SESSION 3A

WEED CONTROL AND WEED CONTROL STRATEGY IN ARABLE CROPS

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UNDERSTANDING HOW TO CONTROL WEED BEET IN SUGAR BEET

P.C. Longden
Broom's Barn Experimental Station, Higham, Bury St.Edmunds, Suffolk IP28 6NP

Summary. Weed beet affects an increasing area of arable land in many countries including England. Developmental observations made in sugar beet crops at 15 sites in 1979, 1980 and 1981 showed that reproductive beets ('bolters') appeared from late May and started to flower around 12 July. About 35 days later the first viable seeds were found. Several control measures were tested. Cutting bolters down three times at fortnightly intervals starting 14 or 28 days after flowering began achieved 92 to 100% control. Two cuts were often satisfactory but one cut only gave adequate control on a third of the occasions tested. Cutting treatments started 42 days after flowering started were not satisfactory. Glyphosate applied selectively through a rope wick applicator on two occasions starting at the onset of flowering or 14 days later reduced viable seed production by 95 to 100%. Many bolters escaped when two treatments were made before and at flowering. Development studies, flowering, viable seed, cutting, glyphosate, selective applicator.

INTRODUCTION

The ways in which sugar beet can become a weed have already been described (Longden, 1974), and the genetic origins discussed (Hornsey & Arnold, 1979). It is evident that weed beet develop from soil reserves of seed shed by reproductive beets ('bolters') arising from groundkeepers, easy bolting types in root crops or plants which are annuals resulting from pollen contamination during seed multiplication. The problem has increased in recent years in that proportions of the English sugar-beet crop infested with weed beet seedlings between the rows of beet were 18.1, 24.5, 21.8 and 26.9% respectively during the four year period 1978 to 1981 (Maughan, 1982). This implies that about a quarter of the English sugar-beet root crop, or 70,000 ha, is infested. However, to arrive at the true area of land affected, this area must be multiplied by a factor of three or four because most beet is grown on a one in three or four year rotation and it must be assumed that other land currently growing other arable crops also contains viable seed.

The position in other European countries is no better. Estimates of the proportions of the 1981 sugar-beet crop affected by bolters were 100, 100, 72, 84, 22, 76 and 75% for Belgium, Denmark, France, West Germany, Ireland, Netherlands and Sweden respectively, totalling 1.18 million hectares (Longden, 1982). The problem has also been reported in Israel (Cohen, 1977) and in the U.S.A., notably in Washington (Howell & Mink, 1970) and California (McFarlane, 1975).

A weed, such as beet, which propagates itself by seed will be brought under control if a strategy of preventing seed production is followed, and the soil burden of viable seed is then gradually exhausted. Our experiments have therefore sought to describe the development of seed producing beets to define stages at which control measures are likely to be effective in preventing seed production. We then tested some control methods.

METHODS AND MATERIALS

In order to sample a range of sites and seasons, a total of 15 trials were made (five in 1979, six in 1980 and four in 1981) in farmers' crops of sugar beet. Suitable fields were located by British Sugar fieldstaff. Bolting started in late May/early June and each site was then visited regularly to determine the start of flowering. Thereafter, sample rows, each of 15 bolters, were collected at fortnightly intervals, and divided into the parts of the indeterminate racemose inflorescence which were borne above and those within the crop canopy. The separated samples were then air-dried in loose-weave hessian sacks and threshed. After cleaning, the seed was tested for germination in the laboratory in pleated paper according to standard methods (Hibbert & Woodwark, 1969). One set of samples was collected from each site to describe the development of untreated bolters. In other plots in the same experiment the development of bolters was interrupted by cutting off the inflorescences above the crop at different times. In 1979 cutting treatments were done either once, twice or three times at fortnightly intervals starting at early, peak or late flowering stages of development. Because single applications and treatments starting at early stages of flowering were less effective than multiple treatments starting later, in 1980 cutting was done twice or three times starting at peak, late or late + 14 days flowering stages. This last treatment was clearly too late and so cutting treatments were further reduced in 1981. By this time suitable wick applicator equipment had appeared with which to apply non-selective herbicides only to the bolters which largely grow above the crop canopy, and a range of double applications of glyphosate (50% solution of water and Roundup) at different times and intervals were compared with five fortnightly treatments starting about two weeks before flowering. In all these plots the seed produced at the time of making the treatment was collected, and later any regrowth, particularly from cut plants, was also harvested and tested for viable seed. For convenience, and to facilitate the understanding of comparisons, results have been expressed as viable true seed units produced per bolter, which indicates the potential of each bolter to produce seedlings, and control measures expressed as the percentage reduction in viable seed numbers relative to the untreated control at each site. Results have also been related to the days from flowering when treatments were made rather than diary dates which differed for almost every experiment.

RESULTS

The dates on which flowers first opened varied a little from year to year, averaging 12 July. There was considerable variation from site to site within a year, the largest difference being in 1980, from 30 June at a site in the Bury St. Edmunds factory area to 29 July at Kidderminster.

Viable seeds were first detected from 28 to 42 days after the onset of flowering (Fig. 1). The numbers of viable seed per bolter increased rapidly during August to reach a peak 70 to 84 days after the start of flowering ranging from 304 (Kidderminster, 1979) to 6603 (Ely, 1980) viable seeds per bolter (Table 1). Seed production also varied from year to year being greater in 1980 and 1981 than in 1979. An average peak number of 1919 viable seeds per bolter occurred in these experiments in the first half of September. Shedding then commenced, which reduced the numbers of viable seed harvested but not of course the numbers returned to the soil.

Fig. 1

Number of viable seeds per bolter at different numbers of days from flowering in 1979, 1980 and 1981

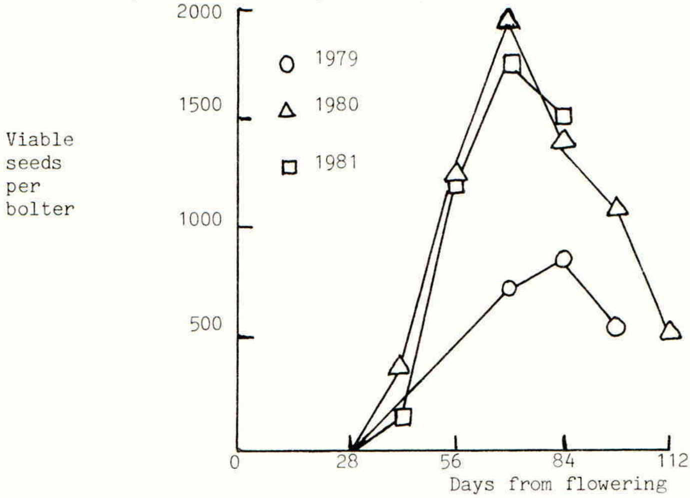

Table 1

Peak numbers of viable seeds per bolter

Site	1979	1980	1981
Bury St. Edmunds	1390	1370	1651
Cantley	569	2317	1891
Ely	-	6603	-
Kidderminster	304	1412	-
King's Lynn	1199	2350	1296
Wissington	1542	1817	3088

Against the background of viable seed development, treatments were planned to prevent viable seed production and so were concentrated in the period from 14 days before to 28 days after the start of flowering. Treatments which involved cutting down the bolters always reduced viable seed production with three cuts being generally superior to two which in turn were generally better than one. Particularly good control of viable seed production was achieved in 1979 with three cuts at 14 day intervals starting 14 or 28 days after flowering (Table 2). Also effective were three cuts starting when flowering commenced and two cuts starting 14 or 28 days after flowering and one cut 28 days after flowering started. These results were as expected in that the more times cutting was done the greater was the reduction in viable seed formed. Also some loss of efficiency occurred with the single cut when carried out progressively earlier up to the onset of flowering. This was because early cutting in particular only controlled those bolters present at that time. Others which appeared later, and therefore escaped a single early cut were capable of producing seeds.

Table 2

Percentage reduction in viable seed production following cutting in 1979

Days from flowering when cut					Site				
0	14	28	42	56	Bury St. Edmunds	Cantley	Kidder-minster	King's Lynn	Wissing-ton
X	-	-	-	-	66	85	83	92	91
-	X	-	-	-	72	87	98	92	95
-	-	X	-	-	98	99	99	98	99
X	X	-	-	-	44	90	99	73	76
-	X	X	-	-	96	86	≃100	99	98
-	-	X	X	-	97	98	99	99	99
X	X	X	-	-	98	96	100	99	94
-	X	X	X	-	99	99	100	≃100	≃100
-	-	X	X	X	≃100	99	99	100	100

In 1980, three cuts starting 14 or 28 days after flowering started were again the best treatments (Table 3),although two cuts starting 14 or 28 days after flowering started were almost as effective in preventing viable seed production. There were no single cut treatments in 1980. Two or three cuts starting 42 days after flowering began gave poor control because viable seed were already present before the first cut was made.

Table 3

Percentage reduction in viable seed production following cutting in 1980

Days from flowering when cut					Site					
14	28	42	56	70	Bury St. Edmunds	Cantley	Ely	Kidder-minster	King's Lynn	Wissington
X	X	-	-	-	89	96	96	100	92	92
-	X	X	-	-	97	97	99	78	92	94
-	-	X	X	-	90	92	96	37	88	89
X	X	X	-	-	99	99	98	≃100	97	93
-	X	X	X	-	99	97	≃100	98	99	92
-	-	X	X	X	98	89	97	37	43	94

In 1981 there were no triple cut treatments. Two cuts 14 and 42 or 28 and 42 days after flowering started gave good control (Table 4); a single cut 28 days after the onset of flowering, giving only 88% average reduction in seed numbers.

Table 4

Percentage reduction in viable seed production following cutting in 1981

Days from flowering when cut				Site			
14	28	42	56	Bury St. Edmunds	Cantley	King's Lynn	Wissington
X	-	X	-	98	93	94	85
-	X	X	-	96	90	96	86
-	X	-	X	93	84	95	91
-	X	-	-	98	93	87	74

Also in 1981, chemical control treatments were introduced and treatment with glyphosate (50% solution of water and Roundup) in a Weedwiper gave excellent control over seed production, with the exception of two applications about 14 days before and at flowering (Table 5). Five applications, aimed at giving complete control, were not superior to two since the latter gave virtually complete control.

Table 5

Percentage reduction in viable seed production following glyphosate application in 1981

Days from flowering when treated					Site			
-14	0	14	28	42	Bury St. Edmunds	Cantley	King's Lynn	Wissington
X	X	-	-	-	89	92	81	80
X	X	X	X	X	≃100	99	≃100	≃100
-	X	X	-	-	99	≃100	95	98
-	-	X	X	-	≃100	≃100	98	98
-	X	-	X	-	≃100	97	98	98
-	-	X	-	X	≃100	≃100	≃100	≃100

DISCUSSION

Although there was considerable variation (up to one month) in the date of first flowering between sites in any one year, the similarity in average flowering dates over the three years (12 July a day) may indicate flowering is more dependent on daylength than on the weather during a particular season. The degree to which the site-to-site variation might be genetic due to slightly different strains having developed at different locations is uncertain.

Viable seeds were found 28 to 42 days after flowering. With more precise knowledge of the energy required to drive a flower from opening and pollination to viability it should be possible to record the current season's flowering date and temperatures to enable predictions to be made as to when viable seed are likely to appear. Specific advice on the timing of control measures could then be given to prevent viable seed production. In our experiments this was around mid-August, but in a warm season, such as 1976, it could well be the end of July.

As expected, the critical period for control of bolters was between their appearance (the first come in late May or early June) and the production of viable seed (mid-August). Because the bolters appear as a population over a period of time, and because the opening of first flowers is an identifiable development stage, our experiments concentrated on investigating control measures covering the period between the start of flowering and the appearance of the first viable seed i.e. from early July to mid-August.

Before considering the efficacy of control treatments, some consideration should first be given to the level of control which can be considered satisfactory. This depends on many factors including the numbers of seeds shed initially, the number which die in the soil or germinate and are killed in intervening crops, the number of intervening crops and the establishment in the next sugar-beet crop, but attempts to model the situation suggest that at least 90% control is necessary.

Three fortnightly cuts starting at the onset of flowering or 14 or 28 days later always achieved this. Three cuts, starting 42 days after flowering, did not, because live seeds were already present when the first cut was made. Two fortnightly cuts starting 14 or 28 days after flowering commenced also achieved acceptable control, except at Kidderminster in 1980, where seed production appeared to be precocious, and at Wissington in 1981. Two cuts starting 42 days after flowering began in 1980 gave erratic control. Single cuts were also erratic, the best being that done 28 days after the start of flowering. Chemical treatments carried out at or after the start of flowering were very effective.

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POPULATION DYNAMICS OF WEED BEET

J.S.Gunn
Agricultural Development and Advisory Service,
Shardlow Hall, Shardlow, Derby DE7 2GN

Summary. Between 1976 and 1982 the occurrence of weed beet through all crops of the arable rotation was studied in 274 fields known to be infested and distributed throughout the sugar beet growing areas of England. The study indicates a strong association of weed beet with close rotational cropping of sugar beet in which it most commonly occurs. Its incidence in other crops varies - usually being low in winter and spring cereals, but common in potatoes and peas. The method and timing of seedbed cultivations also influences the germination and emergence of weed beet, spring work favouring it. Weed beet most commonly occur on light soils, but this appears to be attributable more to the cropping sequences practised on these soils than to inherent characteristics of the soils themselves. In individual fields weed beet seeds may remain viable to emerge in sugar beet crops grown up to seven years after the last fresh introduction of seed, and instances of longer survival are known. Sugar beet, incidence, persistence, rotation, cultivations

INTRODUCTION

The importance and occurrence of forms of *Beta vulgaris* L. as weeds in sugar beet crops was first recognised in the United Kingdom about 1974 (Longden, 1976). Since then, a considerable programme of survey work and research directed towards achieving effective prevention of further introductions and control of weed beet has been undertaken (Longden, 1982). The work described in this paper is part of that programme.

The origins of weed beet are discussed by Arnold (1977), and Hornsey and Arnold (1979). They have shown that the problem derives from (a) contaminated sugar beet seed, a source now effectively eliminated, (b) seed shed from 'normal' bolters in the sugar beet crop, (c) seed shed by sugar beet groundkeepers growing in other crops of the rotation, (d) seed shed by other weed beet.

Weed beet are most obvious and significant in the sugar beet crop, but the seed may also germinate in other crops (and on waste land or roadsides). When allowed to grow unchecked, the plants flower and most arable crops remain in the ground long enough to allow the weed beet to produce seed. A serious infestation can build up over three cycles of sugar beet cropping.

Since 1977 the British Sugar Corporation (now British Sugar) has carried out an annual random sample survey to determine the occurrence and level of infestation of weed beet in the current national sugar beet crop. These surveys have shown that the incidence of misplaced seedlings (weed beet) has risen steadily from 14.7% in 1977 to 27.1% in 1981 with some seasonal and regional variation (Maughan, 1982). The majority of fields are infested at fairly low level, but more than 10% in 4 factory areas are seriously infested. The survey shows that incidence is affected by length of rotation, close rotations leading to more weed beet, and that weed beet occur more frequently on lighter soils. However, sugar beet is most commonly grown in close rotation on such soils and data presented here will suggest that this may be more important than soil type *per se*. The British Sugar survey uses a different random sample of fields in each year; the work reported in this paper involves the study of the same fields through the arable rotation over a period of years, all of which harboured weed beet at the outset.

METHODS AND MATERIALS

Between 1974 and 1977 some 300 fields were identified by staff of British Sugar and Brooms Barn Experimental Station as being infested with weed beet. The level of infestation was not recorded, but in general was in the severe or moderate categories described below. Since 1977 ADAS staff have visited these fields each year to observe the level of occurrence of weed beet and record various cropping and husbandry details. A few fields have had to be discarded for various reasons over the period, but in 1982 it has been possible to carry out full analysis over all years for all factors recorded on 266 fields. A different observer has been involved each year but there has been good conformity in the standard of assessment. The incidence of weed beet was assessed in the following categories.

1. Severe, overall;
2. Moderate, more than 50 patches per hectare;
3. Slight, less than 50 patches per hectare;
4. Occasional plants;
5. None.

These groupings correspond closely to the categories used in the British Sugar survey.

This procedure recognises the difficulty of accurately quantifying typically patchy infestations especially at the seedling stage under crop canopies as in cereals. Weed beet can be more readily seen in sugar beet, potatoes, peas and some horticultural crops. All the fields could only be visited once; some return visits were made later to assess seed production and efficiency of control measures but these are not reported in this paper.

The data was recorded on Cope Chatterton index cards and processed by 'Package X' through the MAFF computer at Guildford. Because the fields represent the whole population of those known to be infested when the work started, the data is not suitable for normal statistical analysis and is therefore presented without any attempt at formal validation. A further problem of analysis arises from the interactive effects of various husbandry factors both within and between years. Moreover because farmers' choice of crops and cultivation procedures varies from year to year, the numbers of fields in particular category groupings is irregular. In order therefore to allow direct comparisons to be made, most values are presented as percentages.

Another inherent problem in analysing the data is the inevitable occurrence of some 'false negative' observations. These arise for several reasons: (a) weed beet may be present in the soil but not emerge in each year, (b) slight infestations may have been missed by the observer partly because visits had often to be made after herbicides had been applied to the crop and thus some weed beet plants may have been killed (except in sugar beet), but an effort was made to look for killed or weakened plants. As the study progressed some farmers took steps to control weed beet and this must have influenced the data for the later years. Analysis was carried out both nationally and by ADAS Region. Regional differences are fairly small and therefore to limit the size of tables only national data are presented here for the years 1979-82. Details for earlier years are given elsewhere, Gunn (1979); Gunn and Dunkerton (1981). Values deriving from only a small number of observations are enclosed in brackets.

RESULTS AND DISCUSSION

All fields were infested with weed beet at moderate to severe level between 1974 and 1977; Table 1 clearly shows the subsequent decline in incidence (1980 was a 'successful' year for weed beet emergence). This decline is in direct contrast to the increase in national incidence of weed beet shown by the British Sugar surveys (Maughan, 1981 and 1982) and is almost certainly attributable to the fact that the farmers in the ADAS study have been visited every year and are taking measures to control the spread of weed beet.

Table 1

Incidence of weed beet by year

Crop year	No of fields	Percentage of fields in each category of infestation				
		Severe	Moderate	Slight	Occasional	None
1978	235	0.9	5.1	1.4	37.0	50.6
1979	291	1.4	3.4	3.1	15.1	75.9
1980	284	1.8	3.9	9.8	20.4	63.7
1981	274	0.4	3.6	5.5	10.2	80.3
1982	274	0	2.2	4.7	12.4	80.6

Table 2

Incidence of weed beet by crop

Crop and year	Number of fields	Percentage of fields in each category of infestation				
		Severe	Moderate	Slight	Occasional	None
Winter Cereals						
1979	138	1.4	1.4	2.2	8.0	87.0
1980	127	-	-	3.9	10.2	85.8
1981	116	-	-	2.6	5.2	92.2
1982	145	-	0.7	0.7	4.8	93.8
Spring cereals						
1979	65	-	1.5	-	20.0	78.5
1980	37	-	-	2.7	13.5	83.8
1981	46	-	2.2	-	4.3	93.4
1982	43	-	-	2.3	16.3	81.4
Sugar beet						
1979	34	5.9	17.6	14.7	35.3	26.5
1980	77	5.2	11.7	2.6	39.0	18.2
1981	68	2.0	11.7	17.6	23.5	45.5
1982	38	-	10.5	23.7	42.1	23.7
Potatoes						
1979	15	-	6.6	-	26.6	66.6
1980	15	6.7	6.7	13.3	33.3	40.0
1981	16	-	6.6	-	20.0	73.3
1982	16	-	-	12.5	18.7	68.7

Weed beet also commonly occur in peas. No weed beet were found in leys (44 observations) between 1979-82, but some were found previously.

Table 2 shows that weed beet occur more often in spring cereals than in winter cereals, but in both at a much lower level of infestation than in other spring-sown (or planted) arable crops, especially sugar beet, potatoes and peas and (not shown) some vegetable crops.

The data in table 3 suggest that once infestation with weed beet has occurred the survival and emergence of the seed is not strongly influenced by soil type. However, close rotation of sugar beet is common on light land and it appears that the build-up of weed beet on such soils is a consequence of this cropping pattern rather than of inherent soil characteristics, but obviously the two aspects are inextricably linked.

Table 3

Incidence of weed beet by soil type

ADAS Soil Group	Proportion of fields in each group %	Percentage of fields in all categories of infestation (ie 1-4) 1979	1980	1981	1982
Sands	9.8	26.9	26.9	32.0	15.4
Very light	25.7	19.2	34.9	19.7	14.7
Light	34.3	20.0	45.1	17.8	18.7
Medium	24.2	31.1	39.1	22.4	25.0
Heavy	5.7	16.7	26.3	11.7	26.7

Table 4

Effect of interval between sugar beet crops on incidence of weed beet

Years since last sugar beet (s.b.) crop	Percentage of fields in all categories of infestation 1979	1980	1981	1982
8	-	-	-	0.0
7	-	-	0.0	22.2
6	-	30.4	15.4	(33.4)
5	16.1	39.5	(66.7)	18.5
4	30.4	33.3	69.5	17.2
3	61.6	45.8	34.3	31.4
2*	7.0	49.3	12.1	13.0
1*	34.7	48.4	11.0	22.5

* The crops in these years cannot be sugar beet.

Table 4 shows that in seriously infested fields it requires at least 6 years without further seed return before weed beet populations will fall to the level at which sugar beet can again be confidently grown, and there are instances known of weed beet persisting for longer periods than this.

Table 5

Effect of rotational sequences from 1974 to 1982 on incidence of weed beet in 1982

Rotation	No of fields	Percentage of fields in each category of infestation Severe	Moderate	Slight	Occasional	None
3 Course						
2 cereals, s.b.	126	-	2.3	7.9	20.6	69.0
4 Course						
3 cereals, s.b.	26	-	-	7.7	23.1	69.2
2 cereals, pots, s.b.	13	-	-	23.1	38.5	38.5
2 cereals, peas, s.b.	(2)	-	-	-	-	(100)
5 Course						
3 cereals, peas, s.b.	(3)	-	-	-	-	(100)
4 cereals, s.b.	(3)	-	-	-	(33.3)	(66.7)

By 1982 it is just possible to begin to evaluate the effect of rotations, but even now the longer cropping sequences are only sparsely represented and the shortest sequences, typically two cereals followed by sugar beet, have only completed two cycles within the period of study. Other cropping sequences than those identified in table 5 are so far insufficiently represented to allow comment. The data shows that short rotations contribute to a build-up of weed beet if effective control measures are not taken (see also Table 4).

Table 6

Effect of cultivation programme and timing on incidence of weed beet

Operation	Timing	Percentage of fields in all categories of infestation (ie. 1-4) 1979	1980	1981	1982
Ploughed	Autumn	23.1	35.6	19.4	20.1
	Spring	29.6	65.0	27.3	28.6
	None	9.5	14.3	9.1	11.9
Cultivated	Autumn				
after ploughing		14.2	34.1	11.2	5.9
not ploughed		6.3	12.5	0.0	11.6
Cultivated	Spring				
after ploughing		35.1	41.3	29.2	33.4
not ploughed		20.0	0.0	23.3	0.0
Cultivated after ploughing	Autumn & spring	-	71.5	-	43.5
No cultivation after ploughing	Autumn or spring	(0.0)	30.6	(0.0)	4.8
Direct drilled	Autumn or spring	(20.0)	0.0	0.0	(8.3)

Cultivations are directly linked to intended cropping. Thus it is not surprising that in arable rotations which include sugar beet and other crops, especially potatoes, for which ploughing is normal practice, few fields were left unploughed over any two-year period. The proportion autumn ploughed each year ranged from 63.9 to 78.9%; ploughed in spring from 7.1% to 18% and unploughed from 4.2 to 17.4%. Ploughing, especially in spring, seems to have encouraged the emergence of weed beet; this may be beneficial when opportunities to destroy the weed beet exist in the following crop, a situation which applies to all crops except sugar beet. This result is in direct contrast with the results reported by Cussans and Bastian (1981) when dealing with a first time seeding of weed beet, but the fields in the ADAS study were already infested with weed beet seed which was being ploughed up again, so the results do not in fact conflict.

Autumn cultivation naturally coincides with cropping with winter cereals in which the incidence of weed beet is low. Cultivation in spring, especially following ploughing, appears to encourage the emergence of weed beet in spring-sown crops. This suggests that drilling on a stale seedbed may provide a partial remedy to control weed beet in sugar beet. Direct drilling is currently being evaluated in trials at the Norfolk Agricultural Station,

Detailed experiments now in progress at the Weed Research Organisation and Broom's Barn Experimental Station test the influence of different cultivation practices on survival and emergence of weed beet seed in a limited series of crop rotations. These experiments are running in parallel but several years 'behind' the study reported in this paper; so far the results from both appear to be in broad agreement. There will be an opportunity for these workers to make a closer study of fields in the ADAS investigation having comparable infestation and cropping history, to aid the provision of guidelines for sugar beet growers seeking to avoid or reduce weed beet infestations.

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THE CONTROL OF SUGAR BEET BOLTERS AND WEED BEET BY THE HEIGHT -SELECTIVE APPLICATION OF THE ISOPROPYLAMINE SALT OF GLYPHOSATE

A.J. Norton
Monsanto p.l.c., Thames Tower, Burleys Way, Leicester LE1 3TP, U.K.

Summary. The increase in the problem of weed beet incidence in the sugar beet crop of the U.K. and other countries has led to investigations into new methods of control where cultural practices have been inadequate.

Machines initially designed to apply the IPA salt of glyphosate to tall weeds in row crops in the U.S.A. were modified for use in sugar beet. The most successful machines using ropes saturated in the chemical, wipe it on to bolting beet above the crop canopy with sufficient herbicide to kill the target plants and to reduce the seed viability to a low level, minimising carry-over into following crops.

Provided correct timings and number of applications were made, reductions of viable seeds per bolter up to over 99% were possible. The chemical cost per hectare was directly related to the infestation and was generally low. This paper describes the machinery, and the experiments conducted to determine correct treatment schedules. Ropewick, seed viability, weed control, crop safety.

INTRODUCTION

Bolting sown sugar beet and annual weed beet (Beta vulgaris L.) have become an important and increasing problem in the sugar beet growing areas of the U.K. and Europe. A 1981 survey showed a variation from 1.5% of the sugar beet crop area infested with weed beet in Denmark to 46.8% in France (Longden, 1982) prior to tractor hoeing.

Cultured populations of Beta types have produced between 10,000 and 53,000 viable seeds per m² (Cussans, 1982) and although tractor hoeing, crop rotations, hand pulling, ploughing, cutting, and chemical control in other crops can all reduce significantly the numbers of seedlings, a considerable number may still occur in a subsequent beet crop (Longden, 1982). This paper desribes a recently developed technique which has proved very effective for applying a herbicide, the isopropylamine salt of N-(phosphonomethyl) glycine, the commercial formulation of which is sold by Monsanto p.l.c. under its Registered Trade Mark 'Roundup' to the tall growing parts of the bolting beet plant.

The formulation containing 480 g/l of the IPA salt (equivalent to 359 a.e. glyphosate) is a broad spectrum total herbicide with the activity to control a wide range of grass and broad-leaved species (O'Keeffe, 1982).

In order to apply the herbicide to the tall growing bolters only, in the otherwise susceptible sugar beet crop, a system was devised using machines originally designed to apply the IPA salt of glyphosate to tall growing grass weeds in soyabeans and cotton in the U.S.A.

In 1980 and 1981, British Sugar Corporation, Broom's Barn Experimental Station and Monsanto p.l.c. conducted a series of experiments to determine the best concentrations of chemicals, and correct timing and number of applications at various locations in the S.East of England.

Work was also done in France and Belgium (Vigoureux, 1982) which supports the findings of the U.K. experiments.

METHODS AND MATERIALS

Following preliminary trials work in 1980, Monsanto in association with Broom's Barn Experimental Station and the British Sugar Corporation conducted two replicated field trials using two different machine types. These machines consist of reservoirs of plastic tube connected to nylon ropes. Capillarity or pressure feed supplies the herbicide to the ropes, which become saturated almost the the point of dripping. The herbicide can then be transferred to any tall growing plant above the crop canopy without damage to the crop itself, by mounting the machine at the rear of a suitable tractor on the 3-point linkage; widths from 2m to 6m were used and height above the crop was controlled both mechanically and hydraulically. Two concentrations of the formulated product of the IPA salt of glyphosate were used namely 50% and 33% concentrations in water corresponding to 179.5 and 118.5 g.a.e./l respectively. In addition, 4 replicated trials were carried out by Dr. P. Longden of Broom's Barn using a hand-held section of one machine at one concentration of 50% (179.5 g.a.e./l) but several combinations of treatment timings in relation to the flowering period of the weed beet, namely, an estimated 14 days prior to initiation of flowering and 14, 28, and 42 days after flowering commenced. A further trial was carried out at Holmewood Hall, by C. Fletcher of the British Sugar Corporation, where height-selective chemical application was compared to electrothermal control (Diprose, 1978) and mowing (Longden, 1981). Two applications were made at different timings and a single concentration of 50% (179.5 g.a.e./l) was used. At the various sites, different plot sizes were employed in relation to the size of machines used, varying from 6m wide to 2m wide. Plot lengths varied from field width to 20m and 2 to 4 replications were used. The two Monsanto p.l.c. trials included a three application programme where each treatment was replicated twice at each application timing. Timings were: the second week of July, the last week of July and the second week of August.

At the Monsanto trials site, whole plot counts were taken of bolters present before each application both treated and untreated. Estimates of visual percent foliar kill were made following applications and there was a final count of all untreated bolters remaining in the plots just prior to harvest. At this time a representative seed sample was taken from each treated plot and from the untreated control areas by removal of 20 complete plant tops. The seed samples were tested by a standard procedure (Hibbert and Woodwark, 1969) to determine the viability and the number of viable seeds per bolter was extrapolated. This figure was used to indicate the efficacy of treatments as it is directly related to the return of viable seeds to the soil in the field.

At the Broom's Barn and Holmewood Hall trials individual bolters were labelled at each treatment date, bolter numbers recorded and seed samples taken and analysed in the same way as previously described. The labelling of plants enabled the number of treatments applied to each bolter to be firmly established for sampling purposes.

The plot counts of untreated bolters present before each application were added to the number present untreated prior to harvest. This gave the total bolters occurring in each plot. By subtracting the number of remaining untreated after the final application from the total, the percent that were treated was calculated and is quoted in the tables as a measure of the effectiveness of the application timings in covering the spread of development of the bolting population. This was done for all trials reported.

The two machines used in the Monsanto trials were the 'Weedwiper', a Registered Trade Mark of Hectaspan Limited, and the 'Wedge-Wik', a Trade Mark of the Porter Manufacturing Company, U.S.A.

A height differential of 8cm was maintained between applications and mean crop height. The speed of applications was kept low at approximately 5 k.p.h. to ensure adequate wiping time and that the ropes were not dried out faster than herbicide could be replaced from the reservoirs. Consecutive applications were normally made in opposing directions to ensure adequate treatment in denser clumps.

RESULTS

Table 1 shows the advantages of a three application timing covering the period from onset of flowering to 27 and 31 days after flowering commenced. The percentage viable seeds surviving was lowest with this treatment schedule irrespective of applicator used. A concentration of 179.5 g.a.e./l of the IPA salt of glyphosate was better with both machines.

Table 1

Control of bolting and weed beet using the IPA salt of glyphosate applied by height-selective applicators

Machine type	Herbicide dilution g.a.e./l	1981 Application dates 10-7	27-7	6-8	10-8	Viable seeds per bolter	Total bolters treated %	Surviving viable seed /bolter % c.f. untreated
Untreated	-	-	-	-	-	1800	0	100
Wedge-Wik	118.5	x	x	-	-	1145	65	64
		x	x	x	-	373	90	20
Wedge-Wik	179.5	x	x	-	-	282	80	16
		x	x	x	-	161	87	9
Weedwiper	118.5	x	x	-	-	396	75	22
		x	x	-	x	337	83	19
Weedwiper	179.5	x	x	-	-	334	68	19
		x	x	-	x	93	85	5

Monsanto trial data (Norton, A.J. 1982)

x - 1 application in one direction
Infestation level 0.2 - 10/m².

Results from the 4 timing trials in Table 2 show a similar pattern to the previous results. The five applications treatment, whilst excessive in practical terms indicated that repeated applications when plants were younger at initial treatment was the most effective at reducing viable seed return.

Table 2

Assessment of effect of timing and number of applications on control of weed beet with height-selective application

Treatment timing Days from flowering at treatment -14	0	14	28	42	Total bolters treated %	No. of viable seeds per bolter	Surviving viable seed /bolter % c.f. untreated
-	-	-	-	-	0	1650	100.0
x	x	-	-	-	33	256	15.5
x	x	x	x	x	86	5	0.3
-	x	x	-	-	70	25	1.5
-	-	x	x	-	63	18	1.1

Means of 4 site locations. Conc. of IPA glyphosate 179.5 g.a.e./l.

x - 1 application. Weedwiper applicator used.
Source: Longden, P.C. 1982b .

A comparison of other methods for bolter control in Table 3 shows that two correctly timed applications with a height-selective applicator gave better results than 3 mowing operations or two electro-thermal applications.

Table 3

Control of weed beet comparison of the wiper application of IPA glyphosate with mechanical methods

Treatment method	Application Date 1981 17-7	30-7	17-8	Total bolters treated %	No. of viable seeds per bolter	Surviving viable seeds per bolter % c.f. untreated
Untreated	-	-	-	0	8465	100
Weedwiper	x	x	-	88	228	3
	-	x	x	95	865	10
	Application Date 1981 20-7	30-7	17-8			
Electro-thermal	x	x	-	83	655	8
	-	x	x	93	781	9
	Application Date 1981 6-8	25-8	14-9			
Mowing	x	x	-	-	464	5
	x	x	x	-	393	5

Concentration of IPA glyphosate - 179.5 g.a.e./l.
Source: Longden, P.C. 1982b .

DISCUSSION

It is apparent that two applications of IPA salt glyphosate to sugar beet bolters, correctly timed prior to the production of viable seeds in the first part of August can give a large overall reduction in surviving seeds per bolter. A further application within the period from onset of flowering to 30 days after, gives timing intervals of approximately two weeks and using the 179.5 g.a.e./l concentration of herbicide has given the greatest reduction of viable seed.

The application equipment proved safe to the crop and had the advantage over the mowing operations of a larger width of treatment and the added benefit of some control of other tall weeds present at treatment.

The pressurised machine had the advantage that output could be regulated to the level of infestation of bolters and weeds. This trend should be further developed to increase the possibility of applying the maximum amount of herbicide consistent with crop safety so that speed of application could be increased. The area treated was to some extent restricted by the width of the machine, and the development of 12m wide machines with accurate height control is desirable to improve workrates.

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"THE LITTLE AND OFTEN APPROACH" FOR WEED CONTROL IN SUGAR BEET

W. R. Madge
Arthur Rickwood Experimental Husbandry Farm, Mepal, Ely, Cambs CB6 2BA

Summary. Eighteen trials on mineral and organic soil types were done during the years 1980-82. Repeated low dose sprays of metamitron or phenmedipham gave a consistently high standard of weed control whether or not pre-emergence soil acting residual herbicides were used.

The first low dose spray was applied when the earliest weeds reached the cotyledon stage. When subsequent cotyledons appeared further sprays were applied. Spray timing was the most critical factor. Weeds at the cotyledon stage offered small targets and efficient application of a fine spray avoiding run off was essential.

The method appeared to be safe to the crop. Sugar yields from the low dose treatments equalled those obtained from hand weeded controls.
Repeated low dose, timing, weed size, efficient application.

INTRODUCTION

The use of both pre and post crop emergence herbicides for weed control in the sugar beet crop was established practice by the end of the 1970's. These were normally applied by band-spraying along the row and weed control was completed with inter-row tractor hoeing. These operations gave effective weed control under most conditions. They are however relatively slow operations and the standard of weed control achieved depended on reliable persistent activity from the pre-emergence herbicide. This was not always forthcoming, particularly in the fens of East Anglia where the organic soil mitigates against residual herbicide activity. In such circumstances crops often suffered severe weed competition. Farmers began searching for an alternative method which led to the commercial development of overall spraying a low volume dose of phenmedipham at high pressure for post crop emergence weed control.

Staffs of the Fenland Team of the Weed Research Organisation and of the Arthur Rickwood Experimental Husbandry Farm started work in 1979 to evaluate and further develop this innovation. Glasshouse work by the Weed Research Organisation team suggested that spray timing and frequency were the more important factors for effective weed control by low dose application and that operating pressure was less important.

In 1980 field trials were started at the Arthur Rickwood EHF to compare four quarter or two half volume doses with one full dose of metamitron or phenmedipham. This work led to co-ordinated trials by ADAS on a range of soil types. These began in 1981, continued in 1982 and are reported in this paper.

METHODS AND MATERIALS

Table 1

Individual site details 1980-1982

Site number	Soil texture	Sowing date	Herbicide	Pre-emergence kg/ha a.i.	Pre-emergence Application date	Post-emergence application dates
1980						
1	Loamy peat	30/3	Metamitron	3.5	17/4*	17/4, 30/4, 7/5, 18/5, 28/5
1981						
2	Loamy peat	28/3	Metamitron	3.5	16/4*	16/4, 1/5, 12/5, 18/5, 27/5
3	Zy CL	15/4	Chloridazon	2.5	5/5	12/5, 20/5, 29/5
4	FSL	14/4	Chloridazon	2.5	15/4	4/5, 14/5, 20/5, 3/6
5	Calc FSL	15/4	Chloridazon	2.5	15/4	12/5, 20/5, 1/6
6	LS	6/4	Chloridazon/ ethofumesate	2.5 1.0	7/4	1/5, 8/5, 14/5, 21/5
7	SCL	29/3	Chloridazon	2.5	2/4	10/4, 16/4, 5/5, 13/5, 20/5, 30/5
8	FSL	21/4	Metamitron	3.5	21/4	7/5, 13/5, 21/5, 1/6
1982						
9	Loamy peat	26/3	Metamitron	3.5	8/4*	8/4, 19/4, 26/4, 7/5, 26/5
10	FSL	1/4	Chloridazon	2.5	5/4	19/4, 27/4, 24/5
11	SL	27/3	Metamitron	3.5	31/3	22/4, 5/5, 20/5
12	VFSL	1/4	Chloridazon	2.5	13/4	21/4, 4/5, 10/5, 17/5, 1/6
13	SL	25/4	Chloridazon/ lenacil	1.0 0.7	29/3	9/4, 19/4, 28/4, 21/5
14	VFSL	23/3	Metamitron	3.5	26/3	19/4, 2/5, 15/5, 26/5
15	SCL	1/4	Chloridazon/ lenacil	1.0 0.7	5/4	28/4, 10/5, 18/5

*Peri-emergence application

Eighteen trials on 15 sites located over a wide geographical area, on a range of soil types, consisted of randomised blocks with three or four replicates. The plot size was approximately 45 m^2; weed and yield assessments were made on 24 m^2 of the inner rows.

All herbicides were applied using a CO_2 operated Oxford Precision Sprayer at a pressure of 210 kPa through an 8001 Teejet nozzle; the volume rate was governed by forward speed. Application timing of low dose sprays was determined by weed size. The first spray was applied when the earliest weeds reached the cotyledon stage. Further spray applications were made when subsequent germinations reached the cotyledon stage.

In 1980 and 1981 the trial design was a factorial combination of:-

1) the presence and absence of a pre-emergence herbicide (mineral soil sites) or of a peri-emergence herbicide (organic soil sites) and

2) repeat applications of phenmedipham or metamitron (with or without adjuvant oil) at

3) 60 l/ha which contained 0.28 kg of phenmedipham or 0.87 kg of metamitron and 80 l/ha containing 0.37 kg of phenmedipham or 1.16 kg of metamitron all as kg/ha a.i.

In the 1982 trials timings were based on those of 1980-81 but, the first, or first and second, sprays were omitted in order to better assess any residual effect of pre-emergence herbicide. The post-emergence low volume sprays were metamitron, phenmedipham or phenmedipham plus ethofumesate all applied at 80 l/ha total volume.

A farm standard treatment was included at all sites. The site pre-emergence herbicide (see Table 1) was followed by post-emergence treatments of one application of metamitron 3.5 kg/ha a.i. on sites 4, 5, 7 and 8. On site 13 two applications of phenmedipham (1.12 kg/ha a.i.) were used and one application of this herbicide was used on sites 1, 2, 6, 9, 10, 11, 12, 14 and 15. Site 11 had one application of both metamitron (3.5 kg/ha a.i.) and phenmedipham (1.12 kg/ha a.i.). Site 3 was tractor/hand hoed. There was a hand weeded control on those trials where the sugar yield was assessed.

RESULTS AND DISCUSSION

Weed control. Table 2 shows that the level of weed control achieved with the farm standard treatment was 89 per cent Repeat low dose spraying achieved between 93 and 98 per cent demonstrating the advantage of sequential spray applications. Similar results have been reported by May (1982)

There were treatment differences due to weed species *Viola arvensis*, *Galium aparine* and *Chenopodium album* were difficult to control by phenmedipham in the absence of a pre-emergence residual herbicide in 1981. *Polygonum convolvulus* was also difficult to control with metamitron on some sites in both 1981 and 1982. However on other sites these same species were adequately controlled. This suggests that the site differences were more a reflection of spray timing than weed species.

Table 2

Mean weed control percentage 1980-1981 (15 trials)

Herbicide (l/ha)		No pre-emergence Alone	No pre-emergence With oil	With pre-emergence Alone	With pre-emergence With oil	Mean
Metamitron	60	94	95	96	97	95
	80	97	98	96	98	97
Phenmedipham	60	93	94	94	95	94
	80	94	95	96	96	95
Mean		94	95	95	96	95
Farm standard	89					

On some sites there was an advantage in using the 80 litre rate. This applied to both herbicides and whether or not a soil acting residual herbicide was used. Again, this was probably a reflection of late spray timing and Table 2 shows only a small advantage to the higher rate. The addition of adjuvant oil did not consistently improve the performance of either herbicide.

Metamitron gave a consistent high standard of weed control across all treatments. Phenmedipham was equally good in 1980 and 1981, but was not as effective during the cold, dry weather experienced early in the season of 1982. This is shown in Table 3 and was true of all sites except No 11 where phenmedipham gave the best control. This had a high population of *Polygonum convolvulus*.

Table 3

Mean weed control percentage, 1982 (7 trials)

Herbicide	No pre-emergence	With pre-emergence
Metamitron		
Sprayed at cotyledon	97	97
First spray omitted	-	96
First and second sprays omitted	-	85
Phenmedipham		
Sprayed at cotyledon	93	96
First spray omitted	-	90
First and second spray omitted	-	80
Phenmedipham plus ethofumesate		
Sprayed at cotyledon	96	97
First spray omitted	-	94
First and second sprays omitted	-	89

Table 3 shows there was no advantage in using a pre-emergence residual when metamitron was used but sometimes there was an advantage with phenmedipham. Soil acting herbicide activity is limited in dry seasons. The ineffectiveness of chloridazon and PCF in 1978 was reported (Hilton and Bray, 1980). The use of a pre-emergence herbicide did not reduce weed numbers in 1982, again a dry season. In this case, weed size and vigour was not changed. This table shows the advantages of spraying cotyledon weeds. When sprays are omitted weed size increases and regardless of whether or not a pre-emergence herbicide is used weed control deteriorates This was confirmed by additional trials on the organic site which included treatments with delayed spraying in the absence of a pre-emergence residual.

The trial on organic soil Site 1 included volume treatments of 240 l/ha applied through an 8003 Teejet nozzle. Cotyledon targets were missed, suggesting that a fine spray would be of benefit particularly with lower volumes.

Weed species controlled. Repeat low dose spraying gives consistent weed control because weeds are killed by spraying at the cotyledon growth stage. At this stage weed seedlings are extremely vulnerable, and weeds that were previously difficult to control are killed. Table 4 clearly demonstrates this effect.

Table 4

Weed species controlled, 1981 (1 trial)

	Weeds/m², 10 June
Untreated control	
Stellaria media	49
Polygonum persicaria	46
Polygonum lapathafolium	34
Polygonum aviculare	10
Poa annua	40
Others	144
Total	293
Treated plots (5 x 80 l/ha)	
All species	2

Table 5

Mean weed control percentage by soil type 1980-82

Herbicide (80 l/ha)	Organic soil (5 trials)	Mineral soil (10 trials)	Mean
No pre-emergence			
Metamitron	98	98	98
Phenmedipham	94	92	93
With pre-emergence			
Metamitron	98	98	98
Phenmedipham	96	95	95
Mean	96	96	96

Soil type. Table 5 shows that the percentage weed control achieved was similar on mineral and organic soils. Table 1 shows that while the number of spray applications has generally been greater on organic soils this is not always so. Five applications have been used on the organic sites each year but the number used on the mineral sites has varied from three to six. This suggests that the weed population present and the period of germination affect the number of sprays required more than soil type.

Table 6

Mean yield of sugar as percentage of hand weeded control

Herbicide (l/ha)		No pre-emergence Nil	+ oil	With pre-emergence Nil	+ oil	Mean
1980 (1 trial)			(SED ± 5.3)			
Metamitron	60			91	99	95
	80			98	99	98
Phenmedipham	60			99	90	94
	80			93	87	90
Mean				95	94	94
Control 9.3 tonnes sugar/ha						
1981 (4 trials)			(SED ± 6.5)			
Metamitron	60	96	101	100	99	99
	80	102	100	96	101	100
Phenmedipham	60	101	95	95	97	97
	80	97	91	97	93	94
Mean		99	97	97	97	97
Control 8.6 tonnes sugar/ha						

Sugar yield. Table 6 shows that with one exception metamitron gave yields equal to the hand-weeded control. Phenmedipham was less consistent and caused small reductions in yield, particularly at the higher volume and in the presence of adjuvant oil.

In this trial series the little and often method has proved effective in weed control and safe to the crop.

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REPEAT LOW DOSE HERBICIDE TREATMENTS FOR WEED CONTROL IN SUGAR BEET

M. J. May
ARC Weed Research Organization, Begbroke Hill, Yarnton, Oxford OX5 1PF

Summary. In 1981 seven experiments on organic and mineral soil sites compared the weed control from repeated quarter and single full doses of metamitron or phenmedipham at 210 or 420 kPa through Spraying Systems 8001 'TeeJets'. These treatments were compared with a conventional farm sequence of metamitron followed by phenmedipham. Crop yields were taken on four experiments.
There was little difference in weed control between the spray pressures except on two experiments when metamitron quarter doses gave better control of *Stellaria media* and *Chenopodium album* at 420 compared with 210 kPa. There were differences in yields on two sites when quarter doses of phenmedipham gave lower yields at 420 compared with 210 kPa spray pressure. Overall the repeated quarter doses gave weed control and clean beet yields comparable with the single full doses and the conventional farm sequence, although in most cases a lower total dose of active ingredient was applied. Pressure, metamitron, phenmedipham.

INTRODUCTION

In recent years the technique of using repeat low dose sprays of phenmedipham for weed control in sugar beet has been widely adopted in East Anglia (Breay, 1980; Madge and May,1981). Such applications have been made using overall instead of band sprays at reduced spray volumes through small orifice jets and/or increased spray pressures. This technique has given more reliable weed control than conventional band sprays or single full dose overall treatments (Madge and May, 1981; Madge, 1982). During 1981 the series of experiments described investigated the effect of spray pressure on applications of metamitron and phenmedipham as repeated low doses or single full dose treatments in sugar beet.

METHOD AND MATERIALS

Seven experiments were carried out on five different commercial sites within an area of Cambridgeshire bounded by Mepal, Manea and Chatteris (see Table 1). Pre-emergence treatments A and C were applied in 360 and 450 l/ha respectively by the farmers using their own commercial sprayers. B and D were applied as for the 'commercial farm sequence' (C.F.S.) described below. Two herbicides, metamitron and phenmedipham, were used as either repeated quarter doses or a single full dose and compared with a C.F.S. of full dose metamitron applied either pre- or peri-emergence of the sugar beet and followed by a full dose of phenmedipham at the two leaf stage of the crop. The single full dose treatments of phenmedipham and metamitron were applied at 1.14 and 3.5 kg a.i./ha respectively in 240 l/ha spray volume, whilst the repeated low doses were applied at a quarter of these rates in 60 l/ha. All treatments were applied through five jets at 0.5m spacing with a tractor mounted plot sprayer. The quarter and full doses were applied through Spraying Systems 8001 'TeeJets' at two spray pressures, 210 and 420 kPa. At 210 kPa forward speed was 6.5 km/h for 60 l/ha and 1.6 km/h for 240 l/ha and at 420 kPa it was 9.4 and 2.3 km/h respectively. The C.F.S. treatments were applied with Spraying Systems 8002 'TeeJets' using 210 kPa at 3.8 km/h.

Table 1

Site details

Experiment number	1	2	3	4	5	6	7
Soil type	PTY SL	PEAT	PTY SL	PTY SL	SCL	ZL	ZL
% o.m.	21	40	27	27	-	-	-
pH	7.1	6.8	7.3	7.3	-	-	-
Pre-em. used	A	-	-	B	C	-	D
Row widths (cm)	45	55	52	52	45	50	50
Dates							
Drilling	10.4.81	28.3.81	7.4.81	7.4.81	7.4.81	5.4.81	5.4.81
Pre-em. overall	9.4.81	-	-	21.4.81	7.4.81	-	1.5.81
Quarter dose 1	5.5.81	17.4.81	1.5.81	22.5.81	5.5.81	22.5.81	22.5.81
" " 2	22.5.81	1.5.81	22.5.81	1.6.81	1.6.81	1.6.81	1.6.81
" " 3	-	12.5.81	1.6.81	-	-	-	-
" " 4	-	30.5.81	-	-	-	-	-
Full dose	22.5.81	1.5.81	22.5.81	22.5.81	1.6.81	22.5.81	1.6.81
C.F.S.							
Metamitron	5.5.81	17.4.81	1.5.81	21.4.81	-	22.5.81	22.5.81
Phenmedipham	22.5.81	12.5.81	22.5.81	22.5.81	1.6.81	1.6.81	1.6.81
Weed counts	17.6.81	8.6.81	16.6.81	16.6.81	22.6.81	22.6.81	22.6.81
Scores	17.6.81	22.6.81	16.6.81	16.6.81	12.6.81	16.6.81	16.6.81
Harvest	6.10.81	-	-	-	4.11.81	3.12.81	4.12.81

A = propham 2.0 kg a.i./ha
B = metamitron 3.5 kg a.i./ha
C = propham, chlorpropham, fenuron 4 l product /ha (as 'Herbon Gold')
D = metamitron 1.75 kg a.i./ha

A randomised block design, replicated four times was used. Plot sizes were five rows wide by 15m long. All assessments were restricted to the centre three rows. Weed counts were by ten random $0.25m^2$ quadrats per plot with individual species recorded. Weed and crop vigour scores were on a 0 to 9 basis where 0 denoted a complete kill and 9 normal healthy plants. Weed scores of 6 or less and crop scores of 7 or more were commercially acceptable. Only four experiments were taken to harvest when 7m lengths of the middle three rows were hand lifted, topped and weighed. Samples from ten random plots were washed and cleaned to determine appropriate dirt tares.

Due to poor spraying conditions few treatments were applied during the first three weeks of May. Handweeded treatments were included. During July all plots were weeded by hand.

RESULTS

There were few differences between weed counts of individual species, total weeds or clean beet yields for the two spray pressures (see Table 2 which gives mean values of pressures for total annual weeds, weed and crop scores and clean beet yields). In experiments 1, 2, 5, 6 and 7 all herbicide treatments gave a significant reduction in weed numbers compared with the untreated controls. In

Table 2

Results - mean of both pressures

Experiment number		1	2	3	4	5	6	7	mean
Treatment		Number of annual weeds per m^2							
Metamitron	qrt.	134	134	129	65	58	64	24	87
"	full	114	180	99	50	67	18	34	80
Phenmedipham	qrt.	84	132	79	47	79	64	8	70
"	full	124	213	72	39	45	14	24	76
C.F.S.		67	148	26	44	56	16	23	54
Untreated		194	264	101	64	138	184	54	143
S.E.M.		±17.4	±13.7	±12.0	±4.8	±11.3	±5.6	±4.9	±10.0
		Weed vigour scores (0 to 9 scale)							
Metamitron	qrt.	7.7	2.5	8.1	8.2	5.9	7.3	6.1	6.5
"	full	7.6	4.5	8.2	7.9	6.1	6.3	6.1	6.7
Phenmedipham	qrt.	6.4	1.6	7.7	7.8	5.9	7.0	4.9	5.9
"	full	7.4	5.1	8.2	7.4	5.4	5.8	5.5	6.4
C.F.S.		6.8	6.3	6.4	7.1	5.4	6.0	5.4	6.2
Untreated		8.3	9.0	8.6	8.6	7.6	9.0	7.3	8.3
S.E.M.		±0.43	±0.40	±0.22	±0.25	±0.38	±0.23	±0.26	±0.31
		Crop vigour scores (0 to 9 scale)							
Metamitron	qrt.	7.6	7.4	8.1	8.3	6.3	7.2	6.1	7.3
"	full	7.5	6.4	8.4	8.3	6.0	6.4	6.2	7.0
Phenmedipham	qrt.	6.3	7.1	8.1	8.1	6.1	7.0	4.8	6.8
"	full	6.8	6.4	8.3	7.5	5.7	5.9	5.4	6.6
C.F.S.		6.5	7.3	6.9	7.3	5.5	6.1	5.6	6.5
Handweeded		8.3	6.5	8.4	9.0	7.9	9.0	7.6	8.1
S.E.M.		±0.29	±0.21	±0.20	±0.17	±0.27	±0.19	±0.23	±0.22
		Clean root yields (t/ha)							
Metamitron	qrt.	58	-	-	-	48	65	63	59
"	full	58	-	-	-	49	67	63	59
Phenmedipham	qrt.	60	-	-	-	51	64	65	60
"	full	55	-	-	-	50	68	69	60
C.F.S.		59	-	-	-	50	70	65	61
Handweeded		58	-	-	-	52	69	63	61
S.E.M.		±1.3	-	-	-	±1.7	±2.6	±2.5	±2.0

experiment 4 all herbicide treatments except the repeated low doses of metamitron gave a significant reduction in weed numbers but in experiment 3 only the C.F.S. reduced numbers. Repeated quarter doses of metamitron reduced weed numbers compared with the single full ones in experiment 2 but in experiments 4 and 6 the full were better. Quarter doses of phenmedipham were better than single full rates in experiments 2 and 7 but full were better in experiments 5 and 6. The C.F.S. reduced weed numbers more than quarter and full doses of metamitron and full doses of phenmedipham in experiment 1, all other herbicide treatments in experiment 3 and better than metamitron and phenmedipham quarter doses in experiment 6.

Weed scores showed a similar trend to weed counts but, especially in experiment 2, reflect the large vigour reduction from the herbicide treatments compared with the reduction in plant numbers. All treatments except the metamitron quarter and metamitron and phenmedipham full doses in experiment 1, metamitron and phenmedipham full doses in experiment 3 and metamitron quarter doses in experiment 4 gave a significant reduction in weed vigour compared with the untreated plants. Metamitron quarter doses were better than full doses in experiment 2 but full were better in experiment 6. Phenmedipham quarter doses were better than full in experiments 1, 2, 3 and 7 but full were better in experiment 6. All metamitron and phenmedipham treatments in experiment 2 were better than the C.F.S. but the C.F.S. was better than all other herbicide treatments in experiment 3, the quarter doses in experiment 6, the metamitron treatments in experiment 7 and all except phenmedipham full dose in experiment 4.

In experiment 1 both phenmedipham treatments and C.F.S. gave significantly lower crop vigour scores than the handweeded, in experiment 3 only the C.F.S. was worse than the handweeded but in experiments 4, 5, 6 and 7 all herbicide treatments were significantly worse. Metamitron full doses gave lower scores than the quarter doses in experiments 2 and 6 and phenmedipham full doses were worse than quarter doses in experiments 2, 4 and 6.

No herbicide treatments gave a significant yield reduction compared with the handweeded but in experiment 1 phenmedipham full doses gave significantly lower yields than the quarters.

The few differences in weed control between pressures for individual treatments are shown in Table 3. Chenopodium album in experiment 3 and Stellaria media and the total weeds in experiment 2 were controlled better by quarter doses of metamitron at 420 than 210 kPa spray pressure. Also in experiment 3 quarter doses of phenmedipham gave better control of Chenopodium album at 420 than 210 kPa.

Table 3

Number of weeds per square metre - individual pressures

Experiment number		2		2		3	
Species		Stellaria media		Total annual weeds		Chenopodium album	
Pressure (kPa)		210	420	210	420	210	420
Treatment							
Metamitron	qrt.	31	11	182	87	32	19
"	full	31	27	176	184	21	23
Phenmedipham	qrt.	2	5	107	156	24	10
"	full	19	13	213	214	15	19
S.E.M.		± 4.0		± 19.3		± 3.4	

Differences in clean beet yields between pressures were recorded in experiments 1 and 5 and are given in Table 4. In both cases yields from phenmedipham quarter and full doses applied at 420 kPa were lower than those from the same treatments applied at 210 kPa in experiments 1 and 5. The quarter doses of metamitron gave poorer yields at 210 compared with 420 kPa in experiment 5.

Table 4

Yield of clean beet (t/ha) - individual pressures

Experiment number		1		5	
Pressure (kPa)		210	420	210	420
Treatments					
Metamitron	qrt.	58	58	42	53
"	full	56	60	52	46
Phenmedipham	qrt.	63	57	54	47
"	full	58	53	53	46
S.E.M.		±1.7		±2.5	

DISCUSSION

Due to poor spraying conditions in May fewer repeat low dose applications than intended were applied. Whilst wind speeds were such as to stop experimental spraying because of the close proximity of individual plots; commercial spraying would still have been possible. However, because of the prolonged rainfall, soil conditions were seldom good enough to allow effective tractor hoeing.

Inspite of using a low total dose of active ingredient the repeat low dose sprays showed comparatively high levels of weed control. Except in experiment 6, the C.F.S. treatments failed to give more than 75% reduction of weed numbers despite good timing and that they were full doses of both metamitron and phenmedipham plus (on experiments 1 and 5) the farmer's overall pre-emergence spray.

The poor weed control in experiment 3 was due to the late start of the repeat low dose spraying (24 days after drilling) followed by a further 23 days delay before the second low dose was applied. In experiment 4, which was on the same site, the pre-emergence application of metamitron (applied 14 days after drilling) improved subsequent post-emergence treatments. In this experiment some weeds were not controlled by the pre-emergence herbicide and may therefore have been too large for the quarter dose of metamitron. Many such weeds were controlled by a second full dose of metamitron or by phenmedipham.

In experiment 2, where four repeated low doses were used, they gave better control than the equivalent single full dose and this confirms previous findings (Madge and May, 1981; May, 1981; May, 1982). In all experiments the degree of weed control depended very much on growth stage; those annual weeds in the emerging cotyledon stage were controlled by quarter doses of either chemical, but more resistant species such as Polygonum convolvulus for metamitron and Poa annua for phenmedipham, that were in the cotyledon to first true leaf stage were not adequately controlled.

Overall yields were good from all herbicide treatments. The lower yields from the 420 kPa compared with the 210 kPa treatments in experiments 1 and 5 might be associated with the use of a pre-emergence herbicide. Work in other crops (Lake,

1982) suggests that small slow moving drops as produced by a Spraying Systems 8001 'TeeJet' at 420 kPa could be retained by vertical surfaces to a greater extent than are larger and faster drops. When the sugar beet crop is under stress it adopts an upright habit and this could explain the increased damage from the high pressure sprays on these two sites. It is possible that damage was not noted with metamitron because under the conditions of these experiments it was an intrinsically safer compound than phenmedipham (Preston and Biscoe, 1982).

The results of these experiments, whilst not showing the true potential of the repeat low dose treatments do show that pressure is of minor importance and does not help overcome poor timing. The results also indicate that there may be savings in costs by using this technique if the grower is prepared to accept less than complete weed control. However, work by Madge (1982) indicates relatively small true financial savings if the traditionally high levels of weed control in sugar beet are to be maintained.

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ENVIRONMENTAL FACTORS INFLUENCING SUGAR BEET TOLERANCE TO HERBICIDES

P. E. Preston and P. V. Biscoe
Broom's Barn Experimental Station, Higham, Bury St. Edmunds, Suffolk

Summary. Experiments carried out in controlled environment rooms examined the influence of relative humidity (r.h.) and temperature on the tolerance of sugar beet to metamitron and phenmedipham. At high r.h. metamitron decreased plant dry weight by about 25% compared with an application at low r.h., whereas temperature had no effect on the response of plants to metamitron. By contrast, with phenmedipham plant dry weights were similar at both high and low r.h. but plant weights were 35% lighter after treatment at high as compared with low temperature.

In a series of field experiments the extent of crop damage was analysed in relation to the weather around the time of spraying and the results were found to be entirely consistent with those from the experiments in controlled conditions. Metamitron was less safe when applied in humid, wet conditions, whereas phenmedipham was more damaging to sugar beet if the weather was warm and bright around spraying. Sugar beet herbicides, crop tolerance, environmental conditions.

INTRODUCTION

In recent years there have been frequent reports of herbicides causing poor growth in sugar-beet crops during the spring. For example, a survey of the problem samples submitted to the Plant Clinic at Broom's Barn during the past 5 years has shown that herbicide damage was identified or suspected in around 10-20% of the cases and that often this damage was seen following a post-emergence application. On many occasions when damage has occurred weather conditions about the time of spraying have been implicated and it is relatively well documented that in years when phenmedipham caused widespread damage in the commercial crop the weather was warm and bright around spraying (Swalwell, 1971; Bray, 1977). While metamitron has proved relatively safe to the crop (Morris et al., 1978) those occasions when damage has been reported (Turner, 1979) have been mainly cool and dull.

Using field experiments it is very difficult to make progress in understanding how individual weather variables influence the safety of herbicides. First, weather variables are often closely correlated (for example during the spring radiation and temperature tend to increase together). Second, the uncertainty with which specific weather conditions occur when the crop is at the correct stage for post-emergence spraying means that a large number of field experiments over several years would be necessary to measure the effect of individual weather variables on safety. Consequently, it is necessary to use controlled environment rooms where one environmental variable can be altered independently of all others and where extremes of the environment can easily be maintained. The facilities at the Weed Research Organisation, Oxford, were used to investigate the effects of relative humidity and temperature, in the first instance, on the safety of the two main post-emergence herbicides used in sugar beet. These environmental variables were selected because they have previously been shown to greatly influence the uptake and metabolism of herbicides (Hammerton, 1967). In a series of field experiments the variations in weather that occur from season to season were recorded and the effect on sugar-beet tolerance to the herbicides was examined in relation to the responses expected from the controlled environment work.

METHODS AND MATERIALS

Controlled environment room studies.

Individual plants were raised in 10 cm diameter pots containing sandy loam soil maintained at field capacity by alternately watering the pot from above and below. Ethofumesate, (as the formulated product Nortron) 0.7 kg ai/ha, was applied to the soil at sowing because it is current practice to use post-emergence herbicides in sequence with a pre-emergence treatment. Standard conditions were maintained from sowing until the post-emergence herbicide was applied; temperature 16°C day, 10°C night; 80% r.h.; irradiance, 144 Wm^{-2} and photoperiod, 16 h. When the second pair of true leaves were about 1 cm long a laboratory pot sprayer was used to spray plants with either metamitron (as the formulated product Goltix), 3.5 kg ai/ha, or phenmedipham (as the formulated product Betanal E), 0.8 kg ai/ha. Oil, 'Actipron', 5 l/ha, was added to both herbicides to increase the contact activity.

It was intended that environmental treatments should be imposed a few days before post-emergence spraying to allow plants to become acclimatized to the change in conditions. The humidity treatments - high 95% r.h. and low 50% r.h. - were imposed three days prior to spraying. However, in the event, the two temperature treatments - high 26°C day/16°C night and low 10°C day/6°C night - had to be imposed immediately after spraying because appropriate space could not be made available earlier. Plants were kept under these environmental treatments post-spraying and plant growth and development measured by harvesting plants at 3 to 7 day intervals until the 10-12 true leaf stage.

Field experiments.

At Norfolk Agricultural Station a large, multifactorial experiment has been conducted each year since 1975, to investigate the effects of different pre- and post emergence herbicide combinations on early crop vigour and final yield in the absence of weeds (Norfolk Agricultural Station, 1980). Treatments representative of those currently being used for effective weed control were selected for more detailed observation and Table 1 gives the herbicides and dates of application in 1980 and 1981 for the treatments reported in this paper.

Table 1

Details of crops and herbicide application in experiments at Norfolk Agricultural Station

Crop details:		1980	1981
Variety		Nomo	Nomo
Crop Sown		5 April	12 April
Crop Emergence		21 April	4 May
Herbicide application:			
Pre-emergence:	Propham/chlorpropham/fenuron mixture (as 7 l/ha Premalox)	7 April	13 April
Post-emergence:	Metamitron 3.5 kg ai/ha + Oil or Phenmedipham 1.14 kg ai/ha	16 May	22 May

Crop growth was measured early in the season by sampling 2.0 m^2 from each of three replicates at approximately 14 day intervals. The harvested plants were separated into leaves, petioles (including the crown) and roots, and fresh and dry weight and leaf area were measured. Records of weather conditions around post-emergence spraying were taken from the meteorological site at Norfolk Agricultural Station, supplemented by records from the nearby RAF Station at Coltishall.

RESULTS

Controlled environment room studies.

Metamitron and phenmedipham applied in sequence with ethofumesate, both decreased plant dry weight compared with the untreated control, but the size of the decrease was greatly influenced by the different environmental regimes tested. Table 2 shows plant dry weight, expressed relative to the untreated control, measured at the 8 true leaf stage when the differences between treatments were largest.

Table 2

The influence of humidity and temperature on sugar-beet tolerance to metamitron and phenmedipham

Post-emergence herbicide treatment	Plant dry wt. % of untreated control			
	Relative Humidity		Temperature	
	95%	50%	26°C/16°C	10°C/6°C
Metamitron + oil	67.6	93.3	85.0	81.4
Phenmedipham + oil	64.3	63.0	27.4	61.7
SED	8.34		8.40	

Metamitron applied at high r.h. decreased plant dry weight by about 25% compared with an application at low r.h. Toxicity symptoms, (in the form of necrosis of leaf margins), were seen within three days of spraying whereas no visible damage was observed at low humidity. On the other hand, for plants sprayed with phenmedipham there was no significant difference in dry weight between the high and low humidity treatments at the 8 true leaf stage. However, there was a large difference in the response of plants grown at the two different temperature regimes following phenmedipham application. At high temperature characteristic symptoms of phenmedipham toxicity, (areas of chlorosis or necrosis over leaf surfaces), appeared within 2 h of spraying and by the 8 true leaf stage plants were over 70% lighter than the control. At low temperature, visible symptoms of damage took several days to appear and the decrease in dry weight was significantly smaller. By contrast, metamitron was equally safe at high or low temperature, and plant dry weights were around 80-85% of the control.

Field experiments.

The results from experiments carried out at Norfolk Agricultural Station in 1980 and 1981 were selected because, as Table 3 shows, the weather around the time of post-emergence spraying was very different.

Crop growth was checked by all herbicide treatments and in both years the effects on plant dry weight and leaf area were most severe around three weeks after post-emergence spraying (Table 4). Leaf area was decreased because of a reduction in leaf size rather than leaf number, and consequently the rate of dry matter production would be slower as the amount of solar radiation intercepted by the crop canopy would be smaller (Milford et al., 1980). Table 4 indicates that over a four week period (three to seven weeks after spraying) the growth checks were overcome to some extent in both years.

Table 3

Weather conditions around the time of post-emergence spraying at Norfolk Agricultural Station in 1980 and 1981

Year + Date	Air temperature °C Max.	Min.	Rain (mm)	r.h. (%) 0900	1500	Radiation MJm^{-2}
1980						
May 13	18.5	8.0	-	57	52	26.8
14	16.8	6.8	-	53	47	27.5
15	16.8	3.6	-	54	35	27.4
16	16.8	5.1	-	58	52	27.2
17	17.5	3.2	-	76	58	25.3
18	21.0	7.6	-	60	47	23.4
19	21.2	5.2	-	45	42	22.8
1981						
May 19	16.2	10.7	-	82	78	10.6
20	22.6	9.6	0.5	94	63	12.6
21	16.9	9.3	1.2	81	87	7.4
22	16.1	9.4	3.9	67	69	21.7
23	15.2	9.0	1.5	95	80	10.2
24	15.8	6.0	2.6	71	53	22.0
25	12.8	5.8	7.5	95	68	10.3

Table 4

The effect of herbicide treatments on early growth of sugar beet at Norfolk Agricultural Station in 1980 and 1981

		Plant dry wt. (g)			Plant leaf area (cm^2)		
				1980			
Days after post-em. spray:		24	38	52	24	38	52
Treatment:							
Pre-em.	Post-em.						
Untreated control		4.88	24.3	52.6	608	1573	3145
PCF mixture	Metamitron + oil	2.93	19.8	53.5	394	1530	3242
PCF mixture	Phenmedipham	2.68	17.2	44.7	371	1418	2808
SED		0.323	1.19	3.47	58.0	113.7	269.0
				1981			
Days after post-em. spray		17	27	48	17	27	48
Treatment:							
Pre-em.	Post-em.						
Untreated control		0.518	3.24	33.1	86.3	409	2321
PCF mixture	Metamitron + oil	0.237	1.70	24.4	45.6	235	1959
PCF mixture	Phenmedipham	0.383	2.16	29.7	60.4	277	2284
SED		0.1151	0.381	2.79	13.73	38.0	458.4

However, the relative effect of the two herbicides on crop growth was very different in the two years. In 1980 phenmedipham was the most damaging, decreasing crop dry weight and leaf area for seven weeks following spraying. The weather records show that in 1980, maximum air temperatures on the days around spraying were generally higher than in 1981 and the radiation receipts were particularly large compared with the long term average for May (15.2 MJm^{-2}/day). In 1981 when metamitron caused more damage, the weather around spraying was cold and dull and the relative humidity recorded at 0900 h was higher than in the previous year and the air remained humid throughout the delay. Rain also fell on all but one of the days in 1981, whereas none fell during the corresponding period in 1980.

DISCUSSION

From the experiments carried out in both the controlled environment room and in the field it is clear that pre- and post-emergence herbicides applied in sequence to sugar beet can cause considerable damage. Results from previous experiments investigating the effect of herbicide application on sugar-beet growth have also shown reductions in crop dry weight soon after post-emergence spraying, and in particular, have highlighted the large seasonal variations which exist in the extent of crop damage (Jaggard, 1978; Scott et al., 1976). In extreme cases, if the check to growth is large and especially if plant populations are reduced, then yield can be lost (Jaggard, 1978). The reasons for the very variable response which has previously been observed are poorly understood, although weather conditions have often been implicated. However, previous experiments have not revealed the importance or significance of individual weather variables in influencing herbicide activity.

In the present experiments, by using controlled conditions it was possible to identify the effect of two environmental variables, humidity and temperature, on the safety of metamitron and phenmedipham. While the range of treatments were at the extreme likely to be encountered in the spring around the time of spraying, a clear difference in the response of the two herbicides to the environmental factors was shown. When these responses were used to interpret the seasonal variation in damage observed in the field experiments the results were found to be entirely consistent. It seems that sugar beet is likely to be less tolerant to phenmedipham if application occurs when temperatures are high and metamitron will be less safe if the air is particularly humid around the time of spraying.

This work has begun to provide a clearer understanding of how herbicide application and weather interact to cause crop damage in sugar beet. However, from the experiments reported here it is not possible to identify the precise time or times, i.e. pre-, at or post-spraying, when the environmental factors exert their greatest effect. If better advice is to be given on conditions and times for safer spraying, then further work adopting the approach described in this paper, will be necessary.

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DEVELOPING A STRATEGY FOR WEED CONTROL IN SUGAR BEET

S.P. McClean
Norfolk Agricultural Station, Morley, Wymondham, Norfolk NR18 9DB

Summary. A cost comparison was carried out with the aim of detecting possible practical weed control programmes that would retain the efficiency of the low volume/low dose (LV/LD) overall post-emergence technique of weed control in sugar beet, while minimising costs. Savings, in increasing order of magnitude, could be made by: (i) reducing the rate of overall pre-emergence spray by $\frac{1}{3}$; (ii) omission of the pre-emergence spray (but with risk of loss of efficiency) (iii) applying the pre-emergence spray in bands and supplementing the overall post-emergence sprays with inter-row tractor-hoeing; (iv) as (iii) but substituting trifluralin applied by the lay-by technique for the last LV/LD spray; (v) following $\frac{2}{3}$ rate pre-emergence band-sprays with LV/LD band-sprays and inter-row contact spraying; (vi) as (v), but employing trifluralin as a last lay-by spray; (vii) as (v), but using tractor hoeing; (viii) as (vii), but using trifluralin as the last spray. Pre-emergence band spraying, post-emergence band spraying, low volume/low dose overall spraying, mechanical cultivations, inter-row post-emergence spraying, trifluralin, weed control programmes.

INTRODUCTION

Earlier papers in this session have shown the effectiveness of the low volume/low dose (LV/LD) technique for overall spraying post-emergence herbicides in sugar beet. Farmers' field scale experience in East Anglia during 1981 and 1982 has confirmed its value on a large scale.

Some farmers on mineral soils suggest that whilst the technique has given them a considerably better level of weed control than they were able to achieve previously, the cost of the new technique is becoming too high and that there is now an urgent need to find ways of economising, whilst still retaining the improved efficiency of the technique.

This paper is an attempt to make a comparison of the likely costs of all the possible programmes of chemical-only or chemical plus mechanical weed control that have a reasonable chance of success on a farm scale. The intention is that this exercise might identify the most promising techniques for testing experimentally.

METHODS AND MATERIALS

The scope of study was limited to the consideration of the control of annual broad-leaved weeds on mineral soils, in which pre-emergence herbicides are normally active.

Each of the various sequences was described on paper, using assumed average numbers of applications of post-emergence sprays or passes with a tractor hoe, based on past experience in experiments and on a farm scale.

The costs of these operations were then added up, to give a total cost for each system.

Generally, the aim was to avoid comparing relatively subtle differences between alternative chemicals that could be used at any particular time in order to concentrate upon the more basic variations in the components of weed control programmes.

The sequences considered in this way were selected combinations of:-

1. Pre-emergence applications of a typical material band-sprayed at a rate applicable to light land (chloridazon **containing 430g/l a.i. at 4.2 l/ha**):
   (a) None
   (b) Full rate band-spray at drilling
   (c) $\frac{2}{3}$ rate band-spray at drilling
   (d) Full rate overall spray after drilling
   (e) $\frac{2}{3}$ rate overall spray after drilling
   (f) full rate overall spray and incorporation before drilling

with:

2. Post-emergence applications of a typical material (phenmedipham):
   (a) (i) Band-spray at full rate
   (ii) Band-spray at $\frac{1}{3}$ rate low volume/low dose
   (iii) Overall spray at $\frac{1}{3}$ rate low volume/low dose

   combined where appropriate with:

   (b) (i) Inter-row tractor hoeing
   (ii) Inter-row tractor hoeing, then lay-by* incorporation of trifluralin
   (iii) Inter-row spraying with paraquat + diquat
   (iv) Inter-row spraying with paraquat + diquat, then lay-by incorporation of trifluralin
   (v) No inter-row work

* Overall sprayed, followed by inter-row cultivation with a tined implement set to throw treated soil into the rows, i.e. round the beet plants.

The following assumptions were made:-

1. When no pre-emergence spray was applied, $2\frac{1}{2}$ full rate or 3 LV/LD post-emergence sprays would be required.

2. When a pre-emergence spray was applied at full rate, $1\frac{1}{2}$ full rate or 2 LV/LD post-emergence sprays would be needed.

3. When the pre-emergence spray was applied at $\frac{2}{3}$ rate the number of LV/LD post-emergence sprays would still remain at 2.

4. When the full-rate pre-emergence spray was incorporated pre-drilling, the number of post-emergence LV/LD sprays would be reduced by $\frac{1}{2}$. Incorporation would be achieved by normal seedbed cultivations.

5. When the post-emergence sprays were band-applied, 3 passes of the tractor hoe or 2 applications of inter-row contact spray would be needed per season. When the post-emergence sprays were applied overall, the tractor hoe or the inter-row contact sprays would be reduced to 1.

6. When trifluralin was applied overall and incorporated using the lay-by technique at the 4 to 6 leaf growth stage of the beet, this would replace the last post-emergence spray, the last two tractor hoeings or the second inter-row contact spray.

7. Manufacturers' list prices for chemicals have been used throughout. However, the costs of the systems were also calculated using list prices discounted by 10% to check that the main differences between systems were not altered

significantly by any reduction in price that farmers might secure from their suppliers, and it was found that the main cost differences were not altered by this.

8. The costs of application of pre-emergence overall sprays and post-emergence overall and band sprays were included using a standard source of such data (Nix, 1981).

9. The costs of tractor hoeing and inter-row contact spraying were derived from the same source, with the full cost of the driver's time included, assuming that if he was not required for these tasks, he would be gainfully employed elsewhere on the farm, or alternatively less overtime would be worked.

10. The costs used for the various operations were as follows:

			£/ha
(a) Pre-emergence sprays:-			
$\frac{2}{3}$ rate in bands (on drill)			9.80
full rate in bands (on drill)			14.70
$\frac{2}{3}$ rate overall	chemical	29.40	
	application	0.64	30.04
full rate overall	chemical	44.10	
	application	0.64	44.74
(b) Post-emergence sprays:-			
band-spray, full rate	chemical	24.80	
	application	2.67	27.47
band-spray, LV/LD	chemical	8.68	
	application	0.64	9.32
overall spray LV/LD	chemical	26.04	
	application	0.64	26.68
trifluralin	chemical	8.30	
	application	0.64	
	incorporation	6.18	15.12
(c) Inter-row operations:			
tractor-hoeing			6.18
inter-row contact spray	chemical	10.38	
	application	6.18	16.56

RESULTS

Table 1

Costs of commonly used systems

Pre-emergence	Post-emergence	£/ha
Band spray	Band spray + tractor hoe	74.44
Overall	Overall LV/LD sprays	98.10
None	Overall LV/LD sprays	80.04

In comparison with the well-established technique of band-spraying full rates of pre- and post-emergence herbicides in conjunction with tractor hoeing, the adoption of an overall spraying system based on the LV/LD post-emergence technique, while retaining the safeguard of a full rate pre-emergence spray, is likely to lead to an increase of about 30% in the cost of weed control. This has to be set against the value of the increased efficiency of this system. This is difficult to calculate. If the pre-emergence herbicide is omitted, cost is greatly reduced, bringing the level down to that of traditional weed control systems, even when it is assumed that an extra post-emergence spray will be necessary to compensate for the lack of the pre-emergence effect (as in this example).

It could be concluded that this latter option is the correct way to achieve maximum efficiency while maintaining cost at a reasonable level. However, there are practical problems: the omission of the pre-emergence spray makes the timing of the LV/LD post-emergence much more critical. Weeds grow unchecked in the absence of pre-emergence sprays, such that the opportunity to spray them whilst still in the cotyledon stage is shorter. Thus the risk of failure if spraying is delayed by bad weather is increased. So, are there likely to be safer ways of achieving economy, whilst still minimising the danger of loss of efficiency?

Some possible options are shown (Table 2).

Table 2

Costs of systems combining pre-emergence band-spraying and tractor hoeing with overall LV/LD post-emergence spraying

Pre-emergence	Post-emergence	£/ha
Full rate overall	Overall LV/LD sprays	98.10
Full rate overall, incorporated before drilling	Overall LV/LD sprays	84.76
$\frac{2}{3}$ rate overall	Overall LV/LD sprays	83.40
$\frac{2}{3}$ rate band-sprayed	Overall LV/LD sprays with tractor hoeing	69.34
$\frac{2}{3}$ rate band-sprayed	Overall LV/LD sprays with one tractor hoeing then trifluralin (lay-by)	57.78

Incorporation of the pre-emergence spray could achieve a cost saving, if it could be reliably expected to reduce the average number of post-emergence sprays required by $\frac{1}{2}$ per season: this is doubtful.

There is experimental evidence accumulating from the Norfolk Agricultural Station indicating that, with the timely application of the post-emergence sprays made possible by the fast work-rate of the overall sprayer used for the LV/LD technique, the rate of the pre-emergence spray applied after drilling can be reduced by at least a third. This is possible without it becoming necessary to increase the number of post-emergence sprays or significantly increasing the weather risk referred to earlier. This makes a substantial cost saving.

However it is interesting to note that a considerably greater economy could be achieved by using overall LV/LD post-emergence spraying with conventional pre-emergence band-spraying and tractor hoeing. This option retains all the timeliness advantages given by the LV/LD technique. It has been assumed in this example that the overall post-emergence applications would reduce the number of tractor hoeings needed from 3 to 1, so the spray falling between the rows would not be totally wasted. It is also interesting to speculate whether in practice, inter-row hoeing might save the application of a final overall spray which would otherwise be required to achieve control of weeds between the rows. Where weed beet occur, this system would be better than the LV/LD systems described earlier, because of its ability to kill the weed beet between the rows. In this context a second tractor hoeing might be needed to deal with late-emerging weed beet. However, it must also be noted that tractor hoeing would not be appropriate when the aim was to control Cirsium arvense with 3,6-dichloropicolinic acid or Agropyron and Agrotis spp. with a selective post-emergence grass herbicide, since such weeds must not be disturbed if herbicidal activity is to be maximised.

It is interesting to note that the cost of the overall LV/LD spraying/tractor hoeing system can be further reduced by the use of an overall spray of trifluralin (with incorporation by the lay-by technique) to replace the last LV/LD post-emergence spray. This economy is due to the low cost of trifluralin. The system has the practical advantage of enabling the farmer to "shut the gate" on the field by bringing a clear-cut end to the weed control programme. This is made possible by the efficient residual action of the trifluralin.

A factor that might well offset the greater cheapness of tractor hoeing compared with complete overall spraying systems is the likelihood of better yields from field headlands with overall spraying, due to avoiding the wheel damage caused by the tractor hoe when turning. However it is virtually impossible to quantify this in financial terms here.

An alternative option to tractor hoeing is the use of a contact herbicide applied between the rows, using a shielded sprayer. This option, when used with overall LV/LD post-emergence spraying following ⅔ rate pre-emergence spraying in bands (assuming one application), cost £76.72 per hectare, which was more expensive than tractor hoeing.

At least one LV/LD post-emergence band sprayer is available. Narrow angle nozzles are used to allow the nozzle height to be kept high enough to produce sufficient dispersion into fine droplets before the spray hits the target. A relatively high forward speed is made possible by including a furrow-following wheel to give a self-steering facility. Can such machines give an even greater degree of economy? The following figures suggest that they can.

Table 3

Costs of systems using the post-emergence LV/LD techniques applied by band sprayer

Pre-emergence	Post-emergence	£/ha
⅔ rate band-spray	Overall LV/LD sprays + tractor hoeing	69.34
"	Band sprayed LV/LD + tractor hoeing	46.98
"	Band sprayed LV/LD + tractor hoeing + trifluralin (lay-by)	40.42
"	Band-sprayed LV/LD + inter-row contact spray	61.56
"	Band sprayed LV/LD + inter-row contact spray and trifluralin (lay-by)	50.80

LV/LD band spraying and tractor hoeing is considerably cheaper than overall LV/LD plus tractor hoeing. The use of trifluralin gives further economy, resulting in the cheapest system modelled in this paper. Substituting inter-row contact spraying for tractor hoeing gives a small cost saving compared with overall LV/LD spraying plus tractor hoeing. If this is combined with the trifluralin lay-by technique, a further cost saving is achieved, albeit insufficient to make the system competitive with the tractor hoeing option.

While band-spraying LV/LD post-emergence appears to give the opportunity for great cost savings when there is no need to avoid tractor hoeing, there is one potential problem, namely a possible reduction in weed control efficiency due to reduced timeliness. The speed of work of an LV/LD band-sprayer may be limited by its working width compared with an overall sprayer: even an 18 row band-sprayer is only $\frac{3}{4}$ the width of a standard overall machine. The question that needs resolution is: assuming that forward speed is similar for both machines, would the reduction of the work rate by a quarter in the case of the band-sprayer be critical on a farm scale?

REFERENCES

NIX, J. (1982). Farm Management Pocket Book. Twelfth Edition, Wye, Ashford, Kent: School of Rural Economics, Wye College.

APPENDIX I. Total costs of weed control systems compared (£/ha)

Post-emergence management	Pre-emergence management: No spray	band-spray $\frac{2}{3}$ rate	band-spray full rate	overall spray $\frac{2}{3}$ rate	overall spray full rate	overall spray incorporated full rate
Band-spray full rate						
+ tractor-hoe	87.22	-	74.44	-	-	-
+ tractor-hoe and trifluralin	62.51	-	49.74	-	-	-
+ inter-row contact spray	101.80	-	89.02	-	-	-
+ inter-row contact S. and trifluralin	72.88	-	60.12	-	-	-
Band-spray LV/LD						
+ tractor-hoe	46.50	46.98	51.88	67.22	81.92	77.26
+ tractor-hoe and trifluralin	39.94	40.42	45.32	60.66	75.36	70.70
+ inter-row contact spray	61.08	61.56	66.46	73.52	88.22	83.56
+ inter-row contact S. and trifluralin	50.32	50.80	55.70	71.04	85.74	81.08
Overall spray LV/LD						
+ tractor-hoe	86.22	69.34	74.24	-	-	-
+ tractor-hoe and trifluralin	68.48	57.78	62.68	-	-	-
+ inter-row contact spray	-	79.72	84.62	-	-	-
+ inter-row contact S. and trifluralin	-	68.16	73.06	-	-	-
+ trifluralin	68.48	-	-	71.84	86.54	86.54
No inter-row work	80.04	-	-	83.40	98.10	84.76

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WEED CONTROL IN WINTER OILSEED RAPE

J. T. Ward
Agricultural Development and Advisory Service,
Shardlow Hall, Shardlow, Derby DE7 2GN

Summary. In the harvest years 1979-81 ADAS carried out a trial series to assess the efficacy of a wide range of herbicides used in winter oilseed rape. The yields and weed control obtained in 15 trials are reviewed. Significant yield responses were obtained in only 4 of the 11 trials from which results were analysed. There was no consistent evidence to suggest that the early elimination of weeds by the use of pre-drilling or pre-emergence herbicides led to higher yields than where post-emergence herbicides were applied. Sequential treatments generally failed to produce significantly better weed control or higher yields than single applications of herbicides possessing the ability to control a similar weed spectrum.

INTRODUCTION

The rapid expansion in area of the oilseed rape crop in the UK in recent years has been accompanied by the introduction of a number of new herbicide recommendations for the control of both grass and broad-leaved weeds in the crop. ADAS experimental work has assessed the efficacy of these herbicides and measured their effect on yields This paper outlines the results obtained in the harvest years 1979-81.

METHODS AND MATERIALS

This series of trials included a range of pre-drilling, pre-emergence and post-emergence herbicides applied either as single treatments or sequences. All herbicides were applied at the normal recommended timings at the doses shown in Tables 1-3. Results only include those treatments that featured in at least 2 sites in a particular year.

The trials were carried out on farm crops and the weed spectrum was influenced to some degree by cultivation method. For example, the land was always ploughed at High Mowthorpe, thus limiting the number of cereal volunteers. Seed yields were measured by harvesting with a combine harvester at all sites except SE(b) where small samples were cut by hand and the results not analysed statistically. 2 sites, EM(b) in 1979 and SE(b) in 1980 were not harvested.

RESULTS AND DISCUSSION

The seed yields are given in Tables 1, 2a, 3. Weed control was assessed in various ways but is presented in Tables 1, 2b, 3 as percent reduction due to treatment. Weed numbers at High Mowthorpe in 1979 were extremely low and are not included.

Only 4 of the 11 trials where results were analysed showed significant yield responses to weed control. There was no consistent evidence to suggest an advantage from the use of pre-drilling or pre-emergence herbicides instead of post-emergence materials. Sequential treatments also failed to produce significantly better weed control or higher yields than single applications, providing that the herbicide concerned was capable of controlling both broad-leaved and grass weeds.

Similar levels of weed control and yield response were given by TCA + trifluralin and TCA + napropamide + trifluralin. Napropamide + trifluralin used alone gave slightly poorer weed control.

At most sites in 1979 and 1980 the higher dose of tebutam produced better weed control than the lower dose. The addition of TCA generally improved weed control. Similar levels of weed control and yield were obtained from pre-drilling and pre-emergence timings in 1981. Good weed control was obtained at 2 sites and a significant yield response at one where tebutam was applied in sequence with alloxydim sodium in 1979.

TCA + alachlor gave similar levels of weed control to TCA + metazachlor at 3 sites in 1981. In 1980 TCA + metazachlor gave small but non-significant yield reductions at 2 sites.

In 1979, alloxydim sodium at various doses gave generally satisfactory control of grass weeds except Poa annua but its efficacy increased to the highest dose. Sequential applications of either benazolin + 3, 6-dichloropicolinic acid or carbetamide + dimefuron following alloxydim sodium gave better weed control than propyzamide used in sequence with alloxydim sodium.

In 1981 fluazifop-butyl followed by propyzamide consistently gave poorer control of weeds than TCA followed by propyzamide, but yields were similar. Fluazifop-butyl followed by benazolin + 3,6-dichloropicolinic acid produced better weed control than TCA followed by benazolin + 3,6-dichloropicolinic acid but again mean yield increases were similar.

Propyzamide at the lower dose of 0.50 kg a.i./ha generally gave slightly poorer weed control than where it was applied at 0.70 kg a.i./ha, especially where Stellaria media was present. At many sites better weed control was given by carbetamide + dimefuron although effects on yield were similar. There were some instances of slight yield reduction where propyzamide was applied in sequence with TCA rather than as a single treatment; this was noticed in particular in the ploughed situation at High Mowthorpe and in EM (b) site in 1980. Results were inconsistent, however.

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R. N. Green	Wye (South East Region - SE (b))
J. MacLeod	High Mowthorpe EHF

Table 1

Crop yields (tonnes/ha @ 92% DM) and percent weed control 1979

	Site	Crop yield EM(a)	Crop yield SE(a)	Crop yield SE(b)	Crop yield HM	Av yield response	Percent weed control EM(a)	Percent weed control EM(b)	Percent weed control SE(a)	Percent weed control SE(b)	
	Dose a.i (kg/ha)						Main weed spp***			S media	Other spp.
							1.5	5	2.4.5.6		
Pre-emergence											
TCA	10.60	-	-	3.35	3.97	(+0.57)	-	-	-	47	83
tebutam	2.88	2.76	-	3.62	3.83	(+0.68)	37	46	-	86	55
tebutam	4.32	2.66	-	3.44	3.92	(+0.61)	56	71	-	94	55
Post-emergence											
dalapon sodium	1.27	2.31	2.04	-	3.70	(+0.02)	25	0	31	-	-
alloxydim sodium	0.56	-	-	3.11	3.96	(+0.44)	-	-	-	53	20
alloxydim sodium	0.75	2.43	2.01	3.37	-	(+0.46)	44	0	27	0	49
carbetamide + dimefuron	2.10+0.70	2.54	2.17	3.27	-	(+0.52)	56	64	73	94	69
propyzamide	0.50	2.80	2.17	-	3.99	(+0.33)	44	36	59	-	-
benazolin + 3,6-DCPA*	0.35	1.95	2.09	-	-	(-0.03)	50	65	55	-	-
alloxydim sodium + benazolin + 3,6 - DCPA	0.75+0.35	2.53	2.04	-	-	(+0.23)	94	31	68	-	-
Sequential applications											
alloxydim sodium/benazolin + 3,6 - DCPA	0.56/0.35	2.80	-	3.30	3.91	(+0.61)	69	65	-	94	51
alloxydim sodium/carbetamide + dimefuron	0.56/2.80	2.63	-	3.40	-	(+0.86)	69	79	-	92	73
alloxydim sodium/propyzamide	0.37/0.25	2.07	-	-	3.99	(+0.09)	37	34	-	-	-
tebutam/alloxydim sodium	2.88/0.56	2.82	-	-	-	-	75	76	-	-	-
Untreated		2.00	2.11	2.31	3.87						
Standard Error ±		0.096	0.121	-**	0.150						

*** Weed key: 1. Volunteer wheat, 2. Volunteer barley, 3. *Poa* spp. 4. Other annual grass weeds. 5. *Stellaria media*. 6 *Veronica* spp. 7. Mayweed spp.

* 3,6 - dichloropicolinic acid

**Not analysed

Table 2a

Crop yields (tonnes/ha @ 92% DM) 1980

	Site	EM(a)	EM(b)	SE(a)	HM	Av yield response
	Dose a.i. (kg/ha)					
Pre-drilling						
TCA + trifluralin	8.00+1.10	4.13	-	3.24	2.40	(+0.29)
Pre-emergence						
TCA	5.70	4.10	-	-	2.21	(+0.38)
TCA	11.40	3.91	2.95	-	2.47	(-0.26)
tebutam	2.88	3.78	-	3.68	2.72	(+0.42)
tebutam	4.32	3.97	4.58	3.48	2.52	+0.27
TCA + tebutam	5.70+2.88	4.18	-	3.35	2.38	(+0.33)
TCA + tebutam	5.70+4.32	4.10	-	-	2.62	(+0.59)
TCA + tebutam	11.40+2.88	4.22	-	3.31	2.46	(+0.36)
TCA + tebutam	11.40+4.32	3.85	-	3.34	2.36	(+0.21)
TCA + alachlor	11.40+1.90	3.70	-	-	2.32	(+0.24)
TCA + metazachlor	8.00+1.20	-	-	3.14	-	-
Post-emergence						
propyzamide + 3,6 - DCPA	0.70+0.075	-	3.72	3.61	2.88	(-0.07)
propyzamide	0.50	-	4.40	-	2.79	(+0.06)
propyzamide	0.70	3.66	4.97	3.42	2.71	+0.32
carbetamide + dimefuron	2.10+0.70	-	4.09	3.49	2.54	(-0.10)
benazolin + 3,6 - DCPA	0.35	-	3.44	-	2.51	(-0.55)
Sequential applications						
TCA/benazolin + 3,6 - DCPA	11.40/0.35	-	3.71	-	2.34	(-0.50)
TCA/propyzamide	11.40/0.50	-	3.84	-	2.50	(-0.36)
alachlor/propyzamide	1.90/0.50	-	3.37	-	2.54	(-0.57)
dalapon sodium/benazolin + 3,6 - DCPA	1.27/0.35	-	4.25	-	2.44	(-0.18)
dalapon sodium/propyzamide	1.27/0.50	-	3.37	-	2.62	(-0.53)
Untreated		3.06	4.58	3.37	2.48	
Standard Error ±		0.165	0.475	0.164	0.166	

Table 2b

Percent weed control 1980

	Site	EM(a)	EM(b)	SE(a)	SE(b)	HM
	Dose a.i. (kg/ha)	Main weed spp* 1.3.5.6	1.5	2.3.5.6	3.5.7	2.4.5
Pre-drilling						
TCA + trifluralin	8.00 + 1.10	89	-	41	-	88
Pre-emergence						
TCA	5.70	70	-	-	-	0
TCA	11.40	73	63	-	63	31
tebutam	2.88	55	-	90	-	74
tebutam	4.32	72	75	100	86	58
TCA + tebutam	5.70 + 2.88	82	-	97	99	36
TCA + tebutam	5.70 + 4.32	88	-	-	-	82
TCA + tebutam	11.40 + 2.88	83	-	100	-	87
TCA + tebutam	11.40 + 4.32	91	-	97	-	90
TCA + alachlor	11.40 + 1.90	91	-	-	-	59
TCA + metazachlor	8.00 + 1.20	-	-	100	96	-
Post-emergence						
propyzamide + 3,6 - DCPA	0.70 + 0.075	-	90	59	-	91
propyzamide	0.50	-	91	-	80	80
propyzamide	0.70	86	93	45	-	92
carbetamide + dimefuron	2.10 + 0.70	-	94	59	74	96
benazolin + 3,6 - DCPA	0.35	-	30	-	73	54
Sequential applications						
TCA/benazolin + 3,6 - DCPA	11.40/0.35	-	98	-	81	89
TCA/propyzamide	11.40/0.50	-	99	-	69	94
alachlor/propyzamide	1.90/0.50	-	92	-	-	94
dalapon sodium/benazolin + 3,6-DCPA	1.27/0.35	-	85	-	-	70
dalapon sodium/propyzamide	1.27/0.50	-	79	-	-	89

*Refer to key in Table 1

Table 3

Crop yields (tonnes/ha @ 92% DM) and percent weed control 1981

	Site	Crop yield						Percent weed control				
		EM(a)	EM(b)	SE(a)	SE(B)	HM	Av yield response	EM(a)	EM(b)	SE(a)	SE(b)	HM
	Dose a.i (kg/ha)							Main weed spp** 1.5.6	1.5	2.3.5	2.5	2.5.6
Pre-drilling												
TCA+trifluralin	7.50+1.10	2.69	2.14	3.06	-	3.87	(+0.12)	97	39	94	-	93
TCA+napropamide+trifluralin	11.40+0.84+0.84	2.65	2.22	3.08	-	3.84	(+0.12)	100	31	96	-	86
napropamide+trifluralin	0.84+0.84	2.79	2.26	3.14	-	3.93	(+0.21)	84	10	93	-	81
TCA+tebutam	11.40+3.60	2.69	2.22	2.98	3.56	4.15	+0.22	89	47	92	87	89
Pre-emergence												
TCA+tebutam	11.40+3.60	2.81	2.25	2.91	-	3.73	(+0.10)	89	33	97	-	94
TCA+alachlor	11.40+1.90	2.64	1.84	-	-	3.61	(+0.05)	100	47	-	-	96
TCA+metazachlor	11.40+1.40	2.74	2.56	2.98	3.53	3.87	+0.24	100	51	98	90	97
Post-emergence												
propyzamide	0.70	2.68	2.06	2.97	3.42	4.24	+0.17	69	37	81	59	92
propyzamide+3,6-DCPA	0.77	2.81	2.18	2.99	-	4.19	(+0.22)	75	55	84	78	89
carbetamide+dimefuron	2.80	2.67	2.20	3.13	3.77	4.12	+0.28	94	37	94	90	87
Sequential applications												
TCA/propyzamide	11.40/0.50	2.73	1.89	2.83	-	3.96	(+0.03)	83	53	88	-	85
TCA/propyzamide	11.40/0.70	2.75	1.95	2.94	3.82	3.96	+0.18	86	61	91	72	88
TCA/benazolin+3,6-DCPA	11.40/0.35	2.97	2.48	-	3.83	3.89	(+0.43)	81	59	-	84	65
fluazifop-butyl/benazolin+3,6-DCPA	0.25/0.35	2.71	2.42	-	-	4.08	(+0.37)	94	64	-	-	65
fluazifop-butyl/propyzamide	0.25/0.50	2.75	1.93	2.91	-	4.17	(+0.12)	58	55	77	-	82
Untreated		2.57	1.81	3.09	3.23	3.80						
Standard Error±		0.044	0.096	0.148	-*	0.190						

** Refer to key in Table 1

* Not analysed

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THE USE OF METAZACHLOR FOR THE CONTROL OF WEEDS IN WINTER OILSEED RAPE

D. A. Stormonth and R. Woodroffe
BASF (UK) Ltd., Lady Lane, Hadleigh, Ipswich IP7 6BQ

Summary. Trials data show that metazachlor can be used as a pre-emergence herbicide for the control of many important broad-leaved and grass weeds in winter oilseed rape. The chemical was used in tank-mixture or sequence with a range of other materials in order to improve its control of cereal volunteers. Metazachlor did not affect the crop if sprayed within 48 hours of drilling and provided there was not subsequent heavy rainfall. Crop yields were maintained.
Broad-leaved weeds, pre-emergence herbicide, grassweeds, cereal volunteers.

INTRODUCTION

Metazachlor is a halogenated aceto-anilide, with the chemical name 2-chloro-N-(2,6-dimethylphenyl) - N - (1 H - pyrazol-1-ylmethyl) - acetamide. It has been formulated as an emulsifiable concentrate and also a suspension concentrate. The suspension concentrate was commercially introduced into the U.K. in 1982 under the trade name 'Butisan S'.

Metazachlor has activity on a wide range of both broad-leaved and grass weeds, being taken up primarily through the roots and causing plants to die before or shortly after emergence. The chemical can be used selectively on a range of crops, particularly *Brassica spp*., including oilseed rape.

The work described here was concerned with the development of metazachlor as a post-drilling, pre-emergence herbicide for winter oilseed rape, in conjunction with herbicides for the control of volunteer cereals.

MATERIALS AND METHODS

Trials were sited in Central and Eastern England and covered a range from light to very heavy soil types. Varieties treated were Jet Neuf, Primor, Quinta and Garant.

Replicated Small Plot Trials

All replicated trials were of randomized block design with four replicates. Plot sizes averaged $48 m^2$. Applications were made using a Van der Weij sprayer fitted with hollow cone nozzles, in a water volume of 250 l/ha at 200 KPa. Spraying normally took place within 48 hours of drilling.

Weed assessments were made by visual inspection of the whole plot. Percentage ground cover of weeds in the untreated plots were recorded, and percentage control of individual weed species relative to the untreated plot was assessed in autumn and the following spring.

Plots were harvested and yields measured using a Claas Compact 25 combine harvester.

Farmer Usage Trials

Metazachlor was given to a number of farmers throughout England. Each farmer treated 1ha of crop with the product, either in tank-mixture with TCA or following pre-drilling incorporation of TCA. Assessments were made by visual inspection, as described, relative to a small untreated area, approximately 3 months after application.

Chemical Formulations

The metazachlor used in the small plot trials was of a 200 g/l e.c. formulation prior to 1981 and a 500 g/l s.c. formulation thereafter. Farmer usage work was carried out only with the 500 g/l s.c. formulation. All rates are expressed as kg a.i/ha.

RESULTS AND DISCUSSION

Cereal volunteers can be a major problem to oilseed rape growers. Metazachlor alone gave varying levels of control, although such levels were not good enough for commercial use (Table 1). TCA alone can also produce variable results, whereas metazachlor in combination with TCA, or in a sequence with fluazifop-butyl or alloxydim-sodium gave acceptable and more consistent levels of control.

Table 1

Effect of metazachlor on the control of cereal volunteers

Metazachlor (kg a.i/ha)	% control - Mean of 3 trials, 1980		
	W.Barley	S.Barley	W.Wheat
1.4	59	39	12
1.8	61	39	12
Metazachlor 1.25 kg a.i/ha + TCA 8.0 kg/ha	98	Means of 3 trials, 1982	
Metazachlor 1.25 kg a.i/ha followed by fluazifop-butyl 250 g a.i/ha + wetter	99		
Metazachlor 1.25 kg a.i/ha followed by alloxydim-sodium 900 g a.i/ha + wetter	97		
Metazachlor 1.25 kg a.i/ha followed by dalapon 2.1 kg a.i/ha	90		

Table 2

% Weed Control, Mean of 3 trials, 1982

	A.myosuroides 4 sites	P.annua 1 site	S.media 3 sites	Veronica spp. 2 sites	Matricaria spp. 4 sites
Untreated (% ground cover)	6	38	11	9	35
Metazachlor 1 kg + TCA 8 kg (a.i/ha)	100	100	100	100	98
" 1.25 " 8 "	100	100	100	100	98
" 1.25, fluazifop-butyl 250 g (+ wetter) (a.i/ha)	100	100	100	100	98

The results in Table 2 show very high levels of control by metazachlor of the 3 major broad-leaved weeds of oilseed rape, as well as Alopecurus myosuroides and Poa annua.

A good indication of weed susceptibility to metazachlor is given in Table 3 which shows maximum and minimum control values observed in a series of 14 small plot trials over 5 years. This can be compared with the results from 48 farmer usage trials carried out in 1982 (Table 4).

Again, high levels of control were observed of the commonly occurring weed species. The farmer usage results agree with the small plot trials results, or in some cases, such as G.aparine, show higher control levels than expected.

Table 3

Weed control in 14 small plot trials, 1978-82

Metazachlor 1.2 kg/ha + TCA 7.6 kg a.i/ha		% Weed Control	
Weed Species	No.of sites	Minimum	Maximum
Stellaria media	13	90	100
Matricaria spp.	8	92	100
Veronica spp.	6	91	100
Poa annua	4	95	100
Urtica urens	3	45	83
Alopecurus myosuroides	2	91	100
Capsella bursa-pastoris	2	94	100
Polygonum convolvulus	2	64	70
Galium aparine	2	48	100
Viola arvensis	2	48	100
Senecio vulgaris	1	98	
Atriplex patula	1	83	
Chenopodium album	1	83	
Polygonum persicaria	1	59	
Sinapis arvensis	1	40	
Polygonum aviculare	1	37	

Table 4

Weed Control in 48 Farmer Usage Trials, 1982

Metazachlor 1.25 kg a.i/ha TCA tank mixture or sequence 7.6 to 14.3kg a.i/ha		% Weed Control	
Weed Species	% sites infested	% Min	% Max
Stellaria media	83	95	100
Matricaria spp.	63	93	100
Veronica spp.	54	90	100
Poa annua	42	95	100
Viola arvensis	25	30	75
Lamium purpureum	21	90	100
Myosotis arvensis	19	90	100
Papaver rhoeas	17	85	100
Alopecurus myosuroides	15	95	100
Capsella bursa-pastoris	15	90	100
Aphanes arvensis	13	70	100
Polygonum aviculare	10	10	15
Galium aparine	8	95	100
Chenopodium album	8	60	95
Polygonum persicaria	6	80	95
Spergula arvensis	6	70	90
Sinapis arvensis	6	50	100
Senecio vulgaris	4	100	100
Fumaria officinalis	4	95	98
Polygonum convolvulus	4	80	100
Lithospermum arvense	2	100	100

The results in Table 4 also provide information on the frequency with which broad-leaved weeds occur in winter oilseed rape throughout England.

Application during germination of rape seed, particularly if followed by heavy rainfall, may cause crop damage, hence it is necessary to apply metazachlor in the period up to 48 hours after drilling (Table 5).

However, once germination of the rape seed is complete, it would appear that the crop again becomes tolerant to treatment.

Table 5

Effect of Spraying Interval after Drilling on Crop Vigour
Farmer Usage Trials, 1982 30 sites

Crop vigour category (5 = no effect, 0 = crop death)	% Crops in each category Days after drilling 0	1	2	3	4	5
No effect (5-4)	100	100	100	75	33	100
Moderate effect (4-3)	0	0	0	25	33	0
Severe effect (3-0)	0	0	0	0	33	0

Table 6 shows the yield advantage which can be achieved through adequate broad-leaved and grass weed control.

Table 6

Crop Yield from 5 sites, 1979/80

Treatment	% Yield relative to untreated crop
Untreated	100
Metazachlor 1.2 kg a.i/ha	100
" 1.4 "	109
" 1.6 "	103
" 1.8 "	120
" 1.0 " + TCA 7.6 kg a.i/ha	117
" 1.2 " " 7.6 "	108
" 1.4 " " 7.6 "	118
" 1.6 " " 7.6 "	112
" 1.8 " " 7.6 "	108

Little or no adverse crop effects were seen in trials in 1979, when metazachlor was applied at three rates or at two rates in tank-mixture with two rates of TCA (Table 7). In a trial series in 1981, however, unacceptable levels of vigour loss were observed at one site (Table 8). Since metazachlor has a relatively high solubility in water (0.1g/100ml) the germinating rape seeds may have been exposed to and taken up sufficient chemical to cause this effect, as heavy rainfall occurred soon after application. This phenomenon was also observed in several farmer usage trials.

These results show that metazachlor is an effective pre-emergence herbicide for the control of weeds in winter oilseed rape.

Table 7

Effect of metazachlor on crop vigour - Mean values from 4 trials - 1979

Treatment	Crop Vigour Weeks after treatment 5 - 8	11 - 12
Untreated	5	5
Metazachlor 1.2 kg a.i/ha	5	5
" 1.4 "	5	5
" 1.8 "	5	5
" 1.2 " + TCA 5.7 kg a.i/ha	5	5
" 1.2 " " 7.6 "	4.9	5
" 1.4 " " 5.7 "	4.9	5
" 1.4 " " 7.6 "	4.9	5

See Table 6 for crop vigour key

Table 8

Effect of metazachlor on crop vigour - 3 trials, 1981

Treatment	Weeks after treatment:	Trial 1 18	Trial 1 25	Trial 2* 13	Trial 2* 22	Trial 3 18	Trial 3 28
Untreated		5	5	5	5	5	5
Metazachlor	1.5 kg a.i/ha	5	5	2.7	2.9	5	5
"	1.0 " + TCA 7.6 kg a.i/ha	5	5	3.0	3.1	5	5
"	1.25 " " 7.6 "	5	5	2.7	2.9	5	5
"	1.5 " " 7.6 "	5	5	2.4	2.5	5	5
"	1.0 " " 9.5 "	5	5	3.0	3.0	5	5
"	1.25 " " 9.5 "	5	5	3.0	2.9	5	5
"	1.5 " " 9.5 "	5	5	3.0	2.7	5	5

* Heavy rain, soil waterlogged after treatment.
See Table 6 for crop vigour key

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BASF (UK) Limited., would like to thank the many farmers who provided sites and undertook work in the course of these trials.

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THE EVALUATION OF THE SELECTIVITY OF METAMITRON POST-EMERGENCE IN SEQUENCE WITH DIFFERENT PRE-EMERGENCE HERBICIDES, 1979-1981

J.G. Hilton and W.E. Bray
Norfolk Agricultural Station, Morley, Wymondham, Norfolk NR18 9DB

Summary. Metamitron and metamitron and the adjuvant oil 'Actipron' were examined post-emergence following a range of pre-emergence herbicides at various locations throughout East Anglia. Most of the pre-emergence treatments appeared to be compatible with metamitron but some doubt was cast on the suitability of lenacil in a metamitron or metamitron + 'Actipron' sequence. Lenacil, chloridazon, ethofumesate, adjuvant oil, interactions.

INTRODUCTION

Metamitron is now well established as a herbicide for use in sugar beet and its efficiency and safety are well documented (Morris et al., 1976). Unfortunately some uses of metamitron have been restricted. Many sugar beet growers would like to use metamitron in non-recommended herbicide programmes to fully utilize the benefits of this material. The authors of this paper conducted a series of trials (Hilton and Bray, 1980) where the herbicidal efficiency of metamitron in sequence with other established herbicides was examined in detail. As a sequel to this trial series a further set of three year experiments was initiated in 1979 to examine possible alternative sequences to the manufacturers current recommendations of metamitron pre-emergence followed by metamitron + an adjuvant oil post-emergence (Anon, 1981). It was considered important, however, that the inherent safety of metamitron should not be reduced and the object of this new investigation was to measure the effect of the various herbicide treatments on the beet crop. To achieve this aim, all sites were kept as weed free as possible by tractor and hand hoeing.

METHOD AND MATERIALS

The pre-emergence herbicides were examined at the recommended rate for the particular soil type and at a rate 50 per cent above this. They included metamitron, chloridazon, lenacil, a mixture of ethofumesate and chloridazon; in addition an untreated control was included. The post-emergence treatments were metamitron used with, or without an adjuvant oil, and an untreated control. These again were tested at the normal dose and at a level 50 per cent above this rate. This overdosing technique was used to indicate possible adverse interactions when normal doses showed complete safety to the crop. If effects were observed from the high rates of application with some of the treatments then this might give some indication of peformance when normal doses are used in the field under stressful conditions. The treatments were arranged in a fully factorial design with two randomised blocks at each site.

Four trials were laid down in each of the first two years of the investigation and three in the final year in commercial crops of sugar beet. In all cases the pre-emergence treatments were applied as soon after drilling as possible using a Van der Weij sprayer arranged to spray five or six rows to match drill width. Plot area was 5 or 6 rows x 12.5 m. Applications were made in a volume of 400-480 l/ha, using Birchmeier 1.6-673a-1.3 nozzles at 250 kPa. The post-emergence spraying was carried out as soon as practicable after full crop emergence and varied from when the beet had fully expanded cotyledons to when the first true leaves were approximately 1.5 cm long. At the time of this series of experiments the commercial recommendations for post-emergence applications of metamitron was for it not to be applied until the first true leaves of the beet were at least 1 cm long. The same sprayer was used for applying the post-emergence treatments in a volume of 240-320 l/ha with Birchmeier 1.6-673a nozzles at 250 kPa or 1.2-2F-0.6 nozzles at 220 kPa, depending upon prevailing weather conditions.

The trials were tractor-hoed at the same time as the surrounding commercial crop and a 'tidying up' operation was carried out by hand at the time of beet seedling counts.

Beet seedling counts and vigour scores were made several weeks after the last post-emergence spray. In addition, a vigour score was made on several of the sites in August.

In the autumn some of the sites were harvested by hand, using the same area used for the beet counts on 5 row plots (3 rows x 10.5 m). 4 rows x 7.5 m were harvested on six row plots to give a similar harvest area. The plots were hand dug, topped manually, washed and analysed for sugar content at the Norfolk Agricultural Station.

The pre-emergence herbicides used were: metamitron (70% wt/wt as 'Goltix'); chloridazon (80% wt/wt as 'Pyramin' wettable powder in 1979; 430 g/l 'Pyramin FL' suspension concentrate in 1980 and 81); lenacil (80% wt/wt as 'Venzar' wettable powder); ethofumesate (200 g/l as 'Nortron' emulsifiable concentrate) + chloridazon (80% wt/wt as 'Pyramin' w.p.) as a tank mix in 1979 and as 'Spectron' suspension concentrate in 1980 and 1981. The post-emergence treatments were metamitron applied with or without the self-emulsifying adjuvant oil, 'Actipron'.

RESULTS

Table 1

Mean beet seedling vigour

Pre-emergence	untreated	Post-emergence metamitron R*	Post-emergence metamitron 1.5 R	metamitron + oil R	metamitron + oil 1.5 R	Mean
			(S.E. ±0.31)			(±0.14)
Untreated	8.0	7.7	8.0	7.2	7.8	7.7
metamitron R*	7.7	7.3	8.0	7.9	7.3	7.6
metamitron 1.5 R	7.3	6.7	7.0	6.9	7.0	7.0
chloridazon R	7.4	8.3	7.9	7.4	7.2	7.6
chloridazon 1.5 R	7.2	7.4	7.1	7.3	7.0	7.2
lenacil R	7.3	6.4	5.7	6.6	6.4	6.5
lenacil 1.5 R	6.7	6.2	5.8	6.1	5.7	6.1
ethofumesate + chloridazon R	8.2	7.1	7.1	7.0	7.4	7.3
ethofumesate + chloridazon 1.5 R	7.1	7.4	7.0	7.3	7.5	7.2
Mean	7.4	7.2	7.1 (±0.10)	7.1	7.0	

*R = recommended dose

The use of lenacil pre-emergence gave marked and significantly lower overall mean beet vigour scores than the other treatments. At the recommended rate of lenacil, treatment with a high post-emergence dose gave reductions in vigour, whilst at the higher rate of lenacil, the crop was affected regardless of post-emergence treatment, the effect being more pronounced where the post-emergence herbicides were overdosed. The higher rate of the other pre-emergence herbicides gave significantly lower mean vigour scores, whilst the post-emergence treatments gave only slight reductions in overall mean vigour of the beet seedlings when compared with untreated controls (see Table 1).

Table 2

Mean beet seedling population (thousands/ha)

Pre-emergence	Post-emergence untreated	metamitron R*	metamitron 1.5 R	metamitron + oil R	metamitron + oil 1.5 R	Mean
			(S.E. ±1.50)			(±0.67)
Untreated	68.9	71.3	74.1	67.8	72.5	70.9
metamitron R*	71.4	68.4	70.3	68.6	70.2	69.8
metamitron 1.5 R	64.5	64.6	65.6	66.1	66.6	65.5
chloridazon R	71.8	69.7	72.9	68.5	68.1	70.2
chloridazon 1.5 R	68.6	68.4	65.8	68.3	68.8	68.0
lenacil R	68.2	56.9	56.2	59.8	62.0	60.6
lenacil 1.5 R	59.5	58.8	52.0	55.3	51.8	55.5
ethofumesate + chloridazon R	71.8	66.1	68.4	69.5	69.0	69.0
ethofumesate + chloridazon 1.5 R	67.9	68.2	65.5	68.3	68.5	67.7
Mean	68.1	65.8	65.7 (±0.50)	65.8	66.4	

*R = recommended dose

Beet seedling populations were similarly affected, with lenacil causing marked and significant reductions in numbers (see Table 2). The overall effect of the post-emergence herbicides on beet seedling population was less marked compared with the observations on seedling vigour.

Table 3

Mean sugar yield at harvest (t/ha)

Pre-emergence	Post-emergence: untreated	metamitron R*	metamitron 1.5 R	metamitron + oil R	metamitron + oil 1.5 R	Mean
			(S.E. ±0.22)			(±0.10)
Untreated	9.4	9.5	9.9	9.5	10.3	9.7
metamitron R*	9.7	9.7	9.8	10.0	9.5	9.7
metamitron 1.5 R	10.1	9.8	9.9	9.8	9.7	9.9
chloridazon R	9.4	9.5	9.7	9.6	9.3	9.5
chloridazon 1.5 R	9.9	9.5	9.7	10.0	9.7	9.7
lenacil R	9.5	9.4	8.9	9.5	9.7	9.4
lenacil 1.5 R	9.1	9.3	9.1	8.8	9.1	9.1
ethofumesate + chloridazon R	9.8	9.6	9.5	9.5	9.5	9.6
ethofumesate + chloridazon 1.5 R	9.6	9.9	9.1	9.5	9.6	9.5
Mean	9.6	9.6	9.5 (±0.07)	9.6	9.6	

*R = recommended dose

The harvest data revealed that the lenacil treatments still showed significant population reductions at the time of lifting. Sugar yield determinations showed a significantly lower overall mean yield with the higher dose of lenacil than with the other pre-emergence treatments, but there was no obvious interaction between this and the post-emergence sprays. No other pre- or post-emergence treatment reduced sugar yield.

DISCUSSION

This series of experiments suggests that most of the herbicides tested are compatible in a herbicide sequence with metamitron or metamitron + adjuvant oil when crop selectivity is considered. The one exception to this being lenacil, where consistent vigour, population and yield reductions have been recorded when this herbicide has been used at above normal rates of application. Therefore the use of lenacil pre-emergence in a programme with metamitron post-emergence should be treated with caution, since the effects observed in the overdosing treatments might reflect what could happen under field conditions that were not ideal. None of the other herbicides gave any cause to suspect adverse interactions with metamitron in this series of experiments and therefore might be useful components of a herbicide sequence using metamitron as a post-emergence treatment.

Hilton and Bray (1980) found several herbicide programmes utilising metamitron that could provide satisfactory weed control. These observations, together with those discussed in this paper indicate that the safety and efficiency of this herbicide are not necessarily prejudiced by judicious use of other herbicides in a weed control programme with metamitron. Other workers (Elliot and Jung, 1980) have shown that metamitron may also be used in mixture with other herbicides rather than a single component in a sequence of applications.

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EFFECTS OF SEVERAL HERBICIDES ON DISEASES OF WINTER OILSEED RAPE

P. Gladders and T.M. Musa*

Agricultural Development and Advisory Service, Block C
Government Buildings, Brooklands Avenue, Cambridge CB2 2DR

Summary. Observations on disease incidence in replicated herbicide trials during 1978-82 showed that pre-emergence application of TCA, alone or with post emergence treatments consistently increased the incidence of leaf and stem infections of *Leptosphaeria maculans*. This was associated with an increase in leaf wettability and a decrease in the amount of leaf wax. Tebutam applied alone pre-emergence had no significant on disease incidence. In 1982, a range of herbicide treatments increased the incidence of Alternaria leaf spot, significant differences ($P<0.01$) were recorded at one site in all treatments where TCA mixtures were applied pre-emergence. TCA, canker, alternaria, leaf wax, wettability.

INTRODUCTION

Diseases of winter oilseed rape (*Brassica napus* L. ssp. *oleifera*) have been monitored by ADAS since 1976. This followed severe infections of light leaf spot (*Pyrenopeziza brassicae*) during the winter of 1974-75 (Jones *et al*, 1975) which was associated with the use of dalapon. Rawlinson *et al*, (1978) subsequently showed that dalapon decreased wax on leaves and increased wettability which favoured spore deposition and infection by *P. brassicae*. Since 1975 both canker (*Leptosphaeria maculans*) and dark leaf and pod spot (*Alternaria brassicae*) have been recorded at high levels in oilseed rape crops in the UK (Evans and Gladders, 1981). Changes in agronomic practice as well as intensification and seasonal weather variations may have contributed to these changes in disease incidence.

During the period 1977-1982 our records from disease monitoring sites indicate there have been changes in varieties, a trend towards earlier drilling and major changes in herbicide usage. A survey of pesticide usage in oilseed rape carried out in 1977 (Steed *et al*, 1979) indicated that 56% of the crop was treated with dalapon. This herbicide has now been replaced by another aliphatic acid herbicide, TCA which, although used as a pre-emergence treatment, also reduces leaf waxes (Juniper, 1959). In 1982 probably less than 10% of the oilseed rape crop was treated with dalapon but about 70% of the crop received TCA (Provisional results of Pesticide Survey Group, Harpenden, Oilseed rape survey 1982). This paper reports observations made on diseases in ADAS Eastern Region herbicide trials during 1978-1982.

METHODS AND MATERIALS

Site details and treatment rates are given in Tables 1-4. The herbicides used were:-

*Present address: Plant Protection Institute, PO Box 8100, Causeway, Zimbabwe

alloxydim sodium (NP48, 75% w.p.); benazolin and 3, 6-dichloropicolinic acid (Benazalox, 30% + 5% w.p.); carbetamide (Carbetamex, 70% w.p.); carbetamide + dimefuron (Pradone Plus, 52.5% + 17.5% w.p.); carbetamide + dimefuron (LFA 2237, 1.6% + 0.4% w.p.); clofop-isobutyl (Alopex, 36% e.c.); dalapon (Dowpon, 85% w.p.); 3, 6-dichloropicolinic acid (Dowco 290, 10% liquid); diclofop-methyl (Hoegrass, 37.8% e.c.); endothal sodium (Herbon Pennout), 19.2% e.c.); fluazifop-butyl (Fusilade, 25% liquid); metazachlor (Butisan S, 50% e.c.); napropamide + trifluralin (Devrinol T, 14% + 14% e.c.); propyzamide (Kerb 50W, 50% w.p.); propyzamide + 3, 6-dichloropicolinic acid (Matrikerb, 43% + 4.3% w.p.); sethoxydim* (NP55, Formulation 34/02, 19.3% e.c.); TCA(Tecane, 95% soluble granule); TCA + trifluralin (MC 7011, 22% + 2% soluble granule); tebutam (Gulf Butam, 72% e.c.); trifop-methyl (HOE 29152, 36% e.c.). These were applied by knapsack sprayer at recommended pressures in 330 litres of water per ha (Sites 1-4) or 225 litres of water per ha (Sites 5 and 6).

Benazalox, Dowco 290 and Matrikerb are called 3, 6-DCPA without distinction in the text.

Growth stages of the oilseed rape plants were recorded using key devised by Harper and Berkenkamp (1975).

Foliar diseases were assessed on a sample of ten plants per plot. At harvest 25 stems per plot were assessed for the presence of canker and/or Phoma stem lesions.

The effects of some of these herbicides on leaf waxes and leaf wettability was examined in a separate experiment (Table 3). TCA was applied four weeks before drilling and tebutam was applied post emergence.

Leaf wettability was measured by the concentration of Manoxol OT surfactant (in a ten-step serial dilution from 0.1 to 0.02%) required to wet ten replicate leaves per treatment (Silva Fernandez, 1965). The amount of wax on leaf surface was measured by the method employed by Silva Fernandez (1965). Fifty leaves from 10 plants of each cultivar given each herbicide treatment (Table 3) were dipped sequentially into four separate washes of chloroform and the washings combined dried and weighed. Leaf area was measured using a photoelectric cell planimeter (Rawlinson et al, 1978). These measurements were made at GS 2.10, 28 days after the post-emergence herbicide foliar sprays were applied.

RESULTS

At Site 1 (Table 1) all treatments which included TCA had significantly more canker than untreated plants. This appeared to be linked to an increase in incidence of Phoma leaf spot in the spring. As one block was severely grazed by wood pigeons in the spring, leaf spots were only assessed on the two relatively ungrazed plots on 5 April. However, by harvest there were no significant differences in canker incidence between blocks. Pre-emergence application of carbetamide + dimefuron also significantly increased canker incidence.

*Proposed BSI common name.

Table 1

Effect of herbicide treatments on the incidence of

Leptosphaeria maculans on cv Primor

Herbicide Treatment Pre-em 23 Sept. 1977	Post-em GS 2.5 18 Nov 1977	Rate kg a.i./ha	% plants with Phoma leaf spot GS 3.2 5 April 1978	% Plants with Canker GS 5.3 20 July 1978
TCA	-	8.0	55	81***
TCA	propyzamide	8.0 0.7	50	85***
TCA	carbetamide + dimefuron	8.0 1.84 + 0.61	65	79***
TCA	clofop-isobutyl +diclofop-methyl	8.0 0.54 + 1.32	60	73***
Carbetamide + dimefuron	-	0.064 + 0.016	35	69**
-	propyzamide	0.7	20	52
	dalapon	3.06	35	42
-	trifop-methyl	0.36	30	37
Untreated'		-	38	40
SE Treatment Mean (between herbicides)			9.0	7.5
SE Treatment Mean (Untreated v Treated)			6.4	5.3
CV (%)			29.9	21.6

'Mean of two control treatments

Site Dennington Suffolk Drilled 16 September 1977 in sandy clay loam

***Significant difference from untreated P<0.001
 **   "   "   P<0.01

On cv. Quinta (Table 2) significant differences in *Phoma* leaf spot incidence were detected on 2 April but treatment differences were more apparent during flowering. At harvest, TCA treated plots had significantly more canker and plants with stem infections. At site 3, there was a slightly lower incidence of *Phoma* leaf spot in the spring but treatment differences were similar during flowering and at harvest except that canker incidence was not significantly increased by TCA treatments.

TCA alone or followed by post-emergence treatments (Table 3) significantly increased the wettability of leaves of cvs. Jet Neuf and Quinta compared with untreated and tebutam treated leaves. This appeared to be linked to a reduction in amount of leaf wax. Similar results, which are not presented here, were obtained on cv. Primor.

Table 2

Effect of pre-emergence herbicides on the incidence of leaf and stem infections of *Leptosphaeria maculans*

	Herbicide Pre-em	Treatment Post-em	Rate kg a.i./ha	Site 2 cv. Quinta: % Plants with Phoma leaf spot GS 3.1, 2 April 1979	Site 2 cv. Quinta: % Plants with Phoma leaf spot GS 4.2, 24 May 1979	Site 2 cv. Quinta: % Canker GS 5.4, 18 July 1979	Site 2 cv. Quinta: % Stems with canker and/or Phoma stem lesions, 18 July 1979	Site 3 cv. Jet Neuf: % Plants with Phoma leaf spot GS 3.1, 2 April 1979	Site 3 cv. Jet Neuf: % Plants with Phoma leaf spot GS 4.3, 24 May 1979	Site 3 cv. Jet Neuf: % Canker GS 5.4, 18 July 1979	Site 3 cv. Jet Neuf: % Stems with canker and/or Phoma stem lesions, 18 July 1979
1.	TCA	-	8.0	32.5*	57.5**	26.0*	68***	5.0	62.5**	15.0	63**
2.	TCA	carbetamide + dimefuron	8.0 2.1+0.7	22.5	72.5**	27.0*	64***	22.5	55.0*	26.0	62**
3.	TCA	propyzamide	8.0 0.7	30.5*	62.5**	35.0**	67***	17.5	57.5*	33.0	65**
4.	TCA	propyzamide + 3, 6-DCPA	8.0 0.7+0.035	12.5	60.0**	30.0**	72***	17.5	65.0**	25.0	65**
5.	Tebutam	-	2.9	25.0	47.5	17.0	38	7.5	35.0	16.0	42
6.*	Tebutam	-	4.3	13.8	45.0	14.5	41	12.5	43.8	17.5	45
7.	Untreated	-	-	12.5	35.0	15.0	33	5.0	32.5	13.0	37
	S.E. Treatment Mean (4 rep v 4 rep)			5.46	4.75	3.64	4.52	4.91	5.91	5.23	3.16
	CV (%)			53.8	17.9	32.6	17.0	78.6	24.0	51.3	11.9

* Treatment 6 had 8 replicates per site, all other treatments 4 replicates per site.

Site 2 Stukeley, Cambs. Drilled 30 August 1978. Clay loam. Pre-em treatments on September 1978. Post-em treatments on 4 December 1978 (GS 2.6-2.8)

Site 3 Bourn, Cambs. Drilled 31 August 1978. Clay loam. Pre-em treatments on 3 September 1978. Post-em treatments on 20 November 1978 (GS 2.5-2.7)

Significant difference from untreated *** $P<0.001$, ** $P<0.01$, * $P<0.05$

Table 3

Effect of herbicide treatment on wettability and amount of wax on leaves of winter oilseed rape (Site 4)

Herbicide Treatment		Rate	cv. Quinta		cv. Jet Neuf	
Pre-em 28 August 1980	Post-em 16 November 1981	kg a.i./ha	Wettability % Manoxol O.T. ± SE	Wt. of wax mg/cm² leaf area	Wettability % Manoxol O.T. ± SE	Wt. of wax mg/cm² leaf area
TCA	-	8.0	0.036±0.001	0.069	0.042±0.003	0.087
TCA	carbetamide + dimefuron	8.0 2.0+0.65	0.030±0.003	0.058	0.038±0.001	0.063
TCA	propyzamide	8.0 0.65	0.032±0.002	0.052	0.034±0.002	0.064
TCA	propyzamide + dalapon	8.0 0.65+1.5	0.018±0.005	0.037	0.028±0.003	0.042
-	tebutam	2.9	0.064±0.001	0.081	0.078±0.001	0.096
-	tebutam	4.3	0.062±0.002	0.078	0.063±0.001	0.083
Untreated	-	-	0.080±0.002	0.123	0.085±0.001	0.143

Site 4. University of East Anglia. Drilled 25 September 1980 in sandy loam soil

In 1982 observations were made at sites where Alternaria brassicae was present (Table 4). Significantly more Alternaria leaf spot was present at Site 5 where TCA mixtures had been used pre sowing or post drilling but pre-emergence. TCA followed by propyzamide and fluazifop-butyl followed by benazolin + 3, 6-DCPA also increased Alternaria incidence. At Site 6 most treatments appeared to increase the incidence of Alternaria but the differences were not significant.

Observations were also made in two trials not reported in detail in July 1979 canker was assessed on cv. Quinta at Heveningham, Suffolk. There were no significant differences between treatments but canker was present on 14% plants in untreated plots and 19%, 28% and 32% plants in TCA only, TCA + propyzamide and TCA + carbetamide + dimefuron treatments respectively.

A post emergence herbicide trial on cv. Jet Neuf adjacent to Site 3 which included different rates and timings of alloxydim sodium showed no significant differences in the incidence of Phoma leaf spot on 2 April 1979 (GS 3.1).

In these trials no differences in the incidence of downy mildew (Peronospora parasitica) or light leaf spot were detected between treatments.

DISCUSSION

Disease incidence in herbicide trials was the net result of herbicide treatment. This includes direct effects on the oilseed rape plant and indirect effects such as weed control which could affect crop development and microclimate. There may also have been differential grazing of plots by wood pigeons and other pests.

TCA alone or followed by post-emergence herbicides consistently increased the incidence of Phoma leaf spot and canker or stem lesions at all sites examined. Most post-emergence treatments appears to have little effect on the incidence of L. maculans. At Site 1, dalapon caused crop damage but did not affect the incidence of Phoma leaf spot or canker unlike an earlier report (Rawlinson et al, 1978).

Table 4

Effect of herbicides on the incidence of *Alternaria brassicae* 1982

Treatment	Rate kg a.i./ha	Site 5 Application Date	Site 5 % Plants with Alternaria GS 2.14 28 January	Site 6 Application Date	Site 6 % Plants with Alternaria GS 3.1 17 February	Site 6 % Plants with Phoma leaf spot 17 February
Napropamide + trifluralin	0.98 + 0.98	24 Aug	36.7	24 Aug	20.0	3.3
Napropamide + trifluralin + TCA	0.98 + 0.98 10.45	24 Aug	56.7**	24 Aug	23.3	3.3
TCA + tebutam	10.45 + 3.60	24 Aug	66.7***	24 Aug	13.3	3.3
TCA sequential propyzamide	10.45 + 0.50	24 Aug 3 Nov	50.0*	24 Aug 4 Nov	23.3	13.3
TCA sequential propyzamide	10.45 + 0.70	24 Aug 3 Nov	40.0	24 Aug 4 Nov	43.3	16.7
TCA + tebutam	10.45 + 3.60	27 Aug	73.3***	26 Aug	23.3	3.3
TCA + metazachlor	7.60 + 1.25	27 Aug	63.3**	26 Aug	30.0	13.3
TCA + trifluralin	11.00 + 1.00	27 Aug	76.7***	26 Aug	16.7	6.7
Propyzamide	0.70	3 Nov	23.3	4 Nov	23.3	13.3
Fluazifop butyl sequential propyzamide	0.25 +0.50	23 Sept 3 Nov	23.3	10 Sept 4 Nov	26.7	3.3
Fluazifop butyl sequential propyzamide	0.25 +0.50	3 Nov 2 Dec	40.0	4 Nov 2 Dec	30.0	20.0
Fluazifop butyl sequential benazolin + 3, 6-DCPA	0.25 +0.30 + 0.05	23 Sept 3 Nov	50.0*	10 Sept 4 Nov	23.3	10.0
Carbetamide	2.10	27 Aug	36.7	26 Aug	33.3	3.3
Carbetamide	2.80	3 Nov	43.3	4 Nov	13.3	3.3
Sethoxydim [A] sequential propyzamide	0.39 +0.50	23 Sept 3 Nov	20.0	10 Sept 4 Nov	23.3	3.3
Endothal sodium sequential propyzamide	0.77 +0.50	1 Oct 3 Nov	20.0	10 Sept 4 Nov	13.3	10.0
Propyzamide + 3, 6-DCPA	0.70 + 0.073	3 Nov	23.3	4 Nov	20.0	6.7
Untreated*		-	23.3	-	11.7	3.3
SE Treatment Mean (Treatment v Treatment)			9.42		7.86	5.32
SE Treatment Mean (Untreated v Treatment)			8.16		6.80	4.60
CV (%)			39.1		61.1	109.4

* 6 replicates, other treatments 3 replicates per site. [A] Proposed BSI name.

Site 5. Heydon, Cambs cv Jet Neuf drilled 25 August 1981 on calcareous very fine sandy loam

Site 6. Childerley, Cambs cv Rafal drilled 25 August 1981 on calcareous silt loam

Significant difference from untreated *** $P<0.001$, ** $P<0.01$, * $P<0.05$.

Differences in disease incidence were first detected in the spring (Table 2) but we have not established when these treatment differences first occurred. The development of L. maculans at Sites 1-3 appears to be similar to that reported in Cambridgeshire during the same period (Gladders and Musa, 1979). Thus treatment differences occurring at any stage could modify disease development for the remainder of the season. In the field TCA treated plots could be easily distinguished from untreated plots throughout the autumn and winter and often in the spring by their greener, less waxy leaves.

In glasshouse experiments, foliar application or carbetamide + dimefuron, propyzamide, propyzamide + dalapon and tebutam to TCA treated plants completely inhibited leaf infection by ascospores of L. maculans when applied one day before or 4 days after inoculation but had no effect when applied 28 days before inoculation (Musa, 1981). Herbicides may therefore have some direct fungitoxic activity as well as effects on leaf wax and leaf wettability (Table 3) but the active component of the formulated products has not been established.

Observations in 1982 also suggest TCA treatments may have contributed to the build up of Alternaria (Evans and Gladders, 1981).

The herbicide disease interactions may be the result of decreasing epicuticular wax this reducing the physical barrier to spore penetration (Skoropad and Tewari, 1977) and/or increasing leaf wettability which favours the spread and retention of splash dispersed spores (Rawlinson et al; 1978).

The current practice of using TCA as a herbicide appears to have increased the incidence of both L. maculans and Alternaria. There is a need for an effective herbicide which does not increase disease incidence. Disease incidence in herbicide trials should be monitored regularly so that positive or negative interactions can be identified prior to widespread commercial usage.

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TIOCARBAZYL FOR THE CONTROL OF GRASS WEEDS IN SUGAR BEET - A NEW FIELD OF APPLICATION

A. Gelmetti, C.A. Lasagna, C. Lusetti and A. Menezes

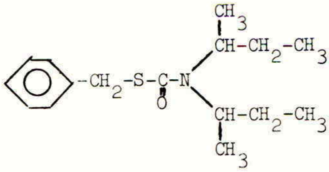
Farmoplant S.p.A., Pesticide Research Centre, Milan, Italy

Summary. Tiocarbazyl is a herbicide synthetised by Montedison S.p.A. and patented worldwide in 1972. This material showed specific activity against *Echinochloa* spp., and was developed for weed control in rice. In addition, in various trials conducted in Italy during 1978-81 on sugar beet, tiocarbazyl showed an excellent activity on grass weeds and good crop tolerance. The results of these trials are reported in this paper. Tiocarbazyl, grass herbicide, sugar beet.

INTRODUCTION

Tiocarbazyl is the common name of a herbicide patented in 1972 and having the following characteristics:

- Chemical name : S-benzyl di-sec - butylthiocarbamate
- Structural formula :



- Empirical formula : $C_{16}H_{25}NOS$
- Molecular weight : 279.4
- Physical state : colourless liquid
- Density (d_4^{20}) : 1.023
- Vapour pressure : 7×10^{-4} mm Hg at 50°C; 5×10^{-5} mm Hg at 25°C
- Solubility in water : 2.5 ppm at 30°C
- Stability : good stability to heat and light

- Toxicology

Acute toxicity	:	in rat, rabbit, chicken, hare, pheasant, quail the LD_{50} is more than 10,000 mg/kg.
Mutagenecity	:	totally negative results in mutagenecity tests.
Chronic toxicity	:	tiocarbazyl showed a high level of safety in two year feeding studies on rats (NOEL 1000 ppm) and dogs (NOEL 300 ppm). (NOEL = No observable effect level).

Tiocarbazyl has been developed in mediterranean rice cultivation for grass weed control, mainly for the control of Echinochloa species, applied either as seed dressing or pre- or post-emergence of weeds (Caracalli et al. 1973; Corradini et al, 1975; Bergamaschi et al, 1975; Gelmetti et al, 1975).

Beginning in 1979 field trials were conducted in Italy to evaluate the herbicidal potential of tiocarbazyl on various other crops leading to the development of the product for grass weed control in sugar beet. This paper reports on trials conducted in the three-year period from 1979-81 in the most important Italian sugar beet growing regions.

Results from analysis of samples obtained from trials carried out to evaluate tiocarbazyl residues in sugar beet are also reported.

METHODS AND MATERIALS

All trials were of a randomised block design, each with four replicates. Plot size was 50 m^2. All applications were made after drilling but pre-emergence of the crop and weeds using a knapsack sprayer mounted with a horizontal boom with five fan jets delivering 1,000 l/ha.

In all trials tiocarbazyl (4 kg a.i./ha) and the tank-mixture of tiocarbazyl + chloridazon (4+2.8 kg a.i./ha) was compared with T.C.A. (9.5 kg a.i./ha) and the tank-mixture of T.C.A. + chloridazon (9.5+2.8 kg a.i./ha).

Tiocarbazyl was formulated as 70% e.c.

Weed control was assessed 50-90 days after spraying by counting individual weed species present in 1-3 m^2 area in each plot. A visual assessment using the EWRC scale was made to evaluate crop safety.

In 1980 two trials were also carried out to evaluate the residues of tiocarbazyl in the leaves and roots of sugar beet. The dose rate used was 4 kg a.i./ha.

RESULTS

Trials results are shown in Tables 1, 2 and 3. Tiocarbazyl alone gave good control of Echinochloa crus-galli, Avena fatua, Avena ludoviciana, Setaria species, Panicum dichotomiflorum, and Alopecurus myosuroides. The material alone has also shown some efficacy against broad-leaved weeds (eg. Solanum nigrum, Veronica persica, Papaver rhoeas, Anagallis arvensis) although much better weed control was achieved in combination with a specific herbicide for broad-leaved weed control, eg. chloridazon. Best results were obtained when rainfall or irrigation followed within 15 days of application of herbicide.

No phytotoxicity from tiocarbazyl was observed in any of the sugar beet varieties used in the trials.

The residues of tiocarbazyl obtained on analysis of leaves and roots of treated sugar beet at harvest time were below 0.01 ppm, i.e. well below the tolerance limits of 1 ppm. **(Ministero della Sanita, 1979).**

DISCUSSION

Tiocarbazyl, in field trials carried out on sugar beet in Italy during the three year period of 1979-81 as a post-drilling, pre-emergence treatment, has given excellent control of grass weeds present in the most important Italian sugar beet growing regions.

The material in tank-mixture with a specific broad-leaved herbicide has given a commercially acceptable level of weed control in sugar beet.

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Table 1

Percentage control of grass and broad-leaved weeds in sugar beet - 1979

Weed	No. of trials	Tiocarbazyl 4 kg a.i./ha	T.C.A. 9.5 kg a.i./ha	Tiocarbazyl + chloridazon 4+2.8 kg a.i./ha	T.C.A. + chloridazon 9.5+2.8 kg a.i./ha
Alopecurus myosuroides	2	86.6	79.3	90.3	80.0
Digitaria sanguinalis	2	84.0	81.2	92.2	91.6
Panicum dichotomiflorum	2	83.3	75.6	100	100
Setaria glauca	2	87.9	79.0	90.6	88.8
Echinochloa crus-galli	2	73.5	74.0	82.8	79.7
Anagallis arvensis	2	73.3	44.1	89.9	90.0
Chenopodium album	2	57.0	25.2	85.6	75.1
Chenopodium polyspermum	3	40.2	43.1	97.6	95.7
Matricaria Chamomilla	2	75.8	68.6	99.2	99.2
Polygonum aviculare	2	28.3	31.8	67.5	71.6
Polygonum persicaria	2	38.2	26.0	87.0	81.5
Polygonum convolvulus	2	24.4	18.9	100	72.2
Solanum nigrum	2	91.9	58.7	92.7	86.4
Sonchus arvensis	2	57.8	14.2	83.3	77.3
Trifolium repens	2	10.8	0	76.8	67.3
Veronica persica	2	79.3	58.8	100	90.5
Viola tricolor	2	58.4	31.6	100	100

Untreated plots - mean no. of grass weeds/m^2 = 38.6
- mean no. of broad-leaved weeds/m^2 = 36.5

Site	Modena	Reggio Emilia	Cremona
Spray date	16/3/79	14/3/79	3/4/79
Assessment date	18/5/79	6/6/79	7/6/79
Sugar beet cv.	Monfort	Monoil	Monogem

Table 2

Percentage control of grass and broad-leaved weeds in sugar beet - 1980

Weed	No. of trials	Tiocarbazyl 4 kg a.i./ha	T.C.A. 9.5 kg a.i./ha	Tiocarbazyl + chloridazon 4+2.8 kg a.i./ha	T.C.A. + chloridazon 9.5+2.8 kg a.i./ha
Alopecurus myosuroides	2	92.2	76.6	95.5	92.2
Avena fatua	2	85.0	50.0	75.5	50.4
Avena ludoviciana	2	87.0	80.4	90.2	85.2
Echinochloa crus-galli	3	85.1	75.3	85.2	80.6
Anagallis arvensis	4	55.3	33.6	83.3	80.8
Bifora radians	2	25.5	47.2	62.3	30.3
Capsella bursa-pastoris	2	50.8	0	100	100
Euphorbia peplus	3	30.1	43.6	89.7	93.0
Galium aparine	2	56.5	41.7	75.8	67.8
Linaria rubrifolia	2	83.3	31.1	100	100
Linaria spuria	3	86.5	50.2	100	96.7
Papaver rhoeas	4	71.5	24.6	86.5	92.8
Polygonum aviculare	3	18.3	0	86.7	73.3
Polygonum convolvulus	4	16.7	20.7	89.9	82.5
Ranunculus arvensis	2	50.5	50.2	70.8	66.4
Sinapis arvensis	2	24.2	0	90.6	81.1
Sonchus oleraceus	2	50.3	60.8	100	85.4
Stellaria media	2	53.0	27.7	70.5	67.2
Stachys annua	2	16.2	0	95.5	90.5
Veronica hederifolia	2	63.4	33.3	82.5	71.5
Veronica persica	4	77.7	54.0	100	95.3

Untreated plots - mean no. of grass weeds/m^2 = 37.2
- mean no. of broad-leaved weeds/m^2 = 85.3

Site	Reggio Emilia	Alessandria	Mantova	Bologna	Potenza	Foggia
Spray date	29/2/80	6/3/80	27/2/79	5/3/80	25/11/79	26/11/79
Assessment date	19/5/80	20/5/80	26/5/80	21/5/80	11/2/80	11/2/80
Sugar beet cv.	Monogen	Monogen	Giada	Monova	Cavepoli	Monofort

Table 3

Percentage control of grass and broad-leaved weeds in sugar beet - 1981

Weed	No. of trials	Tiocarbazyl 4 kg a.i./ha	T.C.A. 9.5 kg a.i./ha	Tiocarbazyl + chloridazon 4+2.8 kg a.i./ha	T.C.A. + chloridazon 9.5+2.8 kg a.i./ha
Echinochloa crus-galli	2	93.5	76.5	89.3	92.9
Panicum dichotomiflorum	2	87.3	78.4	100	100
Setaria glauca	2	81.8	76.3	100	78.2
Amaranthus retroflexus	3	43.7	44.3	85.7	80.7
Anagallis arvensis	2	76.5	56.0	87	85.5
Capsella bursa-pastoris	2	70.2	33.3	100	100
Chenopodium album	2	50.4	30.6	71.1	64.4
Chenopodium polyspermum	2	44.5	57.5	92.5	94.5
Fumaria officinalis	2	75.9	66.7	75.4	75.1
Matricaria Chamomilla	2	95.4	80.8	100	100
Mercurialis annua	2	38.1	52.3	85.5	97.6
Papaver rhoeas	2	85.5	39.9	96.5	97.1
Polygonum aviculare	2	40.2	26.5	56.5	67.3
Polygonum convolvulus	2	33.9	46.1	67.6	63.6
Solanum nigrum	3	99.0	52.8	100	76.0
Veronica persica	2	81.7	69.2	100	100

mean no. of grass weeds/m^2 = 10.3

mean no. of broad-leaved weeds/m^2 = 87.0

Site	Bologna	Modena	Rovigo	Ravenna
Spray date	12/3/81	19/3/81	24/3/81	20/3/81
Assessment date	7/5/81	21/5/81	22/5/81	12/5/81
Sugar beet cv.	Cavemono	Monofort	Vetramono	Cavemono

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TEBUTAM AND ALACHLOR, A HERBICIDE COMBINATION FOR WINTER OILSEED RAPE

E. D. Eberhard
Ruhr-Stickstoff AG, Landwirtschaftliche Forschung Hanninghof, Dülmen,
Federal Republic of Germany

Summary. On the basis of 4-years' field trials, a report is given on the frequency of occurence of annual grasses and broad-leaved weeds and on experimental results with the herbicide combination tebutam + alachlor in West Germany.

A total of 52 weed species were observed, of them 29 occured with frequencies between 7% and 77%. Most common were *Stellaria media* and *Alopecurus myosuroides*.

The herbicidal combination tebutam + alachlor controlled most broad-leaved weeds and grasses. With volunteer cereals and *Galium aparine* unfavourable conditions of soil and weather sometimes limited the effect of the herbicides.

With all varieties tested, the combination demonstrated a good selectivity. Application produced average yield increases of 13 - 16% and in individual cases of up to 53%. There were no significant yield reductions.

INTRODUCTION

Until 1960 there was little interest in winter rape in West Germany. However, when breeders succeeded in reducing content of erucic acid (to less than 0.5%) the demand for rape oil and, with it, the acreage of winter rape, increased (Table 1).

Table 1

Winter oilseed rape acreage in West Germany

Ø Years	1956-60	1961-65	1966-70	1971-75	1976-80
1000's ha	20	37.6	55.2	92.4	109
Yields t/ha	2.23	2.24	2.40	2.39	2.65
Relative yield	100	100	108	107	119

Source: Stat. Jahrbuch über Ernährung, Landwirtschaft und Forsten

The cultivation of oilseed rape was also favoured by the fact that the new varieties produced higher yields.

Breeders' successes in reducing glucosinulate content will constitute a further incentive to develop rape cropping. Reduction of the toxicologically and physiologically objectionable components of rape would make it possible to use the residues of rape oil manufacture (coarse rape meal) in animal nutrition to a larger extent than has hitherto been the case, i.e. rape meal could, at least partly, replace coarse soybean meal. There are, consequently, many reasons to believe that rape cropping will continue expanding. In 1980/81 the area amounted to 130,000 ha and 1981/82 to 150,000 ha.

Crop protection measures are of considerable importance in rapeseed cultivation in Europe since 30% of the possible yield may be lost through, pests (15%), diseases (5%) amd weeds (10%) (Kramer, 1967). In the case of heavy infestation with weeds losses can exceed this value considerably. Additionally, the problems of seed impurity, increased moisture content at harvest and harvesting difficulties caused by weeds are of practical importance.

Herbicidal treatment therefore is a standard measure. Virtually the entire rapeseed acreage is treated, 25% of the area receiving a second herbicide. In West Germany pre-sowing or pre-emergence herbicides are preferred because of favourable climatic conditions which usually prevail at the time of sowing. The time for using post-emergence herbicides often coincides with heavy rains which prevent wheeled equipment from working.

METHODS AND MATERIALS

The tebutam-alachlor combination was an emulsifiable concentrate which contained 500 g/l tebutam and 250 g/l alachlor, formulated as Traton.[R]

Schwartzbeck (1976) and Evans et al. (1968) reported on the herbicidal properties of the single compounds.

Application was made pre-emergence of the crop, using 7 l/ha of the formulated mixture. For comparisons dimethachlor (500 g/l a.i.) was used at 3 and 4 l/ha and metazachlor (200 g/l a.i.) at 7 l/ha. 118 field trials were conducted between 1979 and 1982 throughout the Federal Republic of West Germany. Trials were made on 15 - 25 m^2 plots with four replicates in randomized blocks. The application was done with mobile plot-sprayers. 400 l/ha water were used. Assessment of herbicidal effect and crop tolerance were made in percentage terms at the following times:

1. 5 - 6 weeks after the application in autumn
2. In spring after vegetation starts
3. After panicle emergence of grass weeds

The weed flora in the crop was recorded in the untreated plots of the experiments at the same dates.
Harvesting of the trials was done with a plot combine harvester. Reported yields relate to clean seed at 91% dry matter.

RESULTS

The weed flora of winter rape.

In 86 trials carried out over a span of 4 years a total of 52 species were observed. Of this total 29 species appeared as major weeds.

The most important weeds from the years 1979, 1980, 1981 and 1982 arranged according to the frequency of their appearance on a total of 86 locations, are shown in diagram 1.

S. media and A. myosuroides were the most frequent with 77% and 52% occurence respectively. The next group occurred in every third field on average and included species of Matricaria and Anthemis, volunteer barley, Viola arvensis and Lamium species. Special attention is due to Galium aparine which showed a frequency of 24%. Veronica appeared with 4 species on every 5th field of winter rape. Also of major importance although preferring light soils, were Myosotis arvensis with 14% incidence, Capsella bursa-pastoris with 9%, Apera spica-venti and Papaver rhoeas both with 8% and Poa annua with 7% incidence.

Other weeds of more local importance were Agropyron repens, Aphanes arvensis, Fumaria officinalis, Lapsana communis, Melandrium spp., Polygonum spp. and Thlaspi arvense. Winter rye and winter wheat occurred infrequently.

Other species occurred with varying frequency, but always in modest densities, and did not compete with winter rape.

From one year to another the frequency of incidence of weeds varied. A. myosuroides, C. bursa-pastoris, volunteer barley, S. media and V. arvensis appeared most regularly. G. aparine, Lamium spp., Matricaria spp., and Anthemis species were most variable in year to year incidence.

The herbicidal effect of the tebutam + alachlor mixture

The combination tebutam + alachlor showed a broad spectrum of action controlling both annual grasses and dicotyledonous weeds. Figure 2 shows the results of 4 years' trials. The combination was applied at 7 l/ha and the standard dimethachlor - according to the type of soil - at 3 - 4 l/ha. Both were applied pre-emergence. Figure 2 shows that a high standard of weed control was achieved against most weeds specified but G. aparine and volunteer barley were more resistant. Control of A. spica-venti, M. arvensis, P. rhoeas, Veronica spp., V. arvensis and M. arvensis, was better with alachlor + tebutam than with dimethachlor alone.

Additionally, A. arvensis, Fumaria officinalis, Galinsoga parviflora, Lapsana communis, Melandrium album, P. annua and Polygonum spp., were controlled satisfactory and Raphanus raphanistrum, Sinapsis arvensis and volunteer rye were controlled to a lesser but adequate degree.

Control of G. aparine and volunteer barley was 70 and 74% respectively. If individual sites are considered in 19 instances control of G. aparine was above 80%: on 3 sites the effect was nearly nil, due to spring germination of the weed.

Similarly, for volunteer barley: at 27 sites the combination gave 91% or better control whereas on 9 sites control dropped to 23%. Eight of these instances were associated with clay or loam soils and in one case the soil contained 9.3% organic matter.

In a one year comparison with metazachlor (1400 g/ha a.i. pre-emergence application) both herbicides showed the same effect, with the tebutam + alachlor combination giving marginally better control of volunteer barley (7 sites) and V. arvensis (3 sites).

Selectivity and effect on yield

In field experiments, the mixture showed good selectivity: even on very light soils it was well tolerated. On this type of soil and where heavy rainfall followed sowing, growth retardation occurred initially but was outgrown.

In a tolerance test made with the varieties Belinda, Elvira, Jet Neuf, Garant, Ligora, Quinta and Rapora the combination was found to have no phytotoxic effect.

Mean yields following tebutam and alachlor were significantly greater than on untreated plots (Table 2) in the presence of weeds.

Table 2

Winter rape yields following application of tebutam + alachlor during pre-emergence stage (field trials 1979/80)

	Untreated	tebutam + alachlor combination 6 l/ha	7 l/ha	dimethachlor 3 - 4 l/ha
no. sites	15	15	15	15
t/ha	3.13	3.53	3.62	3.51
relative yield	100	113	116	112
range	-	97 - 149	97 - 153	94 - 139

The average yield increase from 15 trials with an application of 6 l/ha amounted to 13% and of 7 l/ha to 16%. In experiments with heavy weed infestation, the treatment of 7 l/ha resulted in yield increases of up to 53% over untreated. In none of our experiments was there any significant yield diminution.

DISCUSSION

In winter rape 52 weed species were identified. Similar observations from 10-year trials, have been reported (Nuyken, 1981).

A. myosuroides, A. spica-venti, C. bursa-pastoris, Lamium spp., Matricaria spp., S. media, Veronica spp., and P. annua were well controlled with 6 l/ha (Aggour 1981) tebutam + alachlor although these results indicate that 7 l/ha may be necessary for some species.

Volunteer cereals and G. aparine were a special problem, but in the majority of cases tebutam + alachlor achieved a sufficiently good effect against both. Dry conditions in autumn however reduced weed control but due to the persistence of the herbicides most weeds were well controlled when soils become moist (Aggour, 1981).

Unfortunately this residual effect is insufficient to control spring-germinating weeds eg G. aparine.

Pre-requisites for a good effect against G. aparine and volunteer cereals are sufficient moisture, a fine seedbed and good soil consolidation. The lack of these conditions on heavy soils in autumn and adsorption of active ingredients may explain some of the reported results on those soils.

Volunteer barley is well controlled if it is germinating in the surface layers of the soil but winter barley germinating from deeper layers is not sufficiently controlled, especially during dry spells. On sites heavily infested with G. aparine, a combined treatment with trifluralin can be effective (Aggour, 1981).

Aggour reported on selectivity (1981). Initial retardations of growth, which sometimes appeared on light soils after heavy rain, were outgrown and had no influence on yields.

However, if a rape should fail and need to be ploughed up sequential cropping is restricted to potatoes, spring rape, leguminous crops or maize.

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Traton R is the registered trade mark of Ruhr-Stickstoff AG.

tebutam is the proposed BSI name for N-benzyl-N-isopropylpivalamide formerly known as butam.

Fig. 1

Frequency of the most important weeds in winterrape in West Germany (86 field trials 1979 - 81)

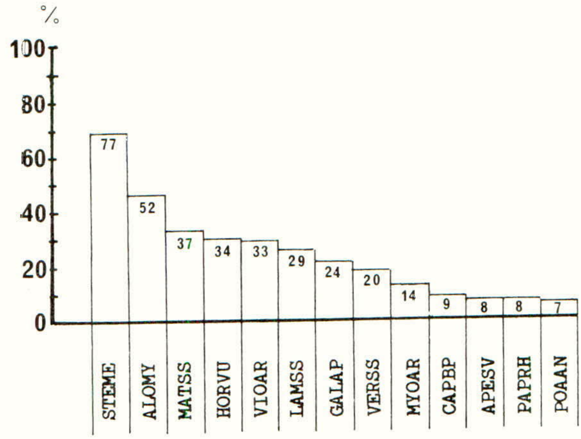

Fig. 2

Herbicidal efficacy of tebutam + alachlor against annual weeds in winter oilseed rape