effect significant at the 5%, 1% or 0.1 level. # = Assessed in zone 25-30 cm above ground level.
- 81.6% a.i. monocarbamide dihydrogensulphate.

commercially acceptable cane suppression and was inferior to the standard dinoseb treatment. Kaufman et al., (1990) tested MCDS (plus wetter) at various heights of young canes and with single or repeated treatments. Earlier applications gave better results than later ones and two applications one week apart were better than either a single treatment, or two applied two weeks apart. Only the best treatments were comparable to adjacent plots treated with dinoseb. In a trial in Washington, using 1:1 or 2:1 ratios of MCDS to water, applied to young canes 15-30 cm tall, desiccation scores were below the acceptable threshold (Howard et al., 1989). However in the absence of any other purely contact alternative to dinoseb in the United States, work continues to find ways of utilising this chemical for cane desiccation.

There were no reports of injury to fruiting canes in the US trials, even with repeated applications. Fruit yields were usually not recorded, although berry size was assessed. The lateral wilt experienced in our experiments, the progressive dying-off of affected canes and the loss of yield were very similar to those we recorded in three years of experimentation with sulphuric acid as a potential cane desiccant (Lawson & Wiseman, 1989). Here also the margin of safety was reduced as spray volume increased or if wetter was added. Injury was attributed to direct physical damage to the basal portion of the canes rather than to root uptake and thinner or less healthy fruiting canes were more susceptible than stronger canes. Scraping of the cane bases one week after treatment revealed the onset of necrosis in patches around the cane. This progressively reduced the supply of water and nutrients to fruiting laterals, although not necessarily in time or sufficiently seriously to cause significant yield loss at lower concentrations. A similar situation applied in our experiments with MCDS. This may merit further examination in the North American context.

A further cause of concern to UK raspberry growers would be the large amount of nitrogen contained in this formulation. Every 100 litres of MCDS contains 22 kg of nitrogen. Established plantations of vigorous cultivars, e.g. Glen Clova, require little nitrogen. Too much leads to increased cane production, poorer fruit quality and greater susceptibility to disease (Turner, 1980). The only indication of such effects in 1989 was the increase in cane numbers recorded in both experiments on plots where the treatment had been least effective as a desiccant. These must have been new canes produced after spray application. There was no evidence of increased numbers or heights on plots where the treatment had been effective and second-flush canes predominated.

Neither plantation received any further treatment in 1990. Yield records (not presented) closely reflected the amount of cane produced per plot in 1989 and young canes emerged and grew normally, suggesting that there was no continuing adverse effect of 1989 treatments.

ACKNOWLEDGEMENTS

This work was financially supported by the Horticultural Development Council and by Unocal Chemicals Inc.

REFERENCES

DeFrancesco, J.T.; Braunworth, W.S.; Nelson, E. (1989) Possible alternatives to dinoseb for cane suppression in caneberries. Proceedings Oregon Horticultural Society, **80**, 146-150.

Howard, S.W.; Libbey, C.R.; Hall, E.R. (1989) Cane burning. Weed Science Report, 1989. Washington State University, Mount Vernon, WA, 186-190.

Kaufman, D.; Sheets, A.; Petrie, S. (1990) Enquik for caneburning in red raspberries. Proceedings Oregon Horticultural Society, **81**, 177-180.

Lawson, H.M.; Wiseman, J.S. (1981) Evaluation of chemical methods of cane vigour control in raspberries. Experimental Horticulture, **32**, 33-37.

Lawson, H.M.; Wiseman, J.S. (1989) Alternatives to dinoseb-in-oil for cane desiccation in red respberry in Scotland. Acta Horticulturae, **262**, 373-379.

Turner, D.H. (1980) Raspberry production. The Scottish Agricultural College, Publication No. 54, 110 pp.

CYCLOXYDIM : A NEW GRAMINICIDE FOR USE IN BROAD LEAF CROPS

O GROSJEAN

BASF plc, Lady Lane, Hadleigh, Ipswich, Suffolk IP7 6BQ, U.K.

S STRATHMANN

BASF Agricultural Research Station, D-6703 Limburgerhof, Germany

ABSTRACT

BAS 517..H, common name cycloxydim, has been developed by BASF in western Europe for the selective control of many important grass weeds in a wide range of broad leaf crops.

The compound is rapidly taken up by the plant and absorption is enhanced by increasing temperature. This fast uptake has benefits in terms of rapid systemic activity and improved rainfastness.

Two formulations of the compound are being approved and marketed following seven years of extensive trials in Europe :

Focus Ultra	:	containing oil additives within the formulation.
Laser (Focus)	:	a 'non-wetted' formulation to be tank-mixed with commercially available additives, eg crop oil concentrates.

INTRODUCTION

BAS 517..H was synthesised and patented by BASF Aktiengesellschaft for the post-emergence control of most commonly occurring grass weeds in a wide range of broad leaf crops. This paper provides information on environmental factors and their effect on its herbicidal activity, together with reports on its safety and efficacy in European field trials.

CHEMICAL AND TOXICOLOGICAL DATA

Cycloxydim is a new active cyclohexenone compound. Its toxicological properties are attractive, having an LD50 of 3940mg/kg (rat - acute, oral), whilst being of low acute toxicity to birds, fish and other species.

MODE OF ACTION

Current results indicate that cycloxydim is mainly taken up by the green parts of the plant, but also to a lesser extent by the roots. It is translocated systemically to the meristematic tissue where, in sensitive plants, it inhibits de novo fatty-biosynthesis which in turn inhibits acetyl-CoA-carboxylase (Lichtenthaler et al., 1989). This results in the malfunctioning of the cell membrane and interference in the division of cells.

MATERIALS AND METHODS

Cycloxydim was evaluated from 1983 to 1990 under code BAS 517..H in approximately 1500 trials in all major western European countries.

Two formulations of the compound were evaluated :

a) BAS 51701H, containing 200g ai/l as an EC. This formulation was always tank-mixed with an oil concentrate at 0.8% of total spray volume.
b) BAS 51722H, containing 100g ai/l cycloxydim, formulated with an oil additive (methyloleat 300g/l) as an EC.

Growth cabinet test

The influence of temperature was investigated using *Triticum aestivum* plants grown in growth cabinets calibrated at 5, 15, 25 and 35°C. Leaf samples collected two hours after treatment with labelled cycloxydim were washed in a water/nekanil 5% solution, to remove residues which had not penetrated. Following combustion of these samples in an oxidizer (Zinser Oxymat Ox 300), the envolved 14 CO_2 was absorbed in a Liquid Scintillation cocktail and radioassayed in a scintillation counter (Packard, Tricarb, 460 CD).

Field trials

Four trials were conducted at the BASF research stations in Nelspruit (South Africa) and Utrera (Spain) to investigate the rainfastness of cycloxydim. Cycloxydim was applied at 0.2kg ai/ha in tank mix with 1.5l oil concentrate to early tillering grass weeds. Rainfall was simulated by overhead sprinkler irrigation, applied either immediately, or 1, or 2 hours after herbicide treatment. Plots measured $10m^2$ and all treatments were replicated three times. Weed species present were : *Avena ludoviciana, Bromus diandrus, Digitaria adscendens, Dactyloctenium aegyptum, Eleusine africana, Eragrostis pilosa, Triticum aestivum.*

Most other trials were of a fully randomised complete block design with three to four replicates. Plot sizes varied from 12 to $30m^2$, the smaller plots being used for efficacy testing, whilst yielded crop tolerance trials were conducted on larger plots.

Treatments were applied using air or CO_2 pressurised small plot sprayers, fitted in the main with Lurmark Cambridge Blue nozzles and calibrated to deliver a spray volume of 100 to 400 l/ha at a pressure of 2.5 bars. Weed control and crop tolerance were visually assessed throughout the season using a 0-100% scale. Yields were obtained by hand harvesting or, in the case of oilseed rape, with small plot combine harvesters.

RESULTS

Growth cabinet test

The rate of foliar uptake of cycloxydim was very rapid, and was further enhanced by increasing temperatures (Figure 1) :

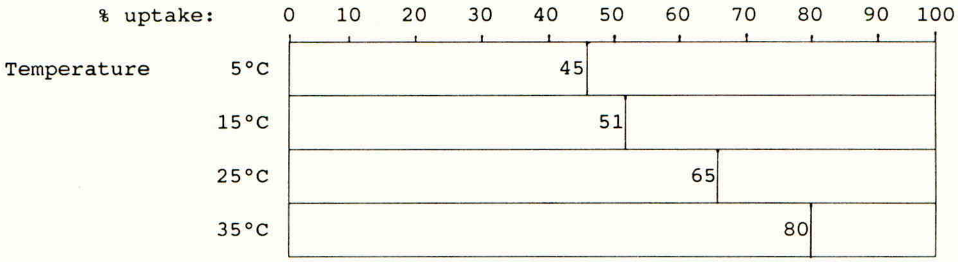


FIGURE 1 Rate of foliar uptake of cycloxydim by *Triticum aestivum* according to temperature over an exposure period of 2 hours

Field development

Rainfastness

The rapid uptake noted in growth cabinet tests reduced the risk of wash-off by rain, as demonstrated when spraying was followed by simulated rainfall (Figure 2).

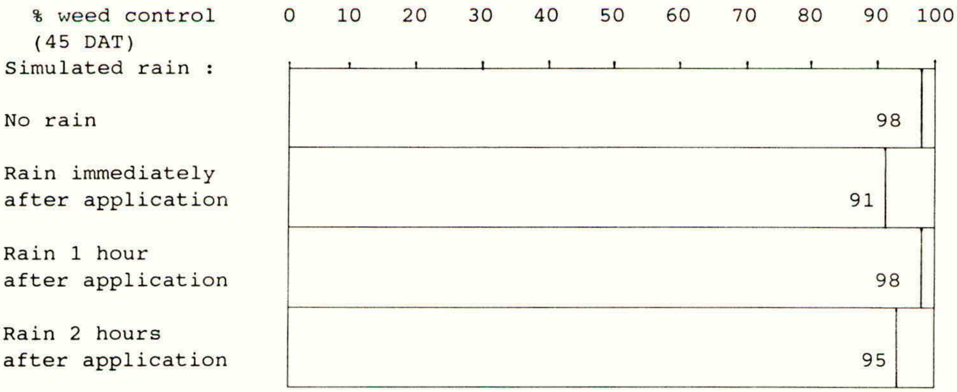


FIGURE 2 Activity of cycloxydim 45 DAT following exposure to simulated rain (mean of 4 trials)

Weed control

Table 1 shows weed control data for some major grass weeds and volunteer cereals with the cycloxydim + oil tank-mix (BAS 51701H) from western European field trials conducted between 1985 and 1990. Treatments were applied either in the autumn (A) or in the spring (S) up to the end of tillering of the weeds.

TABLE 1 Percentage weed control for cycloxydim and fluazifop-P-butyl + oil in western European trials, 1985-90

Weed species	Application timing	No. of trials	% weed control cycloxydim (250g ai/ha)	% weed control fluazifop-P-butyl* (312g ai/ha)
Triticum aestivum	A	8	97	97
(Winter)	S	5	99	98
Hordeum vulgare	A	12	97	96
(Winter)	S	4	98	98
Bromus spp	A	6	98	96
Lolium multiflorum	A	14	98	90
	S	9	100	91
Digitaris sanguinalis	S	9	98	85
Setaria spp	S	6	100	92
			(500g ai/ha)	(750g ai/ha)
Elymus repens	A	8	97	95
	S	10	98	98
Cynodon dactylon	A	2	91	92
Agrostis spp	S	7	99	98

* = racemic formulation, applied in tank-mix with oil concentrate

Cycloxydim proved to be very active against both annual and perennial grass weeds at appropriate application rates.

Application timing

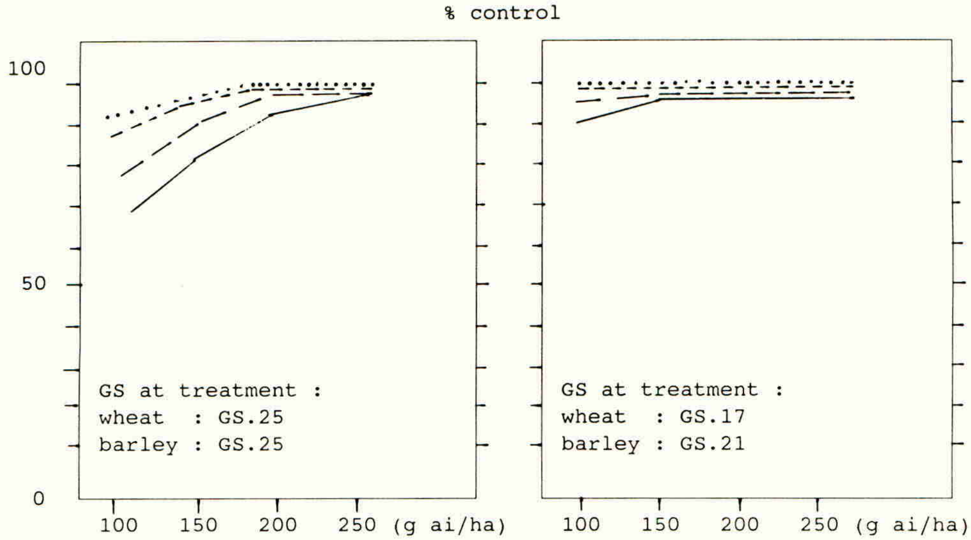
The effect of application timing was investigated in a single trial in Germany (Figure 3). The results demonstrated the benefit from an early post-emergence application in terms of rate requirement and the overall control levels obtained.

In general, it was found that annual grasses and volunteer cereals were more sensitive to cycloxydim from the two leaf stage up to the end of tillering, although at later growth stages good activity was still maintained by using higher rates. Perennial grasses were best controlled at a height of 15-30cm.

Species controlled

Table 2 summarises the susceptibility of all grass species covered in the European trials between 1983 and 1990.

Susceptibility classes are based on the minimum rate of cycloxydim required to provide an average of > 90% control of weeds up to GS.29 when treated.



———— = *Triticum aestivum* (Winter)   ------- = *Hordeum vulgare* (Winter)

– – – – = *Triticum aestivum* (Spring)   .... = *Hordeum vulgare* (Spring)

FIGURE 3 Effect of growth stage of grass weeds at time of treatment on herbicidal activity of BAS 51701H + oil

TABLE 2 Susceptibility of grass weeds to cycloxydim (dose required to give > 90% control)

< 100g ai/ha	100-200g ai/ha	200-300g ai/ha	≥ 300g ai/ha
Avena sativa	*Alopecurus myosur.*	*Brachiara platyph.*	*Bromus tectorum*
Brachiara decum.	*Avena fatua*	*Bromus sterilis*	*Cynodon dactylon*
Brachiara plant.	*Avena ludoviciana*	*Eragrostis pilosa*	*Elymus repens*
Eleusine afric.	*Cenchrus echinatus*	*Rottboellia exalt.*	*Eragrostis spp*
Eleusine indica.	*Dactyloctenium aeg.*	*Triticum aestivum*	*Leptochloa fasci.*
Eriochloa grac.	*Digitaria adscend.*	*(spring, winter)*	*Panicum maximum*
Panicum millac.	*Digitaria ischaemum*	*Triticum durum*	*Saccharum offic.*
Panicum texan.	*Digitaria sang.*	*Zea mays*	*Sorghum halepense*
Phalaris minor	*Echinochloa spp*		*(rhizome)*
Setaria lutescens	*Festuca arundin.*		
Setaria verticil.	*Hordeum vulgare*		
Setaria viridis	*(spring, winter)*		
Setaria faberii	*Lolium multiflorum*		
Urochloa panic.	*Paspalum spp*		
	Pennisetum glaucum		
	Poa pratensis		
	Secale cereale		
	Sorghum halepense		
	(seedling)		
	Sorghum vulgare		

Only *Festuca rubra*, *Poa annua* and *Poa trivialis* were found to be resistant to cycloxydim when used at commercial rates.

Formulation effects

The 'wetted' and 'non-wetted' formulations were compared in several studies. Figure 4 gives the result from one such study for three major species.

Whilst both formulations proved comparable when used against the grass weeds, the 'wetted' formulation, however, proved slightly more active against volunteer barley *(Hordeum vulgare)*.

Comparability of both formulations against other grass weeds has also been demonstrated in other studies.

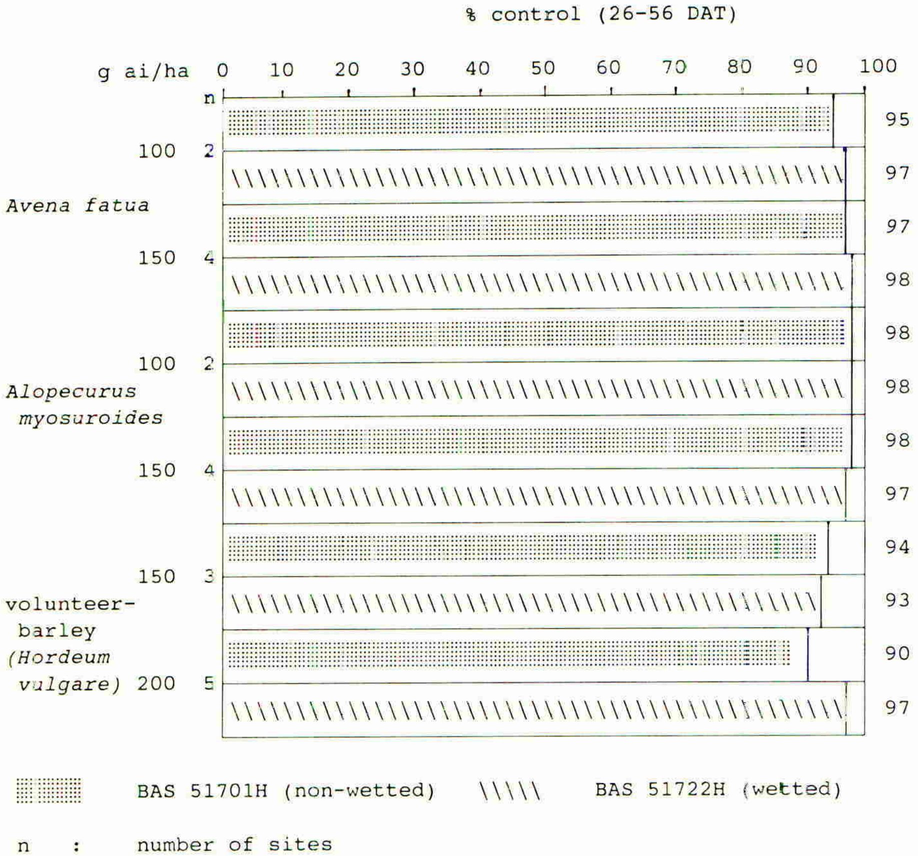


FIGURE 4 Comparison of BAS 51701H and BAS 51722H on annual grass weeds (France, Germany, Italy 1989/90)

Crop tolerance

All broad leaf crops tested so far have shown good crop tolerance. Most were tested from the two leaf stage. Minimal or no damage was recorded at all growth stages (Table 3).

TABLE 3 Tolerance of crops to cycloxydim

Crop	g/ha ai*	Crop	g/ha ai*	Crop	g/ha ai*
Alfalfa (Lucerne)	800	Flax	1200	Savoy cabbage	600
Apple	1200	Grape vines	1200	Seed tomatoes	400
Beans, french	600	Leeks	1200	Soyabeans	1200
Beans, field	400	Lettuce	800	Spinach	600
Beets, sugar	1200	Melon, water	400	Strawberries	1200
Broccoli	400	Mustard, white	800	Sunflowers	600
Brussels sprouts	600	Okra	400	Swedish turnips	800
Caraway	600	Onions	1200	Tobacco	1200
Carrots	1200	Peas, garden	1350	Tomatoes	1200
Cauliflower	1200	Peanuts	800	Witloof chicory	600
Celery	1200	Peppers	400	**Ornamentals :**	
Chives	1200	Potatoes	1500	Delphinium	300
Citrus	800	Pumpkin	400	Gladiolus	400
Cotton	800	Rape, spring	800	Limonium	300
Cucumbers	400	Rape, winter	1200	Pansies	300
Eggplant (Aubergine)	400	Red fescue	800	Roses	800
Fennel	300	Rhubarb	1200	Tulips	400

* Maximum rates tested

DISCUSSION

The large number of trials conducted with cycloxydim demonstrated clear benefits of the product :

Systemic control of both annual and perennial grass weeds and volunteer cereals, coupled with its excellent safety in a wide range of broad leaf and ornamental crops, makes the compound particularly suitable for use in several grass weed and crop situations. In addition, flexible application rates and timings allow for product rates to be chosen which are most appropriate to each situation. Furthermore, the compound is taken up rapidly by grass weeds, resulting in a quick action and good rainfastness, which helps to maintain grass weed activity in adverse climatic conditions.

REFERENCES

Lichtenthaler, H.K.; Kobek, K.; Focke, M. (1989). Differences in sensitivity and tolerance of monocotyledonous and dicotyledonous plants towards inhibitors of acetyl-coenzyme A-carboxylase. British Crop Protection Conference - Weeds 1989, 173-182.

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

SELECTIVE WAVELENGTH TRANSMITTING MULCH FOR YELLOW NUTSEDGE CONTROL

B.A. MAJEK

Rutgers-The State University of New Jersey, Crop Science Department, Bridgeton, NJ 08302

P.E. NEARY

Gloucester County Cooperative Extension, Clayton, NJ 08312

ABSTRACT

Black and clear plastic mulches were evaluated for yellow nutsedge and stinkgrass control. Eleven percent of the yellow nutsedge shoots punctured the black plastic. Clear plastic was not punctured, but the weed grew vigorously, reduced cucumber yield, and produced tubers in late summer. The infrared transmitting (IRT) mulch controlled yellow nutsedge shoots and prevented tuber formation, resulting in increased cucumber yield. The application of bensulide at 5.5 kg a.i./ha prior to laying the mulches did not improve yellow nutsedge control. Black plastic and the IRT mulch effectively controlled stinkgrass. The annual weed survived under the clear plastic and reduced melon yield. Bensulide, applied at 5.5 kg a.i./ha prior to laying the clear plastic, suppressed the annual grass and improved melon yields, but did not equal the yield obtained under the IRT mulch.

INTRODUCTION

Plastic mulches are often used in the production of certain vegetable crops including tomatoes (Lycopersicon esculentum), peppers (Capsicum annuum), eggplant (Solanum melongena), cucumbers (Cucumis sativus), melons (Cucumis melo), and zucchini (Cucurbita pepo). The benefits of using a plastic mulch include increased yield and earlier maturity due to warming of the soil early in the season, conservation of soil moisture, lower incidence of disease, and weed control when black plastic is used.

Certain crops, including eggplant, cucumbers, and melons produce fruit earlier and yield higher when clear plastic is used than when the mulch is black (Pollack et al., 1969). This growth response has been attributed to higher soil temperatures under the clear mulch (Shales & Sheldrake, 1966; Takatori et al., 1964). However, weed growth under the clear plastic must be controlled to obtain the crop response. Many weeds respond to the favorable microclimate under the mulch. The populations of six common summer annual weeds were found to increase under clear plastic, when compared to weed populations in unmulched soil (Bellinder et al., 1991). Only two weed populations were found to decrease under the mulch. Currently registered herbicides do not provide consistently effective weed control under clear plastic, so growers cannot control weeds under clear mulch or realize the yield and earliness benefits compared to the use of black plastic.

Black plastic mulch effectively controls annual weeds, but results are less consistent when perennial weeds are present. Yellow nutsedge (Cyperus esculentus) is a widespread perennial weed that is not effectively controlled by black plastic. Rhizomes sprout from tubers and grow vertically in the spring and early summer (Stoller et al., 1972). The apical meristem of an actively growing rhizome is sheathed in a succession of sharply pointed scale leaves. The emerging rhizome tip forms a basal bulb and leaves in response to light and diurnal temperature fluctuations (Stoller & Woolley, 1983). Rhizomes under black plastic are not subjected to light, and the diurnal temperatures are moderated by the mulch. The tip remains strong and sharp. Some of the rhizomes penetrate black plastic and grow vigorously, producing additional rhizomes that curve upward and form shoots until a dense mat is present to compete with the crop and impede harvest.

A new class of plastic mulch has been under development. These new plastics combine the advantages of clear and black mulch. The plastic selectively filters out photosynthetically active radiation (PAR) and transmits light that is not photosynthetically active. Infrared transmittance, desirable for warming the soil, is high (Loy et al., 1989). The result is a compromise mulch that warms the soil like clear plastic, but suppresses weeds like black plastic. Selective wavelength light transmitting or infrared transmitting (IRT) mulches have performed similarly to clear plastic in terms of the yield and earliness of melons, but without the weed development often experienced under clear mulch (Loy & Wells, 1990).

The objectives of these studies were to evaluate the potential of IRT mulches for yellow nutsedge and annual weed control and to compare the yields of crops grown using an IRT mulch for weed control with those of crops grown on clear and black mulch.

MATERIALS AND METHODS

Field studies were established in 1990 and 1991 to evaluate yellow nutsedge control under IRT mulch and in 1991 to evaluate the effect of mulches on cucumber and melon yield.

The 1990 experiment was conducted on a farm in Gloucester County, New Jersey. Yellow nutsedge control was evaluated under clear, black, and an IRT plastic and compared to unmulched soil. The IRT mulch used, IRT-76, is a wavelength selective mulch reported to transmit 50 percent of the total light, but only 20.2 percent of the photosynthetically active radiation[1]. Bensulide was applied prior to laying the mulches at 5.5 kg a.i./ha to control annual weeds. The soil was classified as a loamy sand soil with 0.86 percent organic matter and a pH of 6.5. The location was chosen for a heavy yellow nutsedge infestation. The soil was ploughed and disced prior to application of the plastic on May 18, 1990. Each plot was 1.5 m by 8.0 m, and treatments were replicated four times. Yellow nutsedge growth was monitored throughout the growing season; shoot number, dry weight, and tubers produced per 0.3 m^2 were recorded.

The cucumber experiment conducted in 1991 was located on a farm in Atlantic County, New Jersey. The site was selected for a heavy yellow

[1] AEP Industries, Moonachie, NJ, USA

nutsedge population and a crop and cultural practices that were compatible with the experiment. Clear, black, and IRT plastic were evaluated without any herbicide treatment, as in the previous year. The IRT mulch used had similar properties to the brand used the previous year, but was provided by a different manufacturer[2]. In addition, bensulide treatments were applied to the soil surface at 5.5 kg a.i./ha under the clear and IRT mulches. Herbicides and plastics were applied on April 26, 1991. Cucumber cv. 'Discovery' was seeded ten days later. Each plot was 1.5 m by 8.0 m, and treatments were replicated four times. The total number of yellow nutsedge shoots that emerged were counted in early May. The shoots that remained under the mulch and those that punched through the mulch were recorded separately. Crop injury and weed control were rated on a scale of zero to one hundred, with zero equal to no effect and one hundred equal to complete death of the evaluated plant. Harvest was concluded on June 26, 1991. The fresh weight of cucumbers and the dry weight of yellow nutsedge shoots in each plot were recorded.

The melon experiment conducted in 1991 was located at the Rutgers Research and Development Center, in Cumberland County, New Jersey. The primary weed present under the mulch was stinkgrass (Eragrostis cilianensis). Clear, black, and IRT-76 plastic were evaluated without herbicide treatment. In addition, bensulide treatments were applied to the soil surface at 5.5 kg a.i./ha under the clear and IRT mulches. Herbicides and plastics were applied on May 6, 1991. Melon cv. 'Cordella' was seeded four days later. Each plot was 2.5 m by 10.0 m, and treatments were replicated four times. Crop injury and weed control were rated on a scale of zero to one hundred, with zero equal to no effect and one hundred equal to complete death of the evaluated plant. The number and fresh weight of the melons were recorded on July 22, 24, and 26, 1991 and combined to represent the early yield. The remaining melons were harvested on July 30, 1991 and combined with the early yield to obtain the total yield for the season.

The results of each experiment were subjected to analysis of variance and LSD means separation tests.

RESULTS AND DISCUSSION

Yellow nutsedge shoots emerged and grew vigorously at the Gloucester County site in 1990 (Table 1). The population was higher on the exposed soil than under the plastic mulching treatments. This may have been due to soil temperature differences under the plastic. The black plastic mulch effectively controlled yellow nutsedge in 1990 and none of the shoots that emerged pierced the mulch. Usually, a small percentage of the shoots that emerge puncture black plastic. No reason was apparent for the weed's failure to puncture the plastic at this site. None of the yellow nutsedge shoots were surviving under the black mulch when the stand was counted, and the control remained effective through September. No tubers were produced under the black mulch. The yellow nutsedge that emerged under the clear plastic grew vigorously (Table 1). The foliage lifted the mulch off the soil to a height of 10 to 20 cm and the upward pressure from the weed foliage caused the edge of the plastic to become dislodged from the

---

[2] PlastiTech Culture Inc., St-Remi, Quebec, Canada

soil in places. Foliage pressed against the plastic became necrotic, but the solarization did not effectively control the weed or prevent tuber formation in the autumn. Under the IRT mulch, (Table 1) shoot growth was etiolated and survived for about six to eight weeks after emergence. The foliage was unable to exert enough upward pressure to loosen the edge of the plastic in the soil. Most of the shoots that emerged had senesced prior to the stand count. The few surviving plants were unable to increase shoot dry matter or produce tubers in late summer.

TABLE 1. Effect of plastic mulches on yellow nutsedge control in Gloucester County, New Jersey, September 11, 1990.

Mulch	No./0.3m² Shoots above mulch	No./0.3m² Total shoots	Tubers	Shoot dry wt. (g/0.3m²)
Black	0	0	0	0
Clear	0	92	198	49
IRT	0	18	29	5
Unmulched soil	0	196	932	186
LSD($P \leq 0.05$)	-	67	396	45

The above experiment was repeated the following year in Atlantic County (Table 2). A heavy, uniform yellow nutsedge stand had emerged within a week of initiating the experiment. Cucumbers were seeded to evaluate the effect of yellow nutsedge control on a crop typically grown on plastic mulch. The weed population was higher under the black plastic than under the other two mulches (Table 2). Only the black plastic was punctured by the emerging shoots. Eleven percent of the shoots that emerged pierced the black plastic, and then grew with accelerated vigour.

TABLE 2. Effects of plastic mulches on yellow nutsedge control in cucumbers in Atlantic County, New Jersey, 1991.

Mulch	Herbicide	Rate kg a.i./ha	Shoot no./0.3m² May 8 Above mulch	Shoot no./0.3m² May 8 Total	Scores (%) June 6 Crop inj.	Scores (%) June 6 Weed control	June 26 Yield t/ha
Black	-	-	18.9	165	0	0	9.3
Clear	-	-	0.9	81	0	0	8.7
IRT	-	-	0.9	108	0	73	14.0
Clear	bensulide	5.5	0.0	90	0	0	11.1
IRT	bensulide	5.5	0.0	126	0	75	16.8
LSD($P \leq 0.05$)			5.4	57	-	11	3.7

The shoots under the black plastic did not senesce rapidly as in the previous year, perhaps because enough light may have reached the weeds under the mulch through the planting holes to sustain growth. Weed growth at the planting holes was vigorous until the crop canopy grew above the yellow nutsedge. The clear plastic was not punctured by the emerging yellow nutsedge shoots, but the weed grew vigorously under the mulch (Table 2). The cucumber foliage protected the weeds from solarization and the edge of the plastic was dislodged from the soil in some plots. The yellow nutsedge foliage was etiolated under the IRT mulch and exerted less upward pressure on the film. The initial weed population was high, but failed to grow (Table 2). Within six to eight weeks after emergence, yellow nutsedge shoots had begun to senesce. The bensulide had no effect on the weed when applied under either clear or IRT plastic. Cucumber yields reflected the control of yellow nutsedge. The IRT mulch yielded significantly more cucumbers than either the clear or the black plastic. Bensulide applied prior to laying the mulch did not improve crop yield.

A second experiment was established in a crop of melons at Rutgers Research and Development Center in 1991 (Table 3). The yellow nutsedge population was light and scattered, the primary weed was stinkgrass. Both the black and IRT mulches controlled the annual grasses under the plastic (Table 3). Weed growth under the clear mulch was heavy, and the crop canopy prevented solarization. Bensulide suppressed but did not control the stinkgrass under the clear plastic. Melon yields reflected the advantage provided by the IRT mulch. The number of melons produced on the IRT mulch was higher than the clear and black mulch without any herbicide treatment. Melon yields were further increased by the application of bensulide under the clear mulch. The suppression of weeds under the clear mulch seemed to be a significant benefit.

TABLE 3. Effects of plastic mulches on stinkgrass control in melons in Cumberland County, New Jersey, 1991.

			Scores (%), June 6		Yield, August 1	
		Rate	Crop	Weed		
Mulch	Herbicide	kg a.i./ha	inj.	control	No./ha	t/ha
Black	-	-	0	90	15,320	29.9
Clear	-	-	0	0	9,480	19.3
IRT	-	-	0	90	17,200	33.7
Clear	bensulide	5.5	0	63	15,600	27.0
IRT	bensulide	5.5	0	90	16,800	29.2
LSD($P \leq 0.05$)			-	8	3,040	9.4

IRT mulch effectively controlled yellow nutsedge and annual weeds in the experiments described, but should not be considered the entire solution to these weed problems. Weed growth at the planting holes remains a problem that must be controlled with a herbicide or by hand. However, the rapid development of a dense crop canopy seemed to assist the control of weeds under the plastic and at the planting hole. IRT mulch is a new and effective tool that may be used in conjunction with the traditional weed control techniques employed when producing crops on plastic mulch to achieve earlier maturity and higher yields.

REFERENCES

Bellinder, R.R; Binning, L.K.; Yourstone, K.S.; Bonanno, A.R.; Gorski, S.F.; Majek, B.A.; Neary, P.E.; Baron, J.J.; Wallace, R.W. (1991) Oxyfluorfen under clear plastic controlled weeds in transplanted cucurbits. Submitted for publication to Weed Technology.

Loy, B; Wells, O. (1990) Effect of IRT mulches on soil temperature, early vegetative development in muskmelon, and weed growth. Proceedings of the 22nd National Agricultural Plastics Congress, **22**, 19-27.

Loy, B; Lindstrom, J; Gordon, S.; Rudd, D; Wells, O. (1989) Theory and development of wavelength selective mulches. Proceedings of the 21st National Agricultural Plastics Congress, **21**, 193-197.

Pollack, B.L.; Smith, N.J.; Cialone, J.C. (1969) A summary of crop response to various agricultural film mulches. Proceedings of the 9th National Agricultural Plastics Congress, **9**, 17-25.

Shales, F.D.; Sheldrake, Jr., R. (1966) Mulch effects on soil conditions and muskmelon response. Proceedings of the American Society for Horticultural Science **88**, 425-430.

Stoller, E.W.; Woolley, J.T. (1983) The effects of light and temperature on yellow nutsedge (*Cyperus esculentus*) basal-bulb formation. Weed Science **31**, 148-152.

Stoller, E.W.; Nema, D.P.; Bahn, V.M. (1972) Yellow nutsedge tuber germination and seedling development. Weed Science **20**, 93-97.

Takatori, F.A.; Lippert, L.F.; Whiting, F.L. (1964) The effect of petroleum mulch and polyethylene films on soil temperature and plant growth. Proceedings of the American Society for Horticultural Science **85**, 532-540.

WEED CONTROL STUDIES ON SUNFLOWER IN THE SUDAN

K. A. FAGEIRY

Agricultural Research Corporation, Wad Medani, Sudan

D.S.H. DRENNAN

Dept. of Agricultural Botany, School of Plant Sciences, The University of Reading, Berks, U.K. RG6 2AU.

ABSTRACT

Weeding and herbicide treatments were investigated in sunflower crops grown in the Sudan in irrigated and rain fed conditions. Yield losses due to weed competition were large (50%-70%) in all cases.

Early weeding, before 4 weeks after emergence, was essential for good yields. Low application rates of oxadiazon, oxyfluorfen and aclonifen with one supplementary weeding gave satisfactory results. Where fertilizer was used (especially nitrogen) weeding was important in getting the best return for fertilizer use.

Oil percentage was maintained at the higher yield levels obtained with weeding but protein percentage was mainly influenced by nitrogen applications. Poorly weeded crops flowered later than well weeded crops.

INTRODUCTION

As a consequence of the recent droughts, the production of major oil crops has been decreasing in Sudan. With sorghum (*Sorghum bicolor*) production from rainfed areas in low supply, the area for sorghum growing is being increased in the irrigated areas. Since 1982/83 the area of irrigated groundnut (*Arachis hypogea*) in the Sudan Gezira Scheme has decreased from 105 x 10^3ha to 18 x 10^3ha and total production in the country has fallen from 840 x 10^3t to 370 x 10^3t. The area of sesame (*Sesamum indicum*) harvested and its yield have also fallen considerably (Anon, 1990). The oil seed processing industry has at times been working at only 20% capacity and the Sudan has changed from an exporter to an importer of edible oil.

To meet the oil deficit the oil seed companies and the Government are encouraging sunflower (*Helianthus annuus*) production in the more reliable rainfall areas on the heavy clay soils of the Central Rainlands. Between 1985 and 1988 the crop area increased from 210ha to 168 x 10^3ha and the aim is to increase the area to 1 x 10^6ha in the future. Crop yields are low, however, and one of the main reasons for this is poor weed control. This paper reports the results of studies on the effects of weeding on sunflower yields and quality.

MATERIALS AND METHODS

Irrigated experiments were carried out between 1989 and 1990 at the

Gezira Research Farm, Wad Medani and a rainfed experiment in 1990-91 at the Gedaref Research Farm. Both areas have soils which are non-saline heavy clays (60-70% montmorillonite clay) of pH 8.5. The soils have 0.4% organic matter content and low available nitrogen contents but satisfactory phosphate and potassium levels.

In irrigated trials the seeds were handplanted on ridges in November (winter crops) or July (summer crops) and given furrow irrigation as necessary. In the rainfed area seeds were planted in July on the flat in rows into disc ploughed land which was lightly cultivated. Plots were thinned to give a population of about 50 x 10^3 plants/ha. The sunflower cultivars used were the hybrids Pioneer 6431 (USA), Hysun 33 (Australia) and De Kalb G100 (Argentina).

Herbicides were applied pre-emergence with a CP3 knapsack sprayer with Polijet red tip (78) flat fan nozzles in a volume of 290 l/ha. Weeding was done by the traditional hand-hoeing method. The main weeds present were the grasses *Brachiaria eruciformis*, *Ischaemum afrum*, *Sorghum sudanense*, *Echinochloa colonum* and *Cynodon dactylon*. The main broad-leaved weeds present were *Ipomoea cordofana*, *Rhynchosia memnosia*, *Sonchus cornuta* and *Phyllanthus niruri*. Weed assessments were made by ground cover estimates and by dry weights in 60 x 90 cm quadrats sampled at the early crop flowering stage.

Fertilizer was only given as treatments in one experiment. The treatments applied were all factorial combinations of 80 kg N/ha (as urea) and 40 kg/ha P (as superphosphate), the current recommendations for sunflower grown in rotation with other crops. The fertilizer treatments were applied with no weeding, weedings at 2, 4, 6 and 8 weeks or oxadiazon applied pre-emergence at 1.07 kg ai/ha. There were only 3 replications in this trial. Other experiments were on fields which had been in fallow before use.

Plot sizes were 5.4m x 7m and treatments were usually replicated 4 times on randomized block designs. Harvested yields were taken from 4.2 x 5m central areas. Seed heads were air dried and manually threshed in the laboratory. Oil content (Soxhlet extraction with ether) and protein content (Kjehldal N x 6.25) were determined at the Agriculture Faculty Analytical Laboratory, Reading.

RESULTS AND DISCUSSION

1. The effects of timing and number of handweedings

Yield data are given for two experiments on irrigated crops in the winter and summer growing seasons of 1989-90. Summer crops (July - early October) experience warmer temperatures (min. 22°C; max 39°C) than winter crops (November to February min 14°; max 37°C).

Yield losses due to full season weed competition in unweeded plots were from 46% (winter crop) to 68% (summer crop) (Table 1). This mainly reflects the more vigorous weed growth during summer since maximum yields with good weeding were quite similar in both seasons. The importance of an early start to weeding is obvious, particularly in summer crops. Delaying the first weeding to 6 weeks gave significant yield losses compared to weeding at 2 weeks and this is commonly the practice in farmers' crops. In these trials the extra response from multiple weedings was not large but in some trials a

TABLE 1. Effect of time of weed removal on seed yield of summer and winter sunflower cv. Pioneer 6431 at Gezira Research Station, 1989-1990.

Time of handweeding (WAE*)	Seed yield, kg/ha	
	Summer	Winter
2	1352	1629
4	1208	1624
6	986	1341
2 + 4	1416	1760
2 + 6	1341	1637
4 + 6	1238	1697
2 + 4 + 6	1744	1799
2 + 4 + 6 + 8	1746	1853
Unweeded	564	999
SED (DF = 24)±	161.2	233.2

*WAE = weeks after emergence

second weeding at 6 to 8 weeks has improved yields.

Weedy crops were shorter, flowered about 1 week later and had smaller 1000 seed weights than the weeded treatments. There were no effects of weeding on oil percentage or protein percentage in these trials.

The yield losses observed here are similar to those reported in North Dakota (53% by Nalewaja *et al.*, 1972) and Manitoba (20-50% by Chubb, 1975). The importance of the early weeding at 2 weeks after emergence was also evident in other studies (Johnson, 1971; Chubb, 1975).

2. Effects of fertilizer applications and weeding methods on sunflower yields and seed quality

Yield data are given for two experiments on irrigated crops in the 1989-90 season for a winter and a summer crop (Table 2).

Responses to phosphate were not large in either experiment but they were additive to the good response from nitrogen application. Both weeding treatments gave substantial yield increases but oxadiazon alone was not as good as frequent handweeding.

The effects of fertilizer and weeding treatments were additive and yields were increased by a factor of 3 to 4 when unfertilized unweeded crops were compared to well fertilized and frequently weeded crops.

Effects of the treatments on oil percentage were complex (Table 3). The largest oil content was in the lowest yielding plot, with no weed control and no fertilizer applications. However, the higher yielding plots receiving both good fertilizer and weeding treatments had a greater oil content than most other treatments. Nitrogen applications alone tended to decrease oil contents.

TABLE 2. Effect of weed management system and fertilizers on sunflower cv. De Kalb G100 seed yield (kg/ha) at Gezira Research Station 1989/90.

Weeding treatment	Fertilizer Rate, kg/ha ONOP	80N	40P	80N+40P	Mean
Winter Crop					
Frequent weeding	2332	2887	2666	3220	2776
Oxadiazon	1554	2554	1554	2887	2137
Unweeded	765	1445	1111	1554	1219
Mean	1550	2295	1777	2554	2044
Summer Crop					
Frequent weeding	1777	2194	1888	2638	2124
Oxadiazon	1416	1860	1610	2471	1839
Unweeded	777	1277	1083	1277	1104
Mean	1323	1777	1527	2129	1689

SED (DF)	Winter crop	Summer crop
Fertilizer (3)	166.6	133.3
Weeding (2)	144.4	122.2
Interaction (6)	288.7	233.2

TABLE 3. Effect of weed management system and fertilizers on oil and protein contents of sunflowers at Gezira Research Station in 1989/90 (Summer Crops)

Weeding treatment	Fertilizer rate, kg/ha ONOP	80N	40P	80N+40P	Mean
Oil percentage					
Frequent weeding	33.5	36.2	30.4	40.0	35.0
Oxadiazon	30.5	27.3	40.3	43.4	35.4
Unweeded	44.3	26.4	38.4	35.8	36.2
Mean	36.1	30.0	36.4	39.8	35.5
Protein Percentage					
Frequent weeding	19.5	19.6	17.6	16.7	17.6
Oxadiazon	17.8	18.2	17.8	17.5	17.8
Unweeded	15.5	20.1	16.9	17.3	17.4
Mean	17.6	19.3	17.4	17.2	17.6

SED (DF)	Oil	Protein
Fertilizer (3)	1.44	0.23
Weeding (2)	1.24	0.20
Interaction (6)	2.49	0.39

Protein percentage was increased by nitrogen application alone but weeding treatments had no significant effect on average. However, the lowest protein percentage was in the unweeded crop without fertilizer application, indicating some interaction between weeding and nitrogen fertilization.

3. Herbicide use and supportive handweeding in rainfed sunflower

This experiment was carried out at Gedaref in 1990/91 in an area which received a reasonable rainfall (640 mm) during the cropping season. Grassweeds were the main weeds present.

Oxadiazon and aclonifen had no visible effects on sunflower but oxyfluorfen caused slight crop injury (stunting) at the seedling stage though crops recovered quickly and matured normally.

Early weed control was good with oxadiazon and oxyfluorfen. Aclonifen was not as good on grassweeds but gave effective broad-leaved weed control (Table 4). Again all weeded treatments flowered 7-10 days earlier than unweeded crops, an important factor in water-shortage conditions. Individual flower heads had more seeds/head and fewer empty seed in the weeded treatments and handweeding gave more seeds/head than low doses of herbicide alone.

Again yield losses due to full weed competition in unweeded plots were very large (68% reduction). The lowest rate of all three herbicides gave poorer yields than the frequently handweeded treatment. However, after a single supplementary weeding at 5 WAE yields were similar to the higher herbicide rates and not significantly lower than the frequently weeded treatment.

TABLE 4. Effect of pre-emergence herbicides and supportive handweeding on rainfed sunflower cv. Hysun 33 grown at Gedaref in 1990/91

Treatments kg ai/ha	% weed control at 3 WAE⁺	Days to 50% flowering	No. of seeds/ head	% empty seeds	Seed yield kg/ha
Oxadiazon					
1.1	74	69	601	13	1003
1.1 + HW*	75	66	707	12	1478
1.4	81	67	698	9	1424
Oxyfluorfen					
0.36	77	68	597	14	1077
0.36 + HW*	77	64	678	9	1389
0.48	83	66	661	9	1272
Aclonifen					
1.9	42	71	571	16	895
1.9 + HW*	44	66	667	11	1310
2.8	68	68	588	13	1025
Three Handweedings					
HW 2 + 4 + 6 WAE	88	63	789	9	1613
Unweeded	0	74	420	18	518
SED (DF=27)	9.2	3	101	4	160

* HW = Supporting handweeding, 5WAE
⁺ WAE = Weeks after emergence

CONCLUSIONS

All three herbicides clearly have a possible role in this crop in appropriate weed situations as found in other countries. (Woon *et al.*, 1984; Grolleau & Millet, 1986; Bedmar, 1989; and Dixon *et al.*, 1989). Oxadiazon and oxyfluorfen are already used in Sudan in cotton (*Gossypium barbadense*) and some other crops. However, full weed control by herbicides is not likely to develop, particularly in rain fed cropping areas, and supplementary hand-weeding will be necessary for satisfactory yields to be obtained and to achieve the best responses to other inputs such as fertilizers or improved varieties. Where handweeding alone is practised farmers need to be convinced of the value of starting this earlier than 2 - 4 weeks after crop emergence.

ACKNOWLEDGEMENTS

We wish to acknowledge support from the International Development and Research Corporation (IDRC), Ottawa, Canada, and from the Agricultural Research Corporation of Sudan for supporting this work.

REFERENCES

Anon (1990) Agricultural Situation & Outlook. Department of Agricultural Economics, Ministry of Agriculture and Natural Resources, Khartoum, VI (3).

Bedmar, F. (1989) Tests of Agrochemicals and Cultivars, No. 10 (Annals of Applied Biology **114** Supplement), 96-97.

Chubb, W.O. (1975) Weed competition in sunflowers. Manitoba Agronomists Conference (Winnipeg, Manitoba). Tech. Papers, 129-132.

Dixon, F.L.; Lutman, P.J.W.; West, T.M. (1989) The control of broad-leaved weeds in sunflower in England. Brighton Crop Protection Conference - Weeds, 1989, 3, 871-876.

Grolleau, G.; Millet, J.C. (1986) Use of aclonifen for weed control in sunflowers. Commptes Rendus de la 13e Conference du Columa, **1**, 127-136.

Johnson, B.J. (1971) Effect of weed competition on sunflowers. Weed Science, **19**, 378-380.

Nalewaja, J.D.; Collins, D.M.; Swallers, C.M. (1972) Weeds in sunflowers. North Dakota Farm Research, **29**, 3-6.

Woon, C.K.; Porter, O.A.; Phillips, H.F. (1984) Field evaluation of herbicides for sunflowers. Arkansas Farm Research **33**, 2.

THE POTENTIAL FOR REDUCING HERBICIDE APPLICATION RATES AND VOLUMES IN KENYAN COFFEE

J.K KIMEMIA, J.M. NJOROGE

Coffee Research Foundation, P.O. Box 4, Ruiru, Kenya

ABSTRACT

Weeds may reduce coffee yields by more than 50%. In Kenya several soil and foliage applied herbicides are recommended for use in coffee plantations. These are usually expensive in terms of the amounts of herbicide and water used and they are therefore largely out of reach of small scale coffee farmers. Furthermore, high application rates may have adverse environmental effects. The development of low volume nozzles has enabled a reduction of 50% in both herbicide application rates and water volumes. Low rates of herbicide application would lead to sustained weed management in coffee production. This paper reports on results obtained in experimental work carried out at the Coffee Research Station, Ruiru, Kenya between 1988 and 1990.

INTRODUCTION

Weeds compete with cultivated crops leading to yield and quality losses. Estimates indicate that worldwide losses attributed to weed effects are about 10%, but with great variations between countries (Fletcher, 1983). In Kenya, weeds have caused up to more than 50% loss in coffee (*Coffea arabica*) yields (Njoroge & Kimemia, 1990).

Various methods have been used to control weeds ranging from cultural and mechanical to chemical methods. In Kenyan coffee farming there are various foliage applied herbicides recommended for use (Anon., 1991). These are mainly used by estate farmers (Roe & Whitaker, 1985) and their use by small scale farmers is very low (Nyoro, 1988).

The increased use of herbicides in both temperate and tropical countries, together with the rising costs has resulted in greater awareness of the need to develop appropriate application methods (Mathews & Garnett, 1983). Recently, the collapse of the International Agreement in 1989, led to a nosedive in coffee prices which then compared unfavourably with the production costs. There is a need therefore to find ways of reducing the production costs of coffee, one of which is to reduce the application rates of the recommended herbicides. The development of low volume sprayer nozzles has made it possible to apply herbicides in low water volumes and still control weeds effectively (Breay, 1981; Njoroge, 1990).

MATERIALS AND METHODS

The initial experiment was carried out from October 1987 to June 1988 at the Coffee Research Station, Ruiru (1.06°S, 36.4°E, 1608 m asl), and aimed to test glyphosate (36% w/v; Roundup) at low application rates as a general herbicide for control of annual weeds in coffee plantations, in particular, Parthenium hysterophorus and Bidens pilosa. These last two weeds have shown tolerance to paraquat (Njoroge, 1986). The herbicides were applied with a Cooper Pegler CP3 knapsack sprayer fitted with a Lurmark AN 1.0 nozzle. A low application volume of water of 80 l/ha was compared to the normal volume of 250 l/ha. Paraquat (20% w/v; Gramoxone 100) at 300 g/ha in 250 l/ha of water was used as a standard. The herbicides were applied to mature arabica coffee cv. French Mission spaced at 3.1 x 3.1 m. The treatments were arranged in a complete randomised block design with three replicates; plot size was one inter-row x ten coffee trees in length.

Visual assessments of weed ground cover were made monthly in all plots and scored as follows:

% weed ground cover	0	2.5	5	10	15	25	35	85	100
Weed score	1	2	3	4	5	6	7	8	9

The results of the first experiment encouraged the testing of some other foliage applied herbicides at low rates of application. Thus, a subsequent trial was carried out from June to December 1990 at the Coffee Research Station, Ruiru. Five herbicides, namely glufosinate-ammonium (20% w/v; Basta 20 EC), paraquat, glyphosate + simazine (10% w/v + 28% w/v; Ricochet) and two formulations of glyphosate, (9% w/v; Kamata) and (18% w/v; Sting), were applied at half and quarter recommended rates in 80 l/ha of water. Full recommended rates are 400-600 g/ha glufosinate-ammonium, 400 g/ha paraquat, 500-700 g/ha glyphosate + 1400-1960 g/ha simazine and 270-540 g/ha glyphosate (both 9% and 18% formulations). Low rate glyphosate (36%) at 360 g/ha and the recommended rate of paraquat at 400 g/ha, both in 250 l/ha of water were used as standards. The herbicides were applied to mature coffee trees, cv. French Mission with a CP3 knapsack sprayer fitted with a Lurmark 0.1 N nozzle. Herbicides were sprayed in June in June 1990 and later treatments depended on the weed regrowth in specific plots. Treatments were replicated four times in a complete randomised block design; each plot was one inter-row x ten coffee trees spaced at 3.1 x 3.1 m. Weed ground cover was scored visually using the same scale as in the first experiment and the scores were subjected to analysis of variance.

RESULTS

The results of the first experiment are shown in Table 1. Glyphosate treatments reduced overall weed scores compared to paraquat and the unsprayed control. Paraquat failed to kill Bidens pilosa and Parthenium hysterophorus, but these were effectively controlled by glyphosate.

In the following experiment in 1990 (Table 2), glufosinate-ammonium at 200 g/ha achieved 75% weed control, similar to the low rate glyphosate (36%) at 360 g/ha, but the but the lower rate of glufosinate-ammonium was inferior. The low rate of paraquat at 200 g/ha in 80 l/ha was as effective as the normal recommended rate of 400 g/ha in 250 l/ha water, attaining 85% weed control. The half and quarter rates of glyphosate +

simazine gave similar levels of weed control to the recommended low rate glyphosate (36%). The 9% and 18% formulations of glyphosate also achieved similar results to the standard glyphosate treatment. Compared to the untreated control, the half doses of the herbicides tested all gave significant levels of weed control at the end of the experiment, but most of the quarter doses did not. Paraquat and glyphosate + simazine did not effectively control Bidens pilosa, but the other herbicides tested gave some measure of control. Cyperus species also proved a difficult weed tocontrol with all the herbicides and rates because of the persistence of the tubers which are unaffected by herbicides (Keighley, 1983).

TABLE 1. Treatment effects on weed scores, 1987-88.

Herbicide	Rate g a.i./ha	Volume of water l/ha	Overall weed scores (all spp) 1987 Dec	1988 Feb	Apr	Jun	Mean
Glyphosate (36%)	180	80	8	3	8	6	6
Glyphosate (36%)	180	250	9	4	8	6	7
Glyphosate (36%)	360	80	8	4	8	5	6
Glyphosate (36%)	360	250	7	3	7	5	5
Paraquat (20%)	300	250	8	9	8	8	8
Untreated	-	-	8	9	8	9	8
LSD (P<0.05)			NS	2	NS	1	-

TABLE 2. Treatment effects on weed scores 1990.

Herbicide	Rate g a.i. /ha	Volume of water l/ha	Overall weed scores (all spp.) Jun	Jul	Aug	Sep	Nov	Dec	Mean
Glufosinate	100	80	7ab	7ab	5a	6ab	7ab	8ab	7
-ammonium	200	80	6ab	6ab	4ab	6ab	7ab	5cd	6
Paraquat	100	80	7ab	7ab	4ab	6ab	8a	8ab	7
Paraquat	200	80	5b	5b	3b	5b	6bc	7bc	5
Glyphosate	200+560	80	7ab	6ab	4ab	6ab	7ab	8ab	6
+ simazine	250+700	80	6ab	5b	3b	5b	7ab	7bc	6
Glyphosate (9%)	90	80	7ab	6ab	4ab	4bc	8a	8ab	6
Glyphosate (9%)	180	80	6ab	7ab	4ab	6ab	8a	7bc	6
Glyphosate (18%)	90	80	6ab	7ab	4ab	6ab	8a	7bc	6
Glyphosate (18%)	180	80	5b	5ab	3b	5b	6bc	5cd	5
Glyphosate (36%)	360	250	6ab	4b	4ab	7a	6bc	6c	6
Paraquat (20%)	400	250	6ab	7ab	3b	5b	4d	4d	5
Untreated	-	-	8a	8a	7a	9a	9a	8a	8

Means in each column followed by the same letter are not significantly different at the 5% level using Duncan's Multiple Range Test.

DISCUSSION

The results of these experiments suggest that low rates of the herbicide glyphosate in reduced volumes of water can give effective controlof most of the common annual weeds in coffee at an early weed growth stage (1-4 leaves). The most effective reduced rate treatments were the 36% formulation of glyphosate applied at 180-360 g a.i.ha in 80-100 l/ha with low volume nozzles. If herbicide doses and application volumes can be reduced, this means that herbicides will be more widely available to farmers, especially small farmers. The resulting improvements in weed control will lead to higher yields and quality, which, in turn, will improve the farmer's margin. Furthermore, commercial adoption of low herbicide doses will reduce the risks of potentially adverse effects of chemicals in the environment. It is envisaged that the future for chemical weed control in Kenyan coffee lies in the development of a low dose/low volume approach.

ACKNOWLEDGEMENTS

The authors wish to thank members of the Agronomy section at the Coffee Research Station, Ruiru for their assistance. This paper is published with the kind permission of the Director of Research, Coffee Research Foundation.

REFERENCES

Anon. (1991) Weed control in coffee. Kenya Coffee, 56, 1043-1046

Breay, T. (1981) Low volume, high pressure post-emergence application. British Sugar Beet Review, 49, p. 50.

Fletcher, W.W. (1983) Recent Advances in Weed Science. London: Commonwealth Agricultural Bureaux, 1-2.

Keighley, V.T. (1989) The Cyperus problem: A review of literature and recent advances in Kenya. Proceedings of the Twelfth Biennial Conference of the Weed Science Society for East Africa, 1, 12-18.

Mathews, G.A.; Garnett, R.P. (1983) Herbicide application. In: Recent Advances in Weed Science, W.W. Fletcher (Ed.), London: Commonwealth Agricultural Bureaux, 121-140

Njoroge, J.M. (1986) New weeds in Kenya coffee - a shortcommunication. Kenya Coffee, 51, 353-355.

Njoroge, J.M. (1990) Glyphosate (Roundup) low rate on annual weeds in Kenyan coffee. Kenya Coffee, 55, 719-721.

Njoroge, J.M.; Kimemia, J.K. (1990) A comparison of different weed control methods in Kenya coffee. Proceedings of the Twelfth Biennial Conference of the Weed Science Society for East Africa, 1, 99-106.

Nyoro, J.K. (1988) Management practices and input usage on smallholder coffee farms in Kenya. Kenya Coffee, 53, 349-359.

Roe, J.D.M.; Whitaker, M.J. (1985) Economics of estate coffee production. Kenya Coffee, 50, 409-427.