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THE ANALYSIS OF WEED GROWTH IN HAND HOED EXPERIMENTS

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Summary Hoe farmers are primarily concerned to hoe their farms frequently enough to maintain crop yields. The inherent limitations of hoe farming result in poorly prepared seedbeds and periods of peak labour demand which limit the productivity of the farmer's family labour. The practicable methods of herbicide application increase the maximum hoeing interval instead of eliminating hoeing completely. Herbicide application therefore needs to be assessed for improvement of crop establishment on poorly prepared seedbeds, reduction of hoe weeding and crop yield increases.

The dates of experimental hoe weedings are inevitably chosen subjectively. The curvilinear pattern of weed growth produces data which is not suitable for quantitative analysis.

The 'logistic weed growth rate' (L) is proposed as a linear, continuous parameter of weed growth rate which is independent of existing weed cover and subjectively chosen hoeing dates. The resulting simplification of field techniques enables large numbers of simple experiments to be conducted at outstations and objectively monitored at one centre. L values can be used to predict hoeing intervals following herbicide application. Summed L values can be used to describe weed growth and herbicide performance during specified periods.

INTRODUCTION

In developing countries, herbicides are still usually applied pre-emergent on a well prepared seedbed and observed for their weed control activity without supplementary hand hoeing. The mechanised farmer may be prepared to accept a small yield reduction when replacing hand hoeing by herbicides. The hoe farmer must obtain an overall yield increase from any herbicide input which supplements his family labour. The family labour is usually inadequate to prepare timely seedbeds thoroughly but can perform post-emergent hoeing with an output which is limited by the size of the family. Late hoeing permits the weed cover to increase to the extent that crop yields are reduced and/or hoeing becomes slower. The potential cropped area is therefore the product of the daily output and the maximum acceptable hoeing interval.

Shortage of water and cost of equipment limit the practicable methods of herbicide application to hand broadcast granular formulations and (since 1974) VLV CDA. Neither method controls weeds perfectly during early crop growth on the 'minimum tillage' seedbeds prepared by hoe farmers but they do reduce weed growth rate and hence increase the hoeing interval.

Herbicides therefore need to be assessed for their value in improving crop establishment on poorly prepared seedbeds, reducing hoe weeding requirement during periods of peak family labour demand, and increasing crop yields directly (or indirectly by releasing labour for timely operations on other crops).

The measurement of 'hoe weeding requirement' is difficult because most crops are only hoed a few times, weed growth rate is a non-linear function of existing weed cover and the time required for hoeing is not directly proportional to the amount of weed present. The data is therefore discontinuous and not linear even in a stable environment.

This paper proposes the use of 'logistic weed growth rate' (L) as a continuous, linear (and therefore additive) parameter of weed growth rate.

L is defined by the following equations:

$$W_1=(W_m-W_s)xW_t/((W_m-W_t)xW_s), \quad \ln W_1=LT, \quad L_t=LT/(T_t-T_s)$$

Where W_s= the weed cover present at the beginning of a period of weed growth. In clean weeded field plots, W_s is conventionally set at 1.0

W_t= the weed cover removed when a plot is weeded.

W_m= the asymptotic limit of seasonal weed growth at the experimental site.

T_s= the date on which a period of weed growth starts.

T_t= the date on which a period of weed growth is interrupted by weeding.

L should express changes in weed growth rate caused by environmental variations but should be independent of subjectively chosen hoeing dates (T_t) and the related weed covers (W_t).

METHOD AND MATERIALS

The pot experiment. Eight pots of soil from an experiment which had received herbicide in 1973 were set up at Samaru at the end of the year. Eight similar pots without herbicide were set up at the same time. Each pot consisted of a translucent polythene bag containing exactly 5 kg of air-dry soil. The bags had a surface diameter of 22 cm when full. The bags had 4 drainage holes 5 mm in diameter punched 4 cm above their base after being set up. The bags were saturated with water once a week by surface flooding. One bag from each set was sampled from the 4th week onwards. The total weed shoot weight was recorded oven-dry to the nearest decigramme. After five pots had been sampled from each set the remaining pots were watered for a further period of 9 weeks until they were thoroughly 'pot-bound'. The oven-dry shoot weight of all the pots was then close to 3500 kg/ha ± 247. This was therefore used as the estimate of W_m.

Field experiment. Weeded by treatment. There were 11 herbicide treatments and 5 'no-herbicide' weeded check treatments laid out as a randomised block experiment with four replicates. The plot size was ha/398.7. The herbicides were broadcast in granular formation on 6/5/72. The plots were prepared for sowing (on ridges) on 15/6, sown to cotton on the 17/6 and was thinned and fertilised in accordance with recommendations by the end of June. The first cotton was ready for picking on 27/10.

Hoeing 'by treatment'. All plots were inspected weekly. As soon as any plot needed weeding, its experimental treatment number was recorded. All the plots with the same treatment number were then weeded as well. The dates of second and subsequent hoeings were chosen by the same method.

Determination of weed shoot weights. The total weed vegetation from each plot was separated root from shoot and the former discarded. The air-dry bulk of the weed shoots was then weighed for each plot and sub-sampled for oven-drying. The weed weights are reported as oven-dry weed shoot weight in kg/ha.

Field experiment. Weeded by plots. There were 6 herbicide treatments and 3 'no-herbicide' weeded check treatments laid out as a triple lattice of 27 plots. The plot size was ha/956.8. The seedbed was roughly prepared by the farmers method of ridge-splitting on 16/6/75 and the cotton was planted on ridges on 17/6. The herbicides were applied as wettable powders fortified with 20% of an oil adjuvant in VLV using a spinning disc applicator, on 19/6. Hoe weeding started on 7/8 and finished on 4/10.

Hoeing 'by plot' All plots were inspected weekly. Each plot was weeded as soon as the field supervisor considered it necessary, irrespective of the state of the other plots with the same treatment number. The dates of later weedings were chosen for each plot individually in the same way. All plots were weeded just before cotton picking started on 1/11 to record 'harvest weed cover'.

Estimation of maximum weed cover (W_m). In savanna climates the annual weed growth stops at the end of the rains. W_m was therefore estimated from the weed shoot growth on check plots left unweeded until the end of the rains. These were additional plots outside the experimental layout.

Calculation of weed growth rate. Using as an example, the first week of sampling in the pot test:- $W_s = 100$, $W_t = 209$, $W_m = 3500$, $T_1 - T_s = 7$, $W_1 = 2.1592$, LT= .7697 and $L_1 = .10996$.

In field experiments where '$W_s = 1.0$', $W_1 = (W_m - 1) \times W_t / (W_m - W_s)$ and W_1 (and hence LT) is defined by the value of W_t.

Statistical analysis of LT and L values. Each time a plot was hoed, it gave rise to a new plot estimate of LT and L. This replaced the previous current value in the population of plot values for the whole experiment. It was therefore possible to perform conventional statistical analysis of L values (measuring weed growth rates) and LT values (measuring weed cover at hoeing) for any experimental period (after appropriate linear extrapolation).

The duration of 'weed control' The use of multiple check treatment permits a check range to be calculated for the treatment L values at each weeding date. Treatments were considered to be 'active' when the treatment mean value was below the calculated lower limit of the weeded checks. The date on which the mean L value rose above this limit was therefore the end of weed control activity in the treatment.

RESULTS

Pot test. (Table 1). The five pots sampled from the 'no-herbicide' group yielded weed weights which increased in an approximate geometric progression with time. 'L' was remarkably constant whether estimated weekly or over longer periods. The logistic growth rate summed over the whole period (Σ LT) was also exactly the same for all modes of estimation. These results therefore confirmed that weed weight increases in pots at Samaru conformed to a logistic growth pattern in the stable conditions of the dry season. 'L' was therefore independent of the amount of weed cover. The presence of degrading herbicide residues produced a continuously changing environment which increased estimates of L with time. Σ LT had the same value however, whether estimated weekly or over the whole sampling period. This confirmed that L was a linear parameter which could be summed over any period when its intermediate values were changing.

Table 1

Weed growth rate in pots. Samaru dry season 1974.

(W_m estimated as 3500 kg/ha)

Sampling day	28	35	42	49	56	
No herbicide pots (Stable environment)						
Weed cover = W_t	100	209	455	886	1539	LT
L every week	.110	.120	.117	.120		3.27
L 1st + 4th week	.110	--------------------	--------------------	.120		3.28
L 2nd + 4th week	----------.116		--------.118			3.28
L 3rd + 4th week	------------------	------------------	.116	.120		3.28
L 4th week only	----------------	----------------	----------------	.117		3.28
Herbicide residue pots (Variable environment)						
Weed cover = W_t	65	115	214	404	779	
L every week	.084	.093	.099	.112		2.72
L 4th week only	----------------	----------------	----------------	.097		2.71

Field experiment. Weeded by treatment. (Tables 2 and 3). The check treatments were weeded 5 times while treatments 1, 5, and 3 presented as typical examples of the whole experiment were weeded 3, 2 and 4 times respectively. The mean L values for each treatment are presented in table 2.

Table 2

Mean treatment L values. Cotton pre-plant herbicides. 1972.

(W_m estimated as 8,500 kg/ha)

T_s	6/5	16/6	10/7	16/8	11/9
T_t	15/6	9/7	15/8	10/9	21/10
Treatment					
1	.130(.000)	.091(.000)	.091(.106)	.051(.118)	.051
5	.035(.000)	.035(.000)	.035(.021)	.039(.089)	.039(.044)
3	.168(.122)	.211(.117)	.097(.123)	.097	.054
Weeded checks	.187	.247	.177	.135	.050
SE (Checks - tr.)	±.0161	±.0299	±.0680	±.070	±.0063

The exact statistical significance of the difference between the check mean and each treatment L value is given in brackets when the treatment mean falls below the range of the checks. (This is not an essential feature of the analysis).

The detailed information in table 2 is conveniently summarised in table 3 in a form which could be used in routine reports on herbicide performance in hand hoed experiments. The extrapolated sums of LT for the June-July period and for the 1972 season were obtained conveniently when the original computer analysis was done because it was known that June-July is the peak labour period for hoe farmers in the Nigerian savanna. Any other periods could be summed by extrapolation and statistically analyses as required.

Table 3

Summarised logistic weed growth data. Cotton pre-plant herbicides.

Treatment	Duration of weed control	Σ LT June - July	Σ LT 1972 season	L at harvest
1	6/5-10/9 = 128	6.13 (.003)	14.57 (.032)	.051
5	6/5-27/10 = 175	2.13 (.000)	6.47 (.001)	.039 (.044)
3	6/5-15/8 = 102	9.72 (.099)	20.61	.054
Weeded checks		12.62	26.61	.050
SE ±(Checks-tr.)		±2.216	±6.362	±.0063

Treatments 1 and 5 were active throughout the critical June-July period of peak labour requirement and the treatment differences were formally statistically significant. Treatment 3 was also active throughout the period but was only just detectably different from the lower range of the checks. This weaker activity is reflected in the low level of significance of the treatment difference from the check mean. The significantly low value of L at harvest on treatment 5 indicated that it was still strongly active at harvest even though there were actually more weeds in this treatment when the experiment ended.

When seasonal totals of LT on the check treatments give a very good indication of the weediness of the site. This will facilitate inter-site and inter-seasonal comparisons.

Field experiment. Weeded by plot. (Tables 4 and 5). The oil adjuvant added to the VLV formulations applied in this experiment was known to enhance foliar activity. The effect of this property of the VLV mode of application would therefore be measured at the first weeding and thinning operation on 8/7/75. The mean treatment L values for the first four weeks are presented in table 4.

Table 4

Mean treatment L values for June-July. Cotton VLV herbicides experiment. 1975.

(W_m estimated at 6751 kg/ha)

T_s	19/6	9/7	16/7	23/7	30/7
T_t	8/7	15/7	22/7	29/7	7/8
Treatment					
9	.266(.076)	.097(.002)	.085(.000)	.086(.000)	.092(.000)
4	.293(.199)	.156(.083)	.149(.025)	.143(.014)	.155(.125)
6	.370	.173(.489)	.168(.201)	.166(.199)	.159(.167)
Weeded checks	.330	.198	.181	.179	.179
SE ± (Checks-tr.)	±.0426	±.0289	±.0151	±.0150	±.0201

Treatment 6 failed to control the established weeds which survived the seedbed preparation but gave detectable weed control when these were removed by the first hoe weeding on 8/7. This treatment was therefore classed as 'active' from 9/7 onwards. This treatment would have been classed as 'failing to control' if scored in the conventional manner on July 7th whereas it subsequently gave detectable control for over a hundred days. Treatments 9 and 4 were evidently active against the established weeds and in fact only 2 out of 3 plots in treatment 9 were weeded on 8/7.

The summarised results for the whole season are presented in Table 5.

Table 5

Summarised logistic weed growth data. Cotton VLV herbicides. 1975.

Treatment	Duration of weed Control	LT June-July	LT 1975 season	L at harvest
9	19/6-1/11 - 136	7.38 (.022)	15.83 (.044)	.086(.036)
4	19/6-4/10 = 108	9.31 (.173)	19.88	.103
6	9/7-1/11 = 116	11.27	19.49 (.182)	.092(.074)
Weeded checks		10.86	23.40	.115
SE (Checks-tr.)		±1.594	±4.176	±.0151

Both treatments 9 and 6 persisted later in the season and were detectably active at harvest. Treatment 4 might therefore be of more practical use to a hoe farmer in spite of the higher seasonal total of LT.

The 1975 season was evidently weedier than the 1972 season because the mean season L values were .172 (23.40/136) and .152 (26.61/175) respectively.

DISCUSSION

The basic assumptions. The form of the logistic equation adopted in this paper was derived by Piélou (1969). It was developed for situations where the early stages of growth were unrestricted and approximately exponential but were constrained to grow asymptotically towards a known maximum. In the Nigerian savanna where annual weed growth stops at the end of the rains these conditions are fulfilled. They do not apply where a substantial proportion of the weed bulk consists of deep rooted perennials which continue to grow into the dry season. This occurs in land newly cleared from bush. Weed control requirements are low and soil active herbicides are of little use.

The known maximum W_m found on unweeded check plots at the end of the rains must be close to the true asymptote of the weed growth curve. The major ambiguity therefore occurs in the value adopted for W_s on clean weeded plots. It can be shown that as weedy plots with high actual values of L are also more likely in practice to have higher true values of W_s and lower values of T_1, any underestimation of W_s increased the estimated difference between effective herbicide treatments and the checks, whenever the experimental error was inflated by poor quality weeding.

The weed growth rate related to hoe weeding dates. The pattern of labour demand on family holdings in the Nigerian savanna shows that they are under stress during June and July. (Norman, 1972). During this period they have to hoe the early planted cereal crop mixtures once or twice, prepare the seedbeds for later sown crops and also weed these at least once in July.

Early in June, farmers may often be seen hoeing and moulding almost weed free ridges. The hoeing is combined with other operations and by curtailing the weed growth curve it delays the time when these ridges have to be weeded again with a full weed cover. The amount of weed present has little effect on the rate of work until it exceeds 500-700 kg d.m./ha.

The farmer and his family should therefore be able to weed their total cropped area in a cyclical time which is less than the time required to develop a weed cover of 500 kg/ha. In 1972, LT equivalent to a W_t of 500=6.275. A plot with a cyclical time of less than 61 days would have to be weeded at least once during June-July. The mean L value must therefore be less than .103(6.275/61) if hoeing is to be avoided completely on a plot which is weed free at the end of May.

In practice the defects of the minimum tillage seedbeds prepared by farmers usually dictate the need to hoe once shortly after the establishment of any crop and this is combined with several other operations such as thinning and manuring. In 1972 this operation was done 24 days after crop establishment on the check plots (table 2). The current L value of .247 on these plots implied a cyclical time of 25.4 days to reach a weed cover of 500 kg/ha. The plots in treatment 1. had a cyclical time of 69 days and need not have been weeded until 23rd August. The farmer would certainly have completed thinning his cotton before this but would have much more freedom to decide when to do it.

Seedbed preparation. When the weed bulk exceeds 500 kg farmers prepare their seedbeds by splitting ridges. At lower values a full hoeing may be done instead. When the weed bulk is 100 kg or less, mininum tillage consisting of a perfunctory scrape round the sowing holes is usually adopted for early sown cereals.

Crop establishment on plots in treatment 1 (table 2) could have been done by this type of minimum tillage up till the 22nd of June when the extrapolated weed bulk would have reached 100 kg.

Presentation of experimental results as practical units. It is possible, by simple linear extrapolation to any selected level of weed cover, to calculate the dates on which treatments would have required hoeing. When hoeing dates are presented in a table which also shows crop yields however, the treatment mean hoeing dates must be calculated from the actual experimental mean LT values. Different weed covers could possibly have competed differently with the crops.

Future potential uses. The logistic growth rate concept makes it possible for a small scientific team to conduct many simple but precise weed control experiments at distant sites with low calibre supervisors. It is therefore adapted to the typical conditions of developing countries.

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A NEW APPROACH TOWARDS EASY APPLICATION FOR COTTON HERBICIDES IN EGYPT

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Summary The present investigation was undertaken to show the preference of the chemical weed control in Egyptian cotton fields and the relevancy of the use of herbicide/superphosphate mixture (field-made granules). Fluometuron, trifluralin, dinitramine and penoxalin - as recommended herbicides for cotton - were tried out in different formulations during 1974 and 1975. The acceptance of such improved application technique encouraged its extension in commercial use during 1976 season in an area estimated at some 64,000 ha. Fluometuron combined with each of the other herbicides mixed with superphosphate post-sowing appeared with special value to overcome the scarcity of hand-labour.

INTRODUCTION

The expensive and scarce hand-labour presents an increasing menace to the production of cotton and other crops in Egypt.

Fluometuron (Cotoran) in combination with trifluralin (Treflan), dinitramine (Cobex) or penoxalin (Stomp:Prowl) has been officially recommended for cotton in Egypt (Pest Control Program, 1975). The tediousness of spraying and incorporation operations impedes the promotion of such herbicides.

The purpose of the present paper is to show the possible use of field-made granules (herbicides/superphosphate mixture) as a relevant application in cotton fields. Similar improved application technique with the use of herbicide/gypsum mixture in paddy rice fields has been accepted and followed in Egypt and some other countries after its recommendation by Zahran and Ibrahim (1975).

METHOD AND MATERIALS

The experimental work was conducted during 1974 and 1975 at Sakha Experimental Station (Lower Egypt) where the soil is clay loam with pH 7.6. Cotton seeds cv Giza 67 and Giza 68 were sown in the first week of March and April during the two seasons respectively. Weed assessments took place ten weeks (for winter annuals) and 20 weeks (for summer annuals) after sowing. The weight of the surviving weeds in the middle two ridges (out of six) was assessed. Hand-picking took place 23 weeks after sowing. The weight of seed cotton yield obtained from the different experimental plots (each of 21.2 m^2) was recorded.

The rates used were according to local recommendations i.e. fluometuron 1.9 kg a.i./ha (2.3 kg product/ha) trifluralin 1.2 kg a.i./ha (2.4 l. product), dinitramine 0.6 kg a.i./ha (2.4 l. product) and penoxalin 1.6 kg a.i./ha (4.8 l. product).

The appropriate rate of commercial formulation plus a small quantity of water was in each case mixed thoroughly with a quantity of superphosphate equivalent to 235 kg/ha and applied by hand while still moist.

Where the spray application was included, the experimental plots were sprayed with a knapsack sprayer at a volume of 940 l/ha. In some treatments, incorporation was by hand-hoes.

RESULTS

The most predominant weeds in the experimental fields were: Beta vulgaris, Melilotus indica, Medicago hispida as winter annuals; Dinebra retroflexa and Echinochloa colonum as summer annuals.

Results can be concisely shown as follows:

Experiment 1 (1974) The herbicidal treatment with trifluralin sprayed and incorporated before planting and followed by fluometuron sprayed after sowing was compared with hand-hoeing 4 times as normal practice. Each treatment was replicated 6 times at random. Data are shown in Table 1.

Table 1

Effect of herbicidal treatment vs hand-hoeing on the stand and yield of cotton plants (expt. 1)

	No. of plants/ha (thousands)	Seed cotton yield (tons/ha)
Herbicides	128.5	24.0
Hand-hoeing	100.7	18.9

Hand-hoeing resulted in a significant reduction in the stand of productive cotton plants as consequently in the seed cotton yield.

Experiment 2 (1974) Both dinitramine and trifluralin were applied and incorporated before planting, either as granules or as sprays. With each, fluometuron was sprayed either immediately post-sowing (PS) or later pre-emergence (PE). Hand-hoeing (4 times) was included. Each treatment was replicated 4 times at random. Treatments and results are given in Table 2.

The application with field-made granules was significantly superior to the spray application against annual weeds (winter and summer). The use of dinitramine granules pre-planting followed by fluometuron pre-emergence was the best treatment for cotton production. No significant difference was found between the granules and the spray as regards the seed cotton yield.

Table 2

Effect of different treatments on the control of annual weeds and seed cotton yield (expt. 2)

% Reduction of winter annual weeds

	Granules			Spray		Mean		Mean
Fluometuron	PS	PE		PS	PE	PS	PE	
Dinitramine	96.0	94.5		71.8	77.8	83.9	86.2	85.0
Trifluralin	92.8	86.3		81.8	97.8	87.3	92.1	89.7
Mean	94.4	90.4		76.8	87.8	85.6	89.1	
L.S.D. (P=0.01			3.8			2.7		
Mean	92.4			82.3				
L.S.D. (P=0.01)			1.9					

% Reduction of summer annual weeds

	Granules			Spray		Mean		Mean
Fluometuron	PS	PE		PS	PE	PS	PE	
Dinitramine	86.8	87.8		87.8	85.8	87.3	86.8	87.1
Trifluralin	89.0	83.8		71.0	78.8	80.0	81.3	80.7
Mean	87.9	85.8		79.4	82.3			
L.S.D. (P=0.01)			3.2			n.s		1.6
Mean	86.9			80.9				
L.S.D. (P=0.01)			1.6					

% Seed cotton yield (hand-hoeing = 100)

	Granules			Spray		Mean		Mean
Fluometuron	PS	PE		PS	PE	PS	PE	
Dinitramine	129.8	138.3		113.3	128.5	120.6	133.4	127.0
Trifluralin	106.3	111.8		117.8	124.0	112.1	117.9	115.0
Mean	118.1	125.1		114.6	124.3	116.3	125.6	
L.S.D. (P=0.01)			3.3			2.8		2.0
Mean	121.6			120.4				
L.S.D. (P=0.01)			n.s					

Experiment 3 (1975) The combinations of fluometuron with each of the other three herbicides (dinitramine, trifluralin and penoxalin) were applied post-sowing either as granule mixed with superphosphate, or sprayed. Hand-hoeing (4 times) was included. Each treatment was replicated 4 times at random. Treatments and data are demonstrated in Table 3.

Table 3

Effect of different treatments on the control of annual weeds and seed cotton yield (expt. 3)

	% Reduction of weed wt								
	Winter annuals			Summer annuals			% Seed cotton yield (hand-hoeing = 100)		
	G	S	Mean	G	S	Mean	G	S	Mean
Dinitramine/ fluometuron	86.3	52.8	69.6	97.8	63.8	80.8	126.3	112.8	119.6
Trifluralin/ fluometuron	78.0	29.0	53.5	63.0	90.8	76.9	117.3	113.0	115.2
Penoxalin/ fluometuron	94.0	81.3	87.7	98.0	96.0	97.0	121.3	137.8	129.6
L.S.D. (P=0.01)	2.6		1.8	2.7		1.9	3.1		2.2
Mean	86.1	54.4		86.3	83.5		121.6	121.2	
L.S.D. (P=0.01)	1.4			1.6			n.s		

G = Field-made granules S = Spray

In respect of weed control, the granular application was significantly superior to the spray against annual weeds (winter and summer). Penoxalin was superior to dinitramine, whereas the latter was superior to trifluralin (each combined with fluometuron). Application methods did not differ significantly from each other from the view point of seed cotton yield.

Commercial use (1976) Fluometuron and trifluralin were applied separately or in combination mixed with superphosphate. Most of the farmers decided to use only one herbicide. The treated area estimated at some 64,000 ha scattered all over the country.

Observations during the season show the relevance and acceptability of the new technique.

DISCUSSION

Hand-hoeing as the traditional method of weeding in Egyptian cotton fields is becoming unavailable due to the scarcity and expense of hand-labour.

Results obtained through the present investigation emphasize the acceptability of chemical weed control.

Evidently, hand-hoeing affected the stand of cotton plants since the number of the productive crop plants was reduced by 21.5%. Meanwhile, the herbicidal application increased the yield by 26.9% (Table 1). In a recent study (Al-Marsafy, 1976) noted that the use of herbicides reduced the cost by 38.8% as compared with hand-hoeing which cost 30.3 Egyptian pounds/ha. He estimated the net income as L.E. 89.3 per hectare.

The officially recommended herbicides used in the present study have not found their way into wide commercial use because of the tedious and costly operations of the application. Hence alternative application methods were considered.

The suitability of field-made granules (in the form of herbicide/superphosphate mixtures) is evident, since the efficacy against annual weeds was increased, (Tables 2 and 3). Hewson and Hays (1972) in field tests showed that herbicides combined with urea retained their normal activity and they were leach-resistant, providing sustained activity for a longer period and reduced phytotoxicity. Miller (1973) noted that granular tri-allate was more effective than a liquid formulation against Avena fatua. Hance et al (1973) pointed out that the volatility of tri-allate was generally lowest from a granule formulation. Kerr and Royster (1974) reported that the granular formulation of alachlor was more effective than the spray formulation. Zahran and Ibrahim (1975) described a similar improved application technique with the use of herbicide/gypsum mixture for paddy rice. This technique has been accepted and is practised in Egypt and in other countries.

The field-made granules of herbicide/superphosphate combinations were used successfully in cotton fields during 1976 season in an area computed to some 64,000 hectares. The growers have accepted the method.

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THE CASE FOR WEED CONTROL TO SPEARHEAD IMPROVEMENTS IN MAIZE AND COTTON HUSBANDRY IN SWAZILAND

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Summary Weeding is the most labour-demanding operation and indirectly determines the area of subsistance crops and limits the area of cash crops on Swazi Nation Land. One reason for the failure of yields to approach the experimental potential may be the policy of recommending to small-scale farmers several improvements in husbandry simultaneously, whereas one at a time may be more effective provided that it is both independent of other factors and acceptable. Thus the interactions between factors of production are as important as their main effects. Nine factors were tested in trials on maize and cotton using a ⅛th replicate of the 2^9 factorial. The importance of the large interactions with weeding, negative with interrow cultivation and N fertiliser in both crops and of opposite sign in maize and cotton with crop density, is discussed. Clean weeding consistently produced the greatest response, worth £78/ha in maize and £186/ha in cotton, and its overall mean interaction was almost zero. Hybrid seed in maize and insect control in cotton were next in order of main effect but interactions with other factors were more variable. For these reasons good weed control using herbicide should receive priority in extension.

Resumé Le désherbage est l'opération culturale en Swaziland la plus couteuse en main-d'oeuvre: il détermine indirectement la superficie devouée a l'agriculture de subsistance, tandis qu'il limite l'aire utilisable pour les cultures de rapport. L'écart élevé entre les rendements actuels et potentiels pourrait être dû a la pratique de conseiller aux petits exploitants plusieurs améliorations simultanes. La recommendation d'une seule technique amelioree pourrait etre plus efficace, pourvu que celle-ci soit au meme temps acceptable et digne de confiance et qu'elle ne dépend pas d'une autre amélioration. Ainsi les interactions entre les facteurs de production sont aussi importantes que les effets principaux de ces facteurs. On a déterminé la réponse a neuf facteurs dans le cours d'une expérience factorielle 2^9 (repetition fractionelle: ⅛) sur le mais et le coton. On discute l'importance des grandes interactions entre le désherbage et les autres facteurs: négatives daus le cas de l'application de l'azote et des travaux machinaux des sols entre les lignes pour le mais et le coton; positive dans le cas de la densité des plantes pour le mais et negative pour le coton. Le desherbage complet a produit la plus grande réponse qui vaut £78/ha pour le mais et £186/ha pour le coton, tandis que l'interaction moyenne de ce facteur avec les autres était près de zero. Après le désherbage complet, l'utilisation des sémences hybrides (mais) et le controle des insectes (coton) avaient les plus grands effets, mais leurs interactions avec les autres facteurs ont variés plus que dans le cas du désherbage. A cause de son indépendance des autres facteurs, et a cause de son importante influence sur la disponibilité du main d'oeuvre, la désherbage efficace doit être considéré comme une priorité par la service de vulgarisation.

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INTRODUCTION

The typical Swazi farming system includes some seasonal arable, with maize as the staple and a small area of cash crop, usually cotton, and oxen are used extensively in land preparation, planting, fertilising and interrow cultivation. Normal planting rains fall in October but before land preparation can begin oxen are fattened on the early flush of grass. On average about 4 ha are cultivated by a family, land preparation often continuing until January when it is halted by competition with weed control on earlier plantings for labour and oxen. Low *et al*, (1976) have shown that although there are large differences between farms in the time spent on different operations, clearly most is spent on weeding, an observation in common with several others of smallscale farming systems in Africa (see for example Dunsmore *et al*, 1976). Almost no herbicides are used by smallscale farmers even on cash crops, no doubt for the reasons discussed in detail by Parker and Fryer (1975) and Hammerton (1974).

In Swaziland, recent yields in field trials of maize and cotton have consistently exceeded 8 and 2.5 t/ha whereas the Swazi National averages are around 1.5 and 0.6 t/ha respectively and are not markedly increasing. Debate of extension problems suggested that one reason for the apparent lack of impact of the extension programme was the simultaneous extension of a wide range of improvements in husbandry on small farms. This would be more true of subsistence crops than of cash crops with which some success had been reported following the introduction of controlled credit 'package deals', selection of farmers and greater intensity of extension effort. Koren in his introduction of a paper to the FAO Regional Seminar in 1972 emphasised the importance in extension programmes for subsistance farmers of selecting a single or a few factors of production for heavy promotion as an alternative to the 'broad spectrum' campaign. The factor(s) so chosen should:

1. be within the capability of the least able farmer to implement

2. yield a clearly visible benefit

3. either

    3.1 not interact with other factors of production and environment or

    3.2 should interact in a manner appropriate to the levels of the other factors.

The 'broad spectrum' approach in extension is based on the assumption that interactions between factors of production are always large and positive. A positive interaction with another factor would imply that a factor could only be recommended in situations where the other could be guaranteed to be at a high level. Conversely a negative interaction (naturally, together with a significant main effect) would mean that a factor could be recommended where the other was at a low level, but no guarantee could be given that it would be effective if the level of the other factor was high. It was for these reasons that a trial series was begun on maize in 1972 and later on cotton, to assess the nature of the interactions between factors.

EXPERIMENTAL

Nine factors of production were chosen for comparison. To establish an optimum at least 3 levels of a factor are required in either a conventional factorial or in one of the more advanced designs for study of response surfaces. Since a 3^n factorial is difficult to fractionally replicate without loosing information then optimisation was sacrificed and the number of levels limited to 2 in each factor, low and high or absence and presence. Thus a ⅛th replicate of the 2^9 factorial in

Table 1

Levels of the factors tested in 2^9 fractional replicate trials on maize and cotton 1972-75

Maize 1973-75		Code	Cotton 1974-75	
lime	- nil and (L) 5 t/ha dolomitic lime (NV= 100)	L	lime	- nil and (L) 7.5 t/ha dolomitic lime
fertiliser	- nil and (F) 85N: 50P: 25K in kg/ha	F	fertiliser	- as maize
insecticide	- nil and (I) cutworm bait plus stalk borer control (Dipterex)	I	insecticide	- nil and (I) DDT plus carbaryl based on scouting
weeding	- single weeding when competition severe and (W) 5 l/ha alachlor + 2.4-D plus clean weeding by hand as necessary	W	weeding	- single weeding when competition severe and (W) 1 kg/ha trifluralin plus clean weeding when competition severe
seed	- open pollinated seed of poor quality and (Sm) hybrid SR52, treated and graded	S	seed dressing	- nil and (Sc) captan dust plus cutworm bait (Dipterex)
cultivation	- nil and (C) machine interrow cultivation	C	cultivation	- as maize
population	- 23 750 and (P) 47 500 plants/ha all in 0.9 m rows	P	population	- 10 000 and (P) 40 000 plants/ha all in 0.9 m rows
planter	- hand planting and (M) machine planting by oxplanter with simultaneous fertilisation	M	planter	- as maize
harvest	- late harvest dried in field and (H) early harvest and crib dried	H	harvest	- single pick at end of season and (H) regular picking through season

64 plots was used leaving all main and 2 factor interaction effects clear of aliases. To remove any site trends 2 third order interactions were confounded to produce 4 blocks and because it is impractical otherwise, the interrow cultivation factor in maize and the weeding and spraying factors in cotton were raised to whole plot status. The 2 levels of each factor are shown in Table 1; generally they are the levels which would be used or attained by a poor to average farmer compared with those which would be recommended to a better than average farmer. Treatment and site changes were made before the 1975/6 season. The sites were at Malkerns Research Station where the altitude is 750 m, the mean annual rainfall 950 mm and temperature range 13-25^{o}c. The soil is the ferralitic Malkerns series with some characteristics of a ferrisol (Murdoch, 1970) having about 32% clay and pH in $CaCl_2$ of about 4.5. Net plot size was 22 m^2.

RESULTS

From Table 2 weeding had the greatest overall effect on yield of both maize and cotton followed by dressed and graded hybrid seed on maize and insecticide sprays on cotton. These responses represent substantial increases in crop value and

Table 2

Main effects and 2 factor interaction effects of factors of production on yield of maize and cotton 1973-75

Maize grain 1973-75 in 90 kg/bags/ha					Seed cotton 1974-5 in kg/ha		
main effect	2 factor interactions mean	2 factor interactions SD	Code	Factor	main effect	2 factor interactions mean	2 factor interactions SD
6.4	-1.7	6.2	(L)	Lime	311	-6	217
12.1	-1.0	10.6	(F)	Fertiliser	-97	38	298
2.8	-0.9	7.8	(I)	Insecticide	508	-13	311
23.8	-0.2	5.6	(W)	Weeding	1 162	3	319
18.1	2.8	6.4	(S)	Seed (treatment)	-3	-129	212
6.1	0.1	5.5	(C)	Cultivation	85	-135	275
9.0	2.2	6.6	(P)	Population	345	-83	241
-5.8	1.7	6.1	(M)	Machine plant	7	18	218
-1.6	0	2.0	(H)	Harvest	225	49	154

are highly profitable. However, interactions are as important as the main effects, as stressed above. With maize, weeding interacted variously with other factors but the mean interaction effect was very small and its standard deviation one of the smallest. In contrast hybrid seed has the largest mean interaction effect, a large positive value of 2.8 bags/ha, and its moderate standard deviation indicates that the interaction with most factors was positive. With cotton, the mean interaction effect of weeding was also small but its standard deviation was large indicating a wide variability in interactions with other individual factors. The pattern for insecticide sprays was similar to that of weeding. Thus effective weed control in both maize and cotton would seem on this evidence to be the single most important factor to promote. The nature of the interactions of other factors with weeding is shown in more detail in Table 3.

In the 1975/6 season the weeding factor was changed to a comparison of clean weeding (by herbicide, hand and interrow cultivation) with moderate weeding (by hand only) at 4, 8 and for cotton 12 weeks from ploughing. Fertiliser treatment was split into a basal dressing factor of N, P and K and a top dressing factor of N alone applied 3 weeks after emergence. Weeding treatment then had little effect on maize yield but on cotton the response was 730 kg/ha of seed cotton. However the change in intensity of weeding on cotton may have contributed towards the interactions with lime and insecticide spray becoming fairly large negative values, -327 and -296 kg/ha respectively. Splitting the fertiliser factor revealed firstly that the response was mainly to nitrogen in both crops but also that weeding interacted significantly with it as shown in Table 4.

Table 3

Interaction of weeding with other factors in maize and cotton 1973-75

Maize grain 1973-75 in 90 kg bags/ha				Seed cotton 1974-5 in kg/ha		
interaction effect	weeding poor	weeding good (W)	Factor	weeding poor	weeding good (W)	interaction effect
6.1	22.6	43.4	nil	467	1 584	93
	26.0	52.8	lime (L)	732	1 942	
-9.0	16.0	44.3	nil	625	1 834	-90
	32.6	51.9	fertiliser (F)	574	1 693	
2.8	23.6	46.0	nil	472	1 383	504
	25.0	50.2	insecticide (I)	728	2 143	
0.4	15.3	38.9	poor seed (or nil)	600	1 765	-4
	33.3	57.3	hybrid (treatment) (S)	600	1 761	
-6.0	19.8	46.6	nil	444	1 833	-452
	28.8	50.0	cultivation (C)	756	1 693	
7.1	21.6	41.8	low	327	1 691	-401
	27.1	54.4	high population (P)	873	1 836	
-1.5	26.8	51.3	hand	630	1 727	132
	21.8	44.8	machine plant (M)	570	1 799	
-1.6	24.7	49.3	late	549	1 590	244
	23.9	46.9	early harvest (H)	651	1 936	
-0.2	21.3	45.2	means over	514	1 676	3
	27.3	51.0	factors	686	1 850	

Table 4

Interaction of weeding intensity of maize and cotton with N top dressing in 1975/6

crop	topdressing in kg N/ha	weeding intensity low	weeding intensity high	interaction effect
Maize	nil	4.99	5.48	-0.69
(t/ha grain)	60	6.81	6.61	
Cotton	nil	1 201	2 124	-386
(kg/ha seed)	60	1 492	2 029	

DISCUSSION

A trial programme on maize in E Africa reported by Allan (1974) compared 6 factors of production in a similar way to the trials reported here but only 3 factors were common to the 2 series, as Allen had included N and P fertilisers as separate factors, more akin to the modified trials in 1975/6. Good weed control came only 4th in order of main effects below time of planting, seed quality and plant population and above N topdressing and P at planting. Thus the order of main effects of the 3 common factors in the 2 series was almost completely reversed. Also with maize, Mate (1972) found herbicide treatment compared with 3 hand weedings produced a larger response than increased plant population and fertiliser but Budan and Popa (1972) reported the difference between herbicide and hand + mechanical weeding as being the smallest in the list of responses headed by N fertiliser alone. The most obvious conclusion to be drawn is that these results should be treated cautiously for the reason that interactions with environment must clearly influence the order of results (cf. IRRI, 1974, p. 75). Indeed until these main effects and their interactions have been related to environmental factors then the study is surely incomplete.

The early period of growth is most critical to competition between weeds and crop (Allan, 1974) and estimates range from 3 weeks (Sankaran and Damodaran, 1974) to 8 weeks (Blanco *et al*, 1973; Laudien, 1976) from planting. In the 1975/6 trials the strong response in cotton to weeding after 12 weeks contrasted with the small response to weeding after 8 weeks in maize suggesting the latter to be a more competitive canopy; Frazee and Stoller (1974) reported maize as growing faster than the 7 common broadleaved weeds they tested. Competitiveness would depend on the weed spectrum and plant population and IRRI (1974) have demonstrated the suppression of *Cyperus rotundus* by densely planted rice. In Table 3 the large negative interaction between weeding of cotton and plant population demonstrates a related effect. In maize the equivalent effect was the most highly positive of the interactions suggesting that at high population competition between maize plants was so severe that any additional competition from weeds was critical, and indeed this had been visually observed during the season.

Weeds and maize compete for N and K but not for P according to Blanco *et al*, (1974). This may explain the failure of yield to respond to basal fertiliser containing mainly P and the lack of interaction in the 1975/6 trials. In contrast and in a way similar to the findings of Allan (1974) and Budan and Popa (1972) with maize and Robinson (1976) with cotton, it was to N topdressing that yield responded strongly and important interactions were recorded (Table 4). In the earlier trials both maize and cotton showed large interactions with fertiliser, which included the N topdressing, such that the fertiliser response was greater (or the negative response in cotton due to seedling scorch was less) where weed competition was severe. Allan (*op. cit.*) attributes this effect to the end of competition for water and nutrients, particularly N. However the failure of crops to respond to P and K fertiliser in 1975/6 is not meaningful in the context of other trial results which clearly indicate the appearance of severe K deficiency after 3 or 4 years of continuous cropping (Armitage, 1972/74).

The remaining interaction of interest is that between weeding and interrow cultivation and the expected large negative values were indeed recorded in both maize and cotton (Table 3). Interrow cultivation may cause root damage and increase evaporation loss of soil moisture, one or other perhaps being responsible for the yield reduction in cotton where the plot was otherwise clean weeded. In maize the small benefit from cultivation in clean weeded plots may be due to the rupture of the soil cap which generally forms on soils at Malkerns. Substantial positive interactions occurred with lime in maize and with insecticde spray in cotton. There is no obvious explanation of these effects other than that they both represent the synergistic effect of optimising the environment.

There were some obvious omissions from this comparison of factors of production, such as time of planting which is known to be critical, but of the 9 tested at this one site in Swaziland it appears that it is clean weeding of maize and cotton which most nearly satisfies the 3 requirements defined earlier. An important observation common to the maize and cotton trials here and to those reported by Allan (*op. cit.*) is the relative stability of the weeding response in relation to the levels of other factors. Thus the mean gross response to good weeding in maize was £78 and in cotton £186 per ha at present prices and these values were the same at both low and high levels of other factors together. At a glance these responses are highly profitable no matter how the clean weeding is achieved. The cost of herbicide treatment in these trials was around £15 per ha applied as a MV spray by knapsack sprayer. This is an impractical recommendation as discussed by Allan and a more practical alternative, the ULV sprayer, has been tested recently. The more expensive machine with horizontal disc was the more successful but both machines tested are rather delicate and careless handling resulted in clogging with soil. Their use precludes intercropping with sensitive crops. The present alternative of hand weeding may not be an expensive alternative but with the peak demand for labour imposing the limit on both the quality of work and the area which can be cultivated there are important implications for the attainment of national objectives. Since maize occupies the bulk of Swazi Nation land and cash crops rather less than 10%, there is little scope for increased production in the cash sector unless an improvement in performance of the maize crop is achieved and hand weeding is replaced by use of herbicide.

Thus it may be concluded of good weed control that because of its clearly visible benefit in maize and cotton, its generally small interactions with other factors, its relatively small cost and its effect on the allocation of farm labour, this is the one factor of production above all others which should receive priority in the National Crop Promotion Campaign in Swaziland.

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SOME EFFECTS OF TIMING OF WEED CONTROL IN THE SUGAR BEET CROP

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Summary In 1975 overall handweeding treatments made on a late March sowing at Sutton Bonington, indicated a distinct critical period for weed control extending from four until six weeks after crop emergence (mid-late May). However, a successful alternative was to weed the crop rows once at four weeks and follow this two weeks later with a single weeding on the strip between the crop rows.

Phenmedipham applied at the cotyledon stage, depressed crop dry weight by 30% during May, but later applications at the two true leaf stage barely affected growth. Adverse effects of phenmedipham were completely outgrown by mid-June and yield losses were due solely to the effects of weeds which evaded control. The early applications effectively dealt with Polygonum aviculare and Tripleurospermum inodorum but Chenopodium album then infested the plots, whereas the later applications effectively killed C. album but the other two species were resistant by this time.

Résumé En 1975, à Sutton Bonington, des sarclages manuels d'une parcelle entière, semée fin mars, indiquèrent que le moment optimal pour le désherbage se définit nettement et s'étend de la quatrième jusqu'à la sixième semaine après la levée de la culture (dans la deuxième moitié de mai). Cependant une réussite semblable se produisit au moyen d'un sarclage dans les rangs à la quatrième semaine, suivi, dans un delai de 15 jours, d'un seul sarclage entre les rangs.

Dans une expérience établie en meme temps, le phenmediphame, appliqué au stade cotylédonaire, effectua pendant le mois de mai une diminution de 30% dans le poids de matière sèche de la betterave; mais des traitements plus tardifs, au stade deux feuilles véritables, n'eurent guère d'influence sur la croissance. A la mi-juin dans tous les traitements la betterave avait complètement surmonté les effets néfastes du phenmediphame et les baisses de rendement resultèrent uniquement de la compétition des mauvaises herbes échappées aux traitements. Les traitements précoces détruisirent Polygonum aviculare et Tripleurospermum inodorum, mais alors le Chenopodium album envahit les parcelles; en revanche les traitements plus tardifs détruisirent C. album mais, à cette epoque, les deux autres espèces se trouvaient résistantes.

INTRODUCTION

Field experiments at Sutton Bonington since 1970 based on a series of handweeding treatments have defined the requirements for control. Invariably the start of weeding can be delayed until the late singling stage (4-6 true leaves) without irreversible effects on yield. Moreover the period when it is necessary to continue controlling weeds is short; weeding may safely cease when plants have about 10-12 true leaves and the crop has a leaf area index of 0.5. For early sown crops (March or early April) the period when they must be weeded extends from mid May until mid June but for later sowings (mid-April to early May) it spans a shorter period, from the middle to the end of June. In these experiments no distinction was made between weeds growing within and between the crop rows, although for much of the crop herbicide usage is confined to a band over the row and weeds growing between the rows are dealt with by the steerage hoe. Thus it seems possible that a different specification might exist, for example it may be that a later start could be made to the control of weeds growing between the rows and conversely the presence of the beet might allow an earlier cessation of within row weeding. Experiments which commenced in 1975 investigated this possibility.

In parallel experiments which compared a series of herbicide treatments, designed to reproduce particular weed control regimes from the hand-weeded series (Scott and Wilcockson, 1974), it was clear that crop growth was checked by post-emergence herbicides. Final yields were also less in treatments which had been checked but since weeds were present it was not possible to apportion the loss to the persistence of the check or to the competitive effects of weeds. In 1975 the course of crop growth was followed at frequent intervals after the use of a post-emergence herbicide both in the presence and absence of weeds.

METHOD AND MATERIALS

Basic cultural details were the same in each experiment. After application of 630 kg/ha kainit in autumn, 125 kg/ha N, 62 kg/ha P_2O_5 and 62 kg/ha K_2O were incorporated into the seedbed. The variety Bush Mono G was sown on 25 March, emergence reached 50% on 19 April and plants were thinned 25 cm apart in rows 51 cm apart on 26 May. Handweeding was done at weekly intervals either from emergence until harvest or during the appropriate treatment period.

There were four groups of treatments in Experiment I. In the first series weeding was done over the whole plot, with weeds controlled until 4,6 and 8 weeks after emergence, or with the start of weeding delayed until 4,6 and 8 weeks after emergence. In the second series weeding was confined to strips 25 cm wide centred on or between the rows. The prolonging weeding series was repeated but with weeding ceasing 2 weeks earlier in the within row strip, i.e. for 2 weeks within the rows and 4 weeks between them, 4 weeks within and 6 weeks between, 6 weeks within and 8 weeks between. Finally there were two treatments in which the start of weeding was longer delayed in the between row strip (until 4 weeks in the within row strip and 6 weeks in the between row strip or until 6 weeks in the within row strip and 8 weeks in the between row strip).

In the second experiment, phenmedipham was applied at two rates, the recommended dose, 1.0 kg a.i./ha, and twice the recommended dose on 28 April, when the beet were in the cotyledon stage, or on 14 May at the 2-4 true leaf stage. On half the plots receiving each treatment, weeds that escaped control by the herbicide were removed and on the other half these weeds were allowed to grow. Plots were sampled at intervals throughout the season and conventional growth analysis procedures used on 12 plants from each plot. Final yields were estimated from $10m^2$.

RESULTS

Experiment 1

Weed growth   Above average rainfall during April resulted in the establishment of a regular beet stand and a dense, evenly distributed weed population. In the absence of weed control, Poa annua predominated until mid-June, but thereafter was progressively killed out by tall-growing Chenopodium album, which thrived despite the unusually dry conditions prevailing throughout May, June and July.

Where uncontrolled weed growth was confined to one or other of the two strips the density and vigour of the weeds changed with their proximity to the beet. Twice as many weeds established on the strips centred on the crop rows so that it seems most likely that the rolling action of the precision drill press wheels created a fine firm seedbed which stimulated extra seeds to germinate (Bleasdale and Roberts, 1960; Scott and Moisey, 1972). Although fewer by half, weeds which established between the rows were less affected by crop competition and grew vigorously, so that by final harvest, their dry matter productivity on a ground area basis was only 20% below that of the strip containing the crop plants.

As the period of overall weeding was prolonged for four or more weeks, the number of weeds which subsequently established in each of the strips was equalised, and weed burdens became progressively lighter (Table 1). Again, weeds growing between the rows grew more vigorously. This was not the case where strips centred on the rows were weeded for two weeks and those between the rows were weeded for four weeks. Two weeks after emergence the beet was only in the cotyledon to two-true leaf stage, and weeds were still able to establish and grow close to the crop plants. By the time weeds infested the between-row strips, those closer to the beet had gained the ascendency so that at final harvest, the weight of weeds between the rows was only half of that in the same position on plots weeded for four weeks overall. When weeding within the row was prolonged for four or more weeks and the between-row strips were weeded for two weeks longer, the re-entry of weeds was sufficiently delayed to allow the crop to become well established. Subsequent weed growth in the two strips was similar to growth after equivalent periods of overall weeding.

Table 1

The effect of time and position of weed infestation on crop yield and weed dry weight

Treatment		Root Yield t/ha	Sugar Yield t/ha	Weed Dry Weight t/ha
Weeding prolonged for:-				
4 weeks overall		33.6	6.02	1.37
6		42.8	7.56	0.71
8		46.6	8.47	0.09
2 weeks within and	4 weeks between the row	20.3	3.70	3.58
4	6	43.9	7.83	0.82
6	8	43.5	7.73	0.40
Weeding delayed for:-				
4 weeks overall		47.2	8.53	-
6		41.7	7.53	-
8		24.7	4.24	-
4 weeks within and	6 weeks between the row	46.3	8.23	-
6	8	35.3	6.31	-
Standard error		±1.41	±0.257	±0.221

Effects of weeds on crop yield Complete failure to control weeds resulted in a 90% loss of sugar yield with a similar depression where weeds were restricted to the within-row band. Where weeds were restricted to a strip between the rows, the yield loss was less, 80%, reflecting lighter weed infestation and the benefit to the crop of allowing it to establish in weedfree conditions.

Table 1 shows that the start of weed control could safely be delayed until four weeks after crop emergence. A further delay of two weeks resulted in a significant loss of both root and sugar yield. It was necessary to prolong the period of weed control until at least six weeks, indicating that there was a critical period for weed control extending from four until six weeks after crop emergence (middle to the end of May). There is a suggestion in Table 1 of an increased benefit from continuing weeding until eight weeks. However, yields were not significantly different from those where weeding ceased at six weeks and the apparent difference is due to exceptionally low yields from two replicates in the latter treatment which were not associated with unusually large weed burdens. The series of treatments in which the cessation of weeding was staggered in the two strips show no benefit from weeding for longer than six weeks.

This second treatment series did demonstrate that it was the weeds growing close to the beet which dictated that the start of weeding had to be at four weeks (mid-May); weeding between the rows could be left until six weeks after crop emergence (end of May). Further, when the specification for weed control is based on the separate requirements of the two strips it is clear there was a successful alternative to the fortnight's overall weeding, i.e. to control weeds within the row at four weeks and then to go through the crop with the steerage hoe two weeks later to remove between-row weeds.

Table 2

The effect of phenmedipham applied either early (28 April) or late (14 May) on the early growth of beet and weeds

Treatment kg a.i/ha of phenmedipham	Crop dry weight g/plant			Crop leaf area cm^2/plant		
	26 May	9 June	23 June	26 May	9 June	23 June
Handweeded	0.38	2.97	14.9	107	285	1162
No control	0.45	1.89	5.6	115	198	425
1.0 applied early	0.28	2.43	15.0	89	251	1143
2.0 applied early	0.27	1.89	14.6	79	208	1258
1.0 applied late	0.38	2.30	12.2	98	245	878
2.0 applied late	0.33	3.10	17.8	93	346	1333
Standard error	±0.031	±0.255	±1.46	±9.7	±27.2	±121.7
	Weed dry weight g/m^2			Weed density number/m^2		
No control	27.7	169	343	530	492	460
1.0 applied early	3.0	28	110	146	182	207
1.0 applied early	1.3	10	52	51	82	98
1.0 applied late	3.5	43	152	129	227	275
2.0 applied late	3.6	20	108	89	192	265
Standard error	±2.28	±25.0	±24.6	±27.1	±47.5	±39.4

xperiment 2

ffects of herbicide on crop growth and yield Checks to crop growth caused by early pplications of phenmedipham were first detected two weeks later on 12 May. The heck was more severe where twice the normal dose had been applied (Table 2). In the ain leaf size rather than leaf number was affected and this restricted dry matter lthough the distribution of dry matter within the plant remained unchanged. These ffects were temporary and outgrown by 23 June (9 weeks after crop emergence). dverse effects of late applications of phenmedipham at both rates were slight and ad completely disappeared by 23 June.

The picture was similar on plots which received phenmedipham but no upplementary hand weeding. By the time weeds re-entered the crop, the beet had ompletely recovered from the herbicide checks. Loss of yield at final harvest was olely due to weed competition (Table 3).

Table 3

The effect of herbicide treatments on crop yield and weed dry weight

reatment g a.i./ha f phenmedipham	Supplementary handweeding	Root yield t/ha	Sugar yield t/ha	Weed dry weight t/ha
o herbicide	Throughout	40.4	7.28	-
o herbicide	Nil	4.2	0.75	8.42
.0 applied early	Throughout	40.3	7.11	-
.0 applied early	Nil	27.6	5.16	4.08
.0 applied early	Throughout	40.7	7.00	-
.0 applied early	Nil	30.3	5.44	3.76
.0 applied late	Throughout	41.4	7.32	-
.0 applied late	Nil	34.2	6.19	2.92
.0 applied late	Throughout	41.7	7.33	-
.0 applied late	Nil	38.1	7.08	1.52
tandard error		±1.78	±0.365	±0.522

ffect of herbicide treatment on the weed flora On each occasion *C. album* proved o be the most susceptible species to either dose rate of phenmedipham and *P. annua* he most resistant. Both *Tripleurospermum inodorum* and *Polygonum aviculare* were usceptible to the early applications at either rate but were more resistant to the ater ones, particularly at the recommended rate, as they had grown beyond the usceptible cotyledon stage.

Early applications effectively delayed the re-entry of *C. album* until three eeks after crop emergence but plants which did establish grew rapidly above the rop and by mid-August, dominated the weed flora. At the time of the late application ore *C. album* plants had emerged and were successfully killed. Re-entry of this pecies was delayed for ten days by which time its growth was severely suppressed y the crop. Thus *P. aviculare* and *T. inodorum* which had been checked but not killed y the late application became predominant.

Senescence of T. inodorum and P. annua was advanced by the very dry conditions during June and July and the weed burden on late sprayed plots decreased rapidly after the end of July. C. album on the other hand seemed less affected by the drought. It remained intact and maintained weight even when senescing, so that the decline of weed dry weight on the early sprayed plots did not commence until mid-August when seed began to shed.

DISCUSSION

A previous experiment made in 1974, when May and June rainfall was also slight, gave no evidence of a critical period for overall weed control. April was unusually dry and prostrate weeds, Stellaria media and P. aviculare, were predominant. In these conditions a single once and for all weeding at the appropriate time would have prevented yield loss (Scott and Wilcockson, 1976). However, the present results show that this specification for overall weeding may need to be changed if wet weather follows soon after drilling and C. album is the problem species. In 1975 rain was plentiful during late March and throughout April. Dense populations of C. album became well established which had to be removed four weeks after crop emergence in order to prevent losses of final yield. Surprisingly, C. album continued to germinate and grow vigorously in the very dry soil, so that a period of two weeks of weeding was then required to enable the crop to form a canopy capable of shading the emerging weeds.

Treatments where weeding was carried out for different periods in the two strips showed that these requirements could be met with equal success but less total effort, with two single procedures, two weeks apart. The first, at the beginning of the critical period for weed control, directed at the within-row weeds and the second at the end of this period to remove between-row weeds. Commercially, this specification could be met by band spraying a post-emergence herbicide over the rows four weeks after emergence, followed by a steerage hoeing two weeks later to remove weeds between the rows. However, since it is well known that post-emergence herbicides are less effective once the weeds have developed two pairs of true leaves, and some species, namely P. aviculare and T. inodorum must be dosed in the cotyledon stage, the time of application might have to be advanced. If P. aviculare or T. inodorum are likely to be a problem, the earlier application will be necessary, before these species have grown beyond the cotyledon stage. If C. album is the dominant species then it may pay to delay the application of phenmedipham so that many of the late germinating plants are controlled, whilst retaining the ability to control those which emerged early. Sequential applications of phenmedipham would be the most effective solution where a mixture of these three species is present.

Even during the most favourable growing season, early sown sugar been fails to intercept some 40% of solar radiation incident between sowing and harvest (Scott et al, 1973) because of the period of inadequate leaf cover during April, May and June. Any factor, e.g. delayed sowing (Scott et al, 1973) or the use of small seed (Scott et al, 1974) which further delays leaf growth depresses yield, there being a close relationship between sugar yield and the amount of radiation intercepted by the crop (Scott et al, 1973).

In adjacent field experiments, post-emergence herbicides have had similar initial effects on leaf growth to delayed sowing and the use of small seed but without loss of yield. The effect of the herbicide check is not so persistent and our data indicate that it is only growth that is affected whereas date of sowing and seed size affect both growth and development. The effects of the herbicide on the leaf surface was completely outgrown within 28 days. Because LAI was still less than one at this time the additional wastage of incident light energy due to the check was probably trivial in comparison with late sowing and the use of small seed whose influence on leaf area persists until mid-July.

Whilst leaf area and the dry weight of tops and roots are depressed by the herbicide, leaf number is unchanged. These observations parallel those of Milford at Rothamsted (pers. comm.) who found that decreasing irradiance during the early stages of growth decreased plant dry weight without radically changing leaf number or leaf area. Within four weeks of returning these plants to normal conditions, treatment effects had disappeared. Sowing date and seed size on the other hand appear to affect the pattern of development as well as growth rate. Leaf areas, but also leaf numbers are affected so that plants sown on different dates or from different sizes of seed encounter the same environmental conditions at different stages of development and yields differ. Decreasing temperatures during the early stages of growth can have similar effects (Milford, pers. comm.). A cold period decreases plant dry weight but drastically decreases leaf number as well as leaf area and these plants are unable to recover on return to normal conditions. Whilst we know that herbicides have affected growth of the tap-root, we have no information of possible effects on extension of the fibrous root system.

The adverse effects of herbicides on sugar beet is obviously a subject which requires further detailed investigation both in the field and in the controlled environment. Current field experiments test the effects of more severe checks to growth induced by more potent herbicide treatments supplemented by bird and mechanical damage to the leaf surface.

Acknowledgements

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ETHOFUMESATE - POST-EMERGENCE USE IN SUGAR BEET

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Summary Ethofumesate/phenmedipham mixtures have been widely studied over the last 4 years in Europe and the USA. This paper presents new results obtained in 1975 and 1976. It can be concluded that the mixture has significant advantages over established materials in the spectrum of weeds controlled, with a high level of crop safety. Sequential post-emergence applications have given particularly promising results. As part of an integrated herbicide programme such techniques offer the possibility of season-long weed control with crop safety under a variety of conditions.

Résumé Les mélanges éthofumésate/phenmediphame ont été largement étudiés ces quatre dernières années en Europe et aux USA. Ce rapport présente les résultats obtenus en 1975 et 1976. Il a été conclu que la solution offrait de grands avantages au point de vue activité herbicide par rapport aux produits connus, avec une marge de sécurité vis-à-vis de la culture importante. Des applications successives de post-levée ont donné des résultats particulièrement intéressants pour l'avenir. Dans le cadre d'un désherbage complet, des techniques telles que celle-ci, offrent la possibilité d'une action de longue durée avec sécurité à l'égard de la culture dans un grand nombre de conditions.

INTRODUCTION

The contribution of ethofumesate to herbicide programmes designed to give season long weed control has long been recognised (Sullivan, Fagala and Ross 1972). Pre-emergence use of ethofumesate mixtures is now well established. Extensive trials carried out in Europe and the United States over several seasons have shown the value of ethofumesate/phenmedipham mixtures for post-emergence use (Holmes, Pfeiffer and Griffiths (1974); Pfeiffer, Holmes and Griffiths (1975); Griffiths, Belien, Salenbier and Verfaillie (1974); Vernie, Pujol and Querre (1975); Durgeat and Morin (1975)).

This paper undates and confirms the authors' previous results in four European countries. It includes results on the use of ethofumesate/phenmedipham in sequential post-emergence applications designed to replace the necessity for pre-emergence treatments in the herbicide programme.

METHOD AND MATERIALS

1975 Experiments

35 experiments were carried out (11 in England, 3 in Greece, 8 in Austria and 13 in France) to study the performance of ethofumesate/phenmedipham mixtures under varying environmental conditions. Phenmedipham alone used as a standard was applied at the cotyledon stage of the beet; ethofumesate/phenmedipham mixtures at the 2 to 4 leaf stage. Plot size was 20m^2 replicated three times. Application was by knapsack sprayer at a pressure of 2 bars using a spray volume of 200 l/ha. Crop scorch was assessed visually one week after spraying and crop vigour and weed control at 2 weeks and 6 weeks after spraying. Beet stand was assessed by counting sample areas of 2 rows x 10 m per plot before and after treatment.

In an additional 13 trials for yield determination, all plots were hoed in order to prevent weed competition from influencing the results on crop safety. The design was a Latin square with 6 replications per treatment. Plot size was 24 m^2 in England, Austria and Greece and 45 m^2 in France; 2-4 rows were harvested per plot.

1976 Experiments

22 trials were carried out; 11 in the UK, 6 in Greece and 5 in Austria. Methods were similar to those used in 1975. 9 yield experiments are still in progress.

The 20% w/v EC formulation of ethofumesate (Nortron)* and the 15.9% w/v EC of phenmedipham (Betanal)* was used in all countries in both years. In the 1976 trials in the UK, the 11.4% w/v EC formulation of phenmedipham (Betanal E) was also used. All doses are in kg a.i./ha.

RESULTS

Single Applications

(a) Crop safety The trials in 1975 and 1976 indicate that a mixture of ethofumesate and phenmedipham (1.0 + 0.8 kg a.i./ha) applied at the 2-4 leaf stage of the beet, causes no more than a temporary crop check. Table 1 shows the number of beet (% stand) and the vigour of the crop assessed 2 weeks and 4-6 weeks after spraying.

*Nortron is a Trade Mark of Fisons Ltd. registered in many countries. Betanal is a Registered Trade Mark of Schering, Berlin, Bergkammen.

Table 1

% stand and vigour of beet after ethofumesate/phenmedipham at

1.0 + 0.8 kg a.i./ha

Country	No. of trials	% stand	% vigour 2 weeks	% vigour 4-6 weeks
1975				
England	14	101	98	100
Greece	6	96	92	99
Austria	12	101	95	100
France	16	103	97	100
1976				
England	11	98	88	100
Greece	6	84	81	96
Austria	5	103	97	100
Means		99	95	100

Stand of beet was not affected by the treatment except in Greece in 1976 where interaction of herbicide with other factors caused loss of plants even after use of phenmedipham alone. Higher crop sensitivity does tend to occur in the growing conditions of Greece as is illustrated by the figures for crop vigour in both 1975 and 1976. Even here however, as in the other countries, the growth check was temporary and had grown out within 4-6 weeks. Yield experiments in 1975 confirmed the 1974 data, (Pfeiffer et al) that this temporary check has no effect on beet yield or sugar content (Tables 2 and 3).

Table 2

Effect of ethofumesate/phenmedipham (E/P) mixtures on beet yield (1975)

Weight of roots in tonnes/ha - Doses in kg a.i./ha

Location	Untreated	E 1.0 + P 0.8	E 2.0 + P 1.6	P 1.0	Statistical Data: LSD P=0.05	Statistical Data: Standard Error of Means
England						
Sawston	25.2	26.9	25.7	26.2	2.56*	0.89
Yeldham	33.3	34.2	32.0	34.5	2.57*	0.89
Hinxton	30.8	30.9	29.4	29.6	3.06*	1.06
France						
Brebieres	52.2	52.8	51.0	52.8	2.31*	0.80
Troyes	37.2	35.3	34.4	39.0	3.08	1.07
Arcis	49.0	48.7	44.7	47.4	2.42	0.84
Austria						
Apetlon	54.9	68.5	63.6	65.2	8.79	3.05
Petronel	39.3	37.2	34.7	37.3	5.22	1.80
Marchfield	43.8	45.1	47.4	48.4	5.81*	2.01
Seewinkel	50.3	57.0	58.5	69.6	8.88	2.99
Greece						
Arachos	46.6	44.8	41.5	37.2	7.15*	2.50
Alexandria I	31.8	39.1	39.5	38.4	5.68	1.99
Alexandria II	45.8	47.7	41.0	44.4	7.10*	2.67
Mean	41.6	44.5	41.8	43.8		

*Variance Ratio not significant at P = 0.05

Table 3

% sugar content of roots (1975)

(mean of 10 trials in 3 countries)

Untreated	Ethofumesate 1.0 + Phenmedipham 0.8	Ethofumesate 2.0 + Phenmedipham 1.0	Phenmedipham 1.0
15.4	15.5	15.5	15.8

In none of the 13 trials did the proposed dose of the mixture (1.0 + 0.8 ethofumesate/phenmedipham) cause any significant loss in yield compared with untreated hoed plots. Even at double dose, which sometimes produced a temporary 25-35% crop check, a significant reduction in yield occurred in one trial only, (Arcis, France) probably because of high temperatures at spraying.

(b) Weed Control The 1975 and 1976 trials have confirmed the advantages of adding ethofumesate to phenmedipham in level, persistence and spectrum of weeds controlled (Table 4).

Table 4

% Weed control assessed 2 and 6 weeks after spraying

(Dose in kg a.i./ha)

	No. of expts.	Phenmedipham 1.0		Ethofumesate 1.0 + Phenmedipham 0.8	
		2 weeks	6 weeks	2 weeks	6 weeks
1975					
England	10	50	48	73	64
Greece	3	86	53	91	84
Austria	8	84	50	92	79
France	13	86	65	94	87
1976					
England	8	72	58	84	77
Greece	3	81	67	96	76
Austria	2	60	64	85	83
Mean	48	73	57	86	78

It must be emphasised that these trials were not treated with a pre-emergence herbicide as would be the case in most commercial situations. In spite of this, the single post-emergence application of the mixture gave over 85% control of 22 broad-leaved weed species and moderate control of the remaining 7. Most of the weeds were at the 2-6 leaf stage at spraying but in 1976, due to the slow emergence of beet under the arid conditions, Polygonum aviculare and Urtica urens were often well branched. Nevertheless a reasonable level of control (>70%) was still obtained.

On annual grass weeds the mixture gave 70% reduction of Avena fatua and Poa trivialis and severely checked Alopecurus myosuroides and Poa annua.

Phenmedipham formulations In previous seasons, trials with the mixture have been carried out using predominantly the standard formulation of phenmedipham (15.9% w/v a.i.). During 1976 a parallel series of treatments was tested in the UK using the 11.4% w/v formulation. Crop safety and weed control obtained with the two formulations in the mixture have been very similar (Table 5).

Table 5

Activity of phenmedipham formulations mixed with ethofumesate

Means of 11 experiments

	Standard formulation	UK formulation	Untreated
Crop safety (% effect)			
Scorch	5	7	0
Vigour	90	89	100
% overall weed control			
2 week assessment	84	84	0
6 week assessment	77	80	0

Sequential post-emergence applications In past years the majority of sugar beet growers have employed mainly pre-emergence herbicides followed, where necessary, by post-emergence treatments. During the recent dry seasons however, repeated failure of some pre-emergence treatments has led to increasing interest in the possibility of using solely post-emergence techniques to achieve season long weed control. Although a single application of ethofumesate/phenmedipham applied at the 2-4 leaf crop stage has given satisfactory control of most weed species, trials have shown that performance can be improved by the prior use of phenmedipham applied at the cotyledon stage of the beet. Overall weed control two weeks and six weeks after spraying the mixtures is shown in Table 6.

Table 6

% overall weed control by ethofumesate + phenmedipham (1 + 0.8 kg a.i./ha)

with and without an early phenmedipham application (1.0 kg/ha)

	No. of Expts.	Without early phenmedipham 2 weeks	Without early phenmedipham 6 weeks	With early phenmedipham 2 weeks	With early phenmedipham 6 weeks
UK	11	73	64	92	89
Greece	3	91	84	91	86
Austria	8	92	79	100	100
France	13	94	87	98	96
Mean	35	86	78	95	93

Control of the more difficult weeds such as P. aviculare, P. lapathifolium, Matricaria sp. and Urtica urens was substantially improved by this technique (Table 7).

Table 7

% control of individual weed species by ethofumesate + phenmedipham (1 + 0.8 kg a.i./ha) with and without an early phenmedipham application (1.0 kg/ha) - assessed 2 weeks after spraying

	No. of Expts.	Without early phenmedipham	With early phenmedipham
Matricaria sp.	13	61	88
Polygonum aviculare	4	76	90
Polygonum lapathifolium	3	69	88
Urtica urens	2	43	88

Crop check following the sequential treatment was usually slight and no more than that which occurred with a single application of ethofumesate and phenmedipham applied at the 2-4 leaf stage of the crop. This grew out within 4-6 weeks. However under environmental conditions in which crop effects are more liable to occur (e.g. high temperature or high light intensities at spraying) doses may need adjustment.

A further technique examined in 1976 was "split-dose" applications of ethofumesate/phenmedipham. A half dose (0.5 kg ethofumesate + 0.4 kg phenmedipham) was applied at the 2 leaf stage of the beet and the same dose repeated 3-5 days later. Trials were carried out with and without a prior phenmedipham spray (0.5 kg a.i./ha) at the cotyledon stage. Results are presented in Table 8.

Table 8

"Split dose" of ethofumesate/phenmedipham (E/P)

	No. of trials	E 1.0*** P 0.8	E 0.5) P 0.4) twice**	P 0.5* E 0.5) P 0.4) twice**	Untreated
Crop Safety					
Scorch %	4	7	4	6	0
Vigour %	4	69	92	88	100
Overall Weed Control %					
Early assessment	4	83	92	96	0
Late assessment	4	86	93	97	0
Individual species % control					
Polygonum aviculare	3	84	90	97	0
P. lapathifolium	2	80	96	97	0
Sinapis arvensis	1	80	84	89	0
Urtica urens	2	88	97	99	0

Application made a * cotyledon stage of beet, ** 2-leaf stage and again 3-5 days later, *** at 2-4 leaf stage.

Split application of ethofumesate/phenmedipham gave improved weed control compared with a single application particularly on weed species more difficult to control. In addition it gave less crop check. The use of an early phenmedipham application in addition to the split dose treatment gave a further increase in weed control but no more crop check than that produced by a single application of ethofumesate/phenmedipham at 1.0 + 0.8 kg a.i./ha.

DISCUSSION

The above results confirm that a mixture of ethofumesate and phenmedipham, (1.0 + 0.8 kg a.i./ha) applied at the 2-4 leaf stage of the beet displays adequate crop safety under a wide variety of soil and climatic conditions.

Although a slight crop check sometimes occurs, this is temporary and yield data show that this does not cause any loss in weight or sugar content at harvest.

A single application of this mixture sometimes gives acceptable weed control over the whole season. However, in most situations it is necessary that the mixture be applied as part of a herbicide programme, e.g.:

a) As a single application at the 2-4 leaf stage of the beet following a pre-emergence treatment.
b) As a sequential treatment at the 2-4 leaf stage of the beet following an early phenmedipham application at the cotyledon stage.
c) As a "split dose" i.e. half rate, applied at the 2-leaf stage and repeated 3-5 days later.

The flexibility of ethofumesate thus offers growers a choice of techniques capable of giving season-long weed control under a variety of conditions.

Research is continuing with post-emergence programmes and with different formulations of ethofumesate. In addition to beet and grass crops interesting results are being obtained in dwarf beans, onions, carrots, sunflowers and rice.

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THE DEVELOPMENT OF METAMITRON, A HIGHLY SELECTIVE AND VERSATILE HERBICIDE, FOR USE ON SUGAR BEET IN THE U.K.

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Summary Over 4 seasons, trials have shown metamitron to be very safe to sugar beet at all growth stages. Single applications using 2.8-7.0 kg a.i./ha gave effective weed control when applied pre-emergence or early post-emergence, cotyledon to first true leaf, of the weeds. Soil and climatic conditions influenced activity less than with comparable residual herbicides but usually further weed control measures were required. Superior weed control was obtained with a programme of two sprays of metamitron at 3.5 kg a.i./ha applied pre-emergence and early post-emergence. This exploited the residual and contact properties of the compound and resulted in optimal control of a wide range of annual weeds on all mineral soils tested.

Résumé En 4 saisons, les essais ont montré que metamitron possède une très grande marge de sécurité à tous les stades de développement des betteraves. Une seule application de 2.8-7.0 kg a.i./ha appliquée pré ou postlevée précoce, cotylédon à première vraie feuille des mauvaises herbes, a donné un désherbage effectif. La condition de la terre et les conditions climatiques ont affecté l'activité de metamitron moins que les autres désherbants residuels, mais on avait besoin presque toujours d'un moyen de désherbage supplémentaire. On a observé un désherbage superieure avec un programme de 2 doses de metamitron à 3.5 kg a.i./ha appliqué prélevée et postlevée précoce. Les propriétées résiduelles et contactes de cette substance ont eté montrées et on a très bien maitrisé une grande assortiment de mauvaises herbes sur tous les sols minéraux misent à l'épreuve.

INTRODUCTION

Sugar beet growing has changed from a labour intensive enterprise into a highly mechanised one, largely due to the declining labour force. Selective herbicides have played an important part in this change. The need for high and prolonged levels of weed control has led to the widespread use of spray programmes involving mixtures or the sequential use of a number of herbicides. The wide range of soil types, weed species and climatic conditions encountered further complicates these programmes. In addition greater crop safety is demanded by the increasing number of crops being 'drilled-to-a-stand'.

In the triazinone group of herbicides several compounds well tolerated by sugar beet were discovered in the laboratories of Bayer AG, Leverkusen, West Germany (Schmidt et al, 1975b). The compound 4-amino-4,5-dihydro-3-methyl-6-phenyl-1,2,4-triazin-5-one was selected for further development and given the common name metamitron. This compound has a low mammalian toxicity and a solubility in water of

1860 ppm. It can be absorbed by plants either via the foliage or, more readily, via the roots and is rapidly translocated to the chloroplasts where it inhibits photosynthesis. Sugar beet shows a very high tolerance to metamitron, apparently due to an ability to detoxify the compound within the plant (Schmidt et al, 1975a).

In the U.K. work started in 1973 with a logarithmic dilution screening trial at Elm Farm Trials Station. On 4 sugar beet cultivars, applications made pre-emergence or at crop 4 leaf were safe at 7 kg a.i./ha and gave good weed control in the range 1.4-4.2 kg a.i./ha. Similar results were obtained in field trials in West Germany (Hack, 1975). Also, in pot experiments, the potential activity of the compound against many weed species was demonstrated (Richardson et al, 1976). Metamitron has shown good selectivity in mangolds, fodder and red beets and to a lesser extent in peas and strawberries. Development work on these crops and on sugar beet grown on highly organic soils is not reported in this paper. The findings from trials carried out during 3 years, on commercial crops of sugar beet grown on a wide range of mineral soil types in England, are reported. The aim of the work was to establish the way metamitron could be used most effectively.

METHOD AND MATERIALS

Metamitron was used as a 70% wettable powder with the code number BAY 6676. Comparison products, mainly pyrazone (80% w.p.) or lenacil (80% w.p.) pre-emergence and phenmedipham (11.4% e.c.) post-emergence, were used at recommended rates.

Small plot replicated trials were used to compare treatment rates and timings at 26 sites. All treatments were replicated three times and applied overall by means of pressurised knapsack sprayers using volumes of 300 l/ha and pressure of 2 bars on plots of 20-25m^2. Crop compatibility trials were carried out by applying 2m strips across a range of cultivars.

In 1976 grower usage trials, supervised by Bayer Trials Officers, a metamitron programme was compared with the grower's normal treatments. Treatments were applied by the grower either as an overall application (22 sites) or as an 18 cm band along the row (15 sites), the majority in a volume of 200 l/ha, to an area of approximately 0.5 ha.

Pre-emergence treatments were applied within a few days of drilling. Post-emergence treatments were applied at two timings in 1974, crop cotyledon to 2 true leaf and crop 2-6 true leaf. In subsequent work post-emergence treatments were timed according to the weed stage, cotyledon to 1 true leaf; this was normally from crop cotyledon to crop 4 true leaf.

Using fixed lengths of row, emergence counts were made prior to singling and, at harvest, the weights of topped roots were recorded. Samples were taken from some treatments to determine percentage sugar contents. All emergence and yield results on replicated trials were analysed statistically and expressed as a percentage relative to the untreated control (100).

Herbicidal effectiveness was based on weed counts made in a number of quadrats, normally of 0.1m^2, in each plot. Counts were generally carried out 6-8 weeks after the pre-emergence application, usually end of May - early June, on the replicated trials. In the grower trials two counts were made, the first just before the post-emergence application in early May, 4-6 weeks after application, and the second at the end of May or early June. Each weed species was recorded separately and the results for populations of $>4/m^2$ were expressed as percentage reductions compared with the untreated control.

Soil samples from each site were analysed for both mineral fractions and organic matter content. Trials were grouped into the following categories; light - coarse sandy loam, loamy sands and sands, medium - sandy loam, fine sandy loam and very fine sandy loam, heavy - silty loams, loams, clay loams and heavier. Rainfall data was obtained from the nearest meteorological station to each site in 1975 and trials were grouped in 3 categories; low - 0-30mm, moderate - 31-60mm and high - 60mm according to the amount of rain from the time of the pre-emergence application until the end of May. National average rainfall figures based on 101 observations throughout England were obtained for March, April and May.

In order to produce summary tables from the large number of trials conducted medians were used; the maximum number of trials normally being indicated. To enable all trials to be included in tables 4 and 5, the 1974 results obtained with 2.8 and 4.2 kg a.i./ha were meaned as an estimate of the 3.5 kg a.i./ha rate. In tables involving the grower trials weed control with metamitron was compared with the standard, i.e. the level of weed control obtained commercially by the growers with their normal herbicide programmes.

RESULTS

Crop tolerance Climatic conditions during the development of metamitron influenced the emergence and the yield of sugar beet (Table 1). Consequently there was great variability in results and the standard error was high resulting in few statistical differences.

Table 1

Emergence and yield results (medians)

		Relative emergence					Relative yield		% sugar
		Replicated trials			Cultivar trials		Replicated trials		
Treatments	Rate kg a.i./ha	1974	1975	1976	1974	1975	1974	1975	1975
Pre-emergence									
metamitron	2.8	98	102	87	-	-	118	109	-
metamitron	3.5	-	102	95	109	112	-	122	17.5
metamitron	4.2	100	100	-	-	-	125	120	-
metamitron	7.0	-	-	-	110	108	-	-	-
pyrazone		-	103	99	-	-	-	109	-
lenacil		101	88	-	-	72	109	123	-
Early post-emergence									
metamitron	2.8	107	-	-	-	-	119	-	-
metamitron	3.5	-	103	-	-	-	-	126	17.3
metamitron	4.2	102	105	-	-	-	123	117	-
metamitron	4.9	-	101	-	-	-	-	138	-
metamitron	7.0	-	98	-	115	-	-	116	17.0
Pre + post-emergence									
metamitron + metamitron	3.5 + 3.5	-	103	95	-	-	-	119	17.2
pyrazone + phenmedipham		104	100	99	-	-	113	125	17.1
Untreated control									
Number per m row		7.1	4.6	3.7	11.5	21.5	t/ha 55.2	27.6	-
Maximum no. trials		(7)	(9)	(2)	(1)	(1)	(7)	(10)	(9)

There were no real differences in emergence due to treatments apart from the obvious depression found with lenacil in 1975 when rainfall was high. In grower trials no differences were found between metamitron and standard treated crops.

At Elm Farm Trials Station the sugar beet cultivars Amono, Anglo Maribo Poly, Bush Mono G, Hilleshog Monotri, Nomo, Sharpes Klein E, Sharpes Klein Megapoly, Sharpes Klein Monobeet, Sharpes Klein Polybeet and Vytomo were tested for sensitivity to high rates of metamitron. Single applications of 10.5 kg a.i./ha and double applications of 7.0 kg a.i./ha caused no significant deleterious effects. No damage was observed on crops of various cultivars in field trials.

All herbicide treatments gave considerable increases in yield of sugar beet roots, in replicated trials, when compared with unsprayed controls. Differences between treatments were attributed to the corresponding levels of weed control.

Herbicidal activity The results obtained with metamitron in the replicated trials are shown for some of the more important weeds found in sugar beet as well as for total weeds (Table 2).

In general single applications gave better weed control than the standard pre-emergence materials. Individual weeds differed in their susceptibilities, Chenopodium album, Poa annua and Polygonum aviculare being best controlled pre-emergence whilst Polygonum convolvulus and Stellaria media were more readily controlled early post-emergence. The late post-emergence applications tested in 1974 gave reduced levels of control of most weed species. In critical work on marked weeds the increasing resistance of the majority of weed species with age was demonstrated.

A progressive increase in weed control with increasing rates was found with single applications; this was more marked in the dry spring of 1974. The higher rates, however, gave more consistent results over all seasons.

In 1975 two applications of metamitron, pre-emergence and early post-emergence, showed a considerable improvement in weed control over single applications; this being best illustrated by Polygonum convolvulus. This was the only treatment comparable with pyrazone pre-emergence followed by phenmedipham post-emergence. Two post-emergence applications of metamitron were less effective.

Grower trials in 1976 tested the pre and post-emergence programme of metamitron (Table 3). Weed control from pre-emergence applications of metamitron was superior to the standard and notably so in the case of Chenopodium album. The post-emergence applications further improved weed control and achieved levels of effectiveness, except with Polygonum convolvulus, equivalent to the farmers' standard. Though generally well controlled Chenopodium album proved a problem at certain sites.

Influence of soil type and rainfall Somewhat reduced weed control was obtained with metamitron on the heavier soils, particularly with pre-emergence treatment (Table 4). This effect was less pronounced than with the pre-emergence standard considering the increasing rates of application, up to 4 fold with some materials, from light to heavy soils.

Total weed control varied with the season (Table 4) and this phenomenon was attributed largely to differences in rainfall, metamitron giving better weed control in the wetter season. This relationship was confirmed when the 1975 trials were grouped according to the amounts of rainfall. The pre-emergence standard was influenced to a greater extent by these factors.

Summary of weed control from replicated trials (median percent control)

Treatments	Rate kg a.i./ha	Total annual weeds 1974	1975	1976	Chenopodium album 1974	1975	1976	Poa annua 1974	1975	1976	Polygonum aviculare 1974	1975	1976	Polygonum convolvulus 1974	1975	1976	Stellaria media 1974	1975
Pre-emergence																		
metamitron	2.8	50	77	82	59	91	85	96	100	-	28	84	85	23	0	50	67	73
metamitron	3.5	-	78	89	-	97	90	-	100	-	-	87	87	-	32	54	-	68
metamitron	4.2	61	84	-	75	87	-	100	100	-	44	89	-	32	47	-	74	79
pyrazone		-	65	59	-	63	65	-	96	-	-	45	62	-	83	46	-	47
lenacil		16	71	-	41	65	-	72	84	-	0	-	-	0	56	-	48	94
Early post-emergence																		
metamitron	2.8	50	-	-	66	-	-	78	-	-	0	-	-	39	-	-	91	-
metamitron	3.5	-	78	-	-	86	-	-	90	-	-	86	-	-	68	-	-	84
metamitron	4.2	61	86	-	77	79	-	98	94	-	39	72	-	25	69	-	91	91
metamitron	4.9	-	84	-	-	90	-	-	96	-	-	94	-	-	51	-	-	92
metamitron	7.0	-	92	-	-	98	-	-	99	-	-	97	-	-	53	-	-	97
Late post-emergence																		
metamitron	2.8	34	-	-	68	-	-	32	-	-	0	-	-	21	-	-	85	-
metamitron	3.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
metamitron	4.2	52	-	-	79	-	-	6	-	-	37	-	-	45	-	-	84	-
metamitron	4.9	47	-	-	63	-	-	3	-	-	35	-	-	30	-	-	92	-
Pre-emergence + post-emergence																		
metamitron + metamitron	3.5 3.5	-	97	99	-	96	100	-	100	100	-	92	98	-	78	83	-	100
pyrazone + phenmedipham		68	96	95	86	95	97	69	100	82	22	93	75	97	96	83	95	99
Post-emergence + late post-emergence																		
metamitron + metamitron	3.5 3.5	-	89	-	-	79	-	-	100	-	-	87	-	-	69	-	-	99
Untreated control																		
Number per m2		189	98	154	67	43	69	83	27	33	83	13	17	42	19	10	22	17
Maximum no. trials		(10)	(12)	(4)	(7)	(3)	(4)	(3)	(6)	(2)	(3)	(3)	(2)	(4)	(5)	(2)	(6)	(7)

Table 3

Summary of weed control from grower trials 1976
(median percent control)

Treatments	Rate kg a.i./ha	Total annual weeds	Major weed species: Chenopodium album	Poa annua	Polygonum aviculare	Polygonum convolvulus	Stellaria media
Pre-emergence							
metamitron	3.5	69	80	94	63	34	67
standard		57	38	86	46	32	53
Pre + post-emergence							
metamitron + metamitron	3.5 3.5	88	97	100	80	50	100
standard		88	98	100	89	77	95
Untreated control							
Number per m^2		80	20	26	20	26	17
Maximum no. trials		(37)	(21)	(14)	(20)	(12)	(18)

Table 4

The influence of soil type, rainfall and season on weed control
(median percent control)

Treatments	Rate kg a.i./ha	Soil type 1974-1976: Light	Medium	Heavy	Rainfall 1975: Low	Moderate	High	Season: 1974 (93)*	1975 (195)*	1976 (117)*
Pre-emergence										
metamitron	3.5	72	66	54	64	71	91	56	78	70
standard		57	63	28	49	86	62	16	68	57
Pre + post-emergence										
metamitron + metamitron	3.5 3.5	93**	91**	84**	87	92	98	-	97	89
standard		88	89	94	92	91	98	68	96	89
Untreated control										
Number per m^2		109	126	53	61	290	114	189	98	100
Maximum no. trials		(37)	(15)	(11)	(4)	(4)	(4)	(10)	(12)	(41)

* National average rainfall for March, April and May in mm.
** Results from 1975 and 1976 only, therefore probably rather high.

Weed spectrum The levels of control of all weed species occurring in trials in reasonable numbers are given in Table 5. Metamitron was effective against a wide range of species and showed advantage over standard treatments in control of *Viola arvensis*, *Veronica spp.*, and *Urtica urens*. Metamitron was somewhat inconsistent against *Polygonum convolvulus* and poor against *Galium aparine*, *Avena fatua* and *Agropyron repens*, although good suppression of the latter 3 species was recorded in some trials.

Table 5

Weed spectrum (median percent control)

Treatments Rate kg a.i./ha	Pre-emergence metamitron 3.5	 standard	Pre + post-emergence metamitron 3.5 + 3.5	 standard
Total annual species	68	57	90	90
Individual species				
Anagallis arvensis	35	55	98	100
Capsella bursa-pastoris	100	99	100	100
Chenopodium album	79	55	99	97
Chrysanthemum segetum	98	81	99	93
Fumaria officinalis	40	4	78	95
Lamium spp.	67	34	100	100
Poa annua	96	86	100	96
Polygonum aviculare	65	40	88	86
Polygonum convolvulus	32	37	67	86
Polygonum persicaria	69	64	94	94
Senecio vulgaris	78	38	100	100
Stellaria media	67	54	100	95
Tripleurospermum maritimum	100	99	100	100
Urtica urens	76	56	98	82
Veronica hederifolia	60	37	79	69
Veronica persica	80	45	100	100
Viola arvensis	77	46	92	74
Alopecurus myosuroides	*	*	**	**
Atriplex patula	***	**	***	***
Daucus carota	***	***	***	***
Euphorbia helioscopia	***	***	***	***
Galium aparine	*	**	**	**
Matricaria matricarioides	***	***	***	***
Papaver rhoeas	***	***	***	***
Polygonum lapathifolium	**	**	***	***
Ranunculus sp.	***	***	***	***
Rumex spp.	***	***	***	***
Silene spp.	**	*	***	***
Sinapis arvensis	*	*	***	***
Solanum spp.	*	**	**	**
Thlaspi arvense	***	***	***	***
Trifolium spp.	***	*	***	***

Where control figures are less reliable indications of sensitivity to metamitron are given as follows: *** = good effect >75% control
** = moderate effect 50-75% control
* = little effect <50% control

Persistence Metamitron was sufficiently persistent to give good control of late germinating weeds, in particular, Chenopodium album. No adverse effects were recorded on following crops including winter wheat, even when high rates or late applications were used.

DISCUSSION

The exceptional safety of metamitron to sugar beet enabled applications to be timed according to the most susceptible stages of the weeds irrespective of the growth stage of the beet. Pre-emergence applications showed a good residual effect against weeds, invariably better than the standard level of control, but were influenced by climatic and soil factors. A certain amount of rainfall after application is important although apparently less critical than with other residual herbicides probably due to the relatively high solubility of metamitron. Herbicidal activity is also affected by temperature and soil organic matter; the correlations being positive and negative respectively (Schmidt et al, 1975a). This could partly account for good results in 1976 replicated trials when treatments were applied in above average temperatures and the poorer results on heavy soils some of which had up to 5% organic matter contents. The activity of metamitron is less dependent on soil type than other pre-emergence herbicides. Early post-emergence applications at the cotyledon to 1 true leaf of the weeds were also effective, having both a contact and residual action. However, as weeds become less sensitive with age accurate application timing is essential and poses a problem in practice.

Only rarely can single applications give adequate weed control due to the effects of soil, climatic and timing factors as well as the differing weed susceptibilities to any one timing. The pre and post-emergence spray programme reduced the effects of these factors and resulted in higher levels of weed control due largely to the maximising of the residual and contact properties of metamitron. It was still important for the early post-emergence application to be correctly timed but this was rendered easier by the reduction in population and vigour of the weeds. Some of the poorer results in grower trials were due to late second applications. A wide spectrum of weeds were controlled with the programme and the level of control of the less susceptible Polygonum convolvulus was much improved. The post-emergence application extended the soil persistence further into the growing season and gave good control of late germinating weeds. The use of metamitron as a two spray programme provides the sugar beet grower with a safe and effective method of weed control for use on all mineral soils with a single rate of use.

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USE OF METAMITRON IN WEED CONTROL SYSTEMS IN SUGAR BEET

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Summary With metamitron, systems for the control of weeds in sugar beet can be offered, both as tank mixes and as sequential applications, which provide optimal freedom from weeds under the most varying of conditions. It is also possible to apply metamitron following metamitron.

INTRODUCTION

Complete control of weeds is an absolutely essential measure in sugar beet growing. It can be accomplished either by hand-weeding or by sequential application of herbicides.

Due to shortage of labour, hand-weeding is a very expensive operation so that today freedom from weeds can be achieved economically only by using herbicides. Yet chemical weed control in sugar beet calls for the use of differentiated systems which must be variable according to geographical and climatic factors, soil texture, weed flora and weed infestation density.

On account of its excellent crop tolerance and its biological properties (Schmidt et al., 1975; Hack, 1975), metamitron is especially suitable for such weed control systems.

On the basis of trials work conducted in Europe, we wish to report on the potential uses of metamitron, especially in tank mixes or sequential applications with other herbicides, for the control of weeds in sugar beet.

METHOD AND MATERIALS

The results were obtained in field trials. The plot size was 25 m^2 (2 m x 12.5 m), and each plot comprised 4 beet rows. Usually there were four replications.

The formulations of tested herbicides are as followed: Metamitron 70 % w.p., cycloate 70.5 % w/v e.c., diallate 40 % w/v e.c., triallate 40 % w/v e.c., phenmedipham 16.4 % w/w e.c. The experimental products were used in the formulation corresponding to the code number.

The products were applied ppi (pre planting incorporation), pre (pre emergence) and post (post emergence).

Herbicidal effectiveness was visually scored and expressed as percentage kill in comparison with untreated. To assess crop tolerance, the beets were scored for damage and beet emergence was determined by making counts on 8 x 10 linear metres, in relation to untreated. The presented results are based on means of comparable experiments.

RESULTS

Application timing Timing of metamitron application is governed chiefly by the composition of the weed flora and by climatic conditions.

A ppi application of metamitron should be made when very small amounts of rain have fallen or are expected because under dry conditions ppi application is markedly more effective than pre emergence application. In very wet conditions, it is the reverse although the decline in effectiveness of the ppi application is only slight (Table 1).

Table 1

Herbicidal effectiveness (in %) of 3.5 kg/ha metamitron under extremely dry and wet conditions (Laacherhof Experimental Station, 1973 and 1976)

Application	Date	Rainfall amount in April	Percent control of Stellaria media
ppi	1.4.1976	10,1 mm	63
ppi	7.4.1973	93,9 mm	96
pre	2.4.1976	10,1 mm	15
pre	9.4.1973	93,9 mm	100

For optimum effectiveness against grass weeds, e.g. Alopecurus myosuroides, and especially if Avena fatua is present, metamitron should be applied ppi. (Eue, 1976)

Tank mixes There are various herbicides which may be considered for use in tank mixes with metamitron, their choice depending upon the composition of the weed flora requiring control. Tables 2 and 3 present the results obtained with several different tank mixes containing metamitron.

The applications were made either ppi, pre emergence or post emergence. The listed tank mixes are still variable with regard to both combination and doses. They represent only a selection of the most useful mixes.

For ppi application, di-allate and cycloate proved to be very suitable components for combination with metamitron for the control of Alopecurus myosuroides, whereas inclusion of tri-allate gave very good control of Avena fatua and combination of metamitron with CGA 24705 produced very good results against Echinochloa crus-galli. With the exception of Galium aparine and Polygonum convolvulus, all other broad-leaved weeds were very well controlled with the tank mixes.

Table 2

PPI-applications of different herbicide tankmixes with metamitron for weed control in sugar beets

(rates in kg/ha a.i.)

	Metamitron 3.5 + diallate 0.8		Metamitron 3.5 + cycloate 1.44		Metamitron 3.5 + triallate 1.2		Metamitron 3.5 +CGA 24705 1.44	
Phytotox. %	(3)*	0	(3)	0	(5)	0	(4)	0
Thinning %	(3)	0	(3)	0	(5)	2	(4)	5
Alopecurus myosuroides	(3)	●	(3)	●	(1)	✸		
Avena fatua					(5)	●		
Echinochloa crus-galli							(4)	✸
Amaranthus retroflexus							(2)	●
Chenopodium album	(3)	●	(3)	●	(4)	●	(4)	✸
Chenopodium polyspermum	(1)	●	(1)	●	(1)	●	(2)	✸
Galium aparine	(1)	⊜	(1)	⊜	(4)	◒	(2)	◒
Lamium purpureum	(2)	✸	(2)	✸			(1)	✸
Polygonum aviculare	(1)	●	(1)	●				
Polygonum convolvulus	(2)	⊜	(2)	⊜	(5)	⊜	(1)	○
Polygonum persicaria							(1)	✸
Stellaria media	(2)	✸	(2)	✸	(1)	✸	(3)	✸
Thlaspi arvense	(2)	✸	(2)	✸	(1)	✸		

–	○	⊜	◒	●	✸	
<35	36-59	60-74	75-89	90-97	98-100	% weed control

( )* number of trials

Table 3

Pre and post emergence applications of different herbicide tankmixes with metamitron for weed control in sugar beets

(rates in kg/ha a.i.)

Treatment No. 1: Metamitron 3.5 + CGA 24705 1.44 pre emergence.
Treatment No. 2: Metamitron 3.5 + CGA 24705 1.8 pre emergence.
Treatment No. 3: Metamitron 3.5 + phenmedipham 0.5 post emergence.
Treatment No. 4: Metamitron 3.5 + HOE 23408 1.08 + Sunoil E11 3.0 l/ha* post emergence.
Treatment No. 5: Metamitron 3.5 + Sunoil E11 5.0 l/ha* post emergence.

	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
Phytotox. %	(3)** 0.5	(5) 3	(12) 3	(14) 5	(10) 0
Thinning %	(3) 0	(5) 0	(12) 0	(14) 0	(10) 0
Echinochloa crus-galli	(3) ✹	(5) ✹	(2) ○	(4) ●	(2) –
Amaranthus lividus		(1) ✹	(7) ✹	(1) ✹	(2) ✹
Amaranthus retroflexus	(2) ✹	(3) ✹	(7) ✹	(9) ✹	(7) ✹
Anagallis arvensis			(3) ✹	(3) ✹	(3) ✹
Chenopodium album	(3) ●	(5) ✹	(10) ✹	(13) ✹	(10) ✹
Galium aparine			(6) ◒	(3) ◒	(6) ◒
Lamium purpureum	(1) ✹	(2) ✹	(5) ✹	(7) ✹	(6) ✹
Matricaria chamomilla			(2) ✹	(2) ✹	(3) ✹
Polygonum aviculare		(1) ◒	(3) ◒	(1) ●	(2) ○
Polygonum convolvulus		(1) –	(6) ●	(9) ◒	(3) ○
Polygonum persicaria	(1) ✹	(2) ✹	(2) ●	(3) ●	(2) ✹
Solanum nigrum			(1) ✹	(2) ✹	(1) ✹
Stellaria media	(2) ✹	(3) ✹	(7) ✹	(11) ✹	(8) ●
Viola tricolor			(2) ✹	(1) ✹	(2) ✹

– <35 ○ 36-59 ⊜ 60-74 ◒ 75-89 ● 90-97 ✹ 98-100 % weed control

*) application rate of product
( )** number of trials

For pre emergence application, tank mixes with CGA 24705 are very interesting because this compound, like metamitron, need not necessarily be incorporated and it has a very good action against Echinochloa crus-galli. Only Galium aparine, Polygonum aviculare and, in particular, Polygonum convolvulus were not fully controlled with the listed doses. However, Galium aparine and Polygonum aviculare can be controlled by raising the metamitron dose.

In Post emergence applications, good control of Echinochloa crus-galli, among the grass weeds, was obtained by tank-mixing HOE 23408 with metamitron. However, kill was in the range between 90 and 97 % because Echinochloa which emerged after the application were not controlled. For the control of most of the broad-leaved weeds, very suitable components for combination with metamitron proved to be phenmedipham and Sun Oil 11E. Surfactants have also been found to enhance activity considerably, especially in the control of larger plants; results obtained with these will be reported elsewhere.

Phenmedipham is preferable to Sun Oil 11E for tank-mixing with metamitron in all instances in which Galium aparine, Polygonum convolvulus, Polygonum aviculare or Stellaria media is the dominant weed. To obtain 100 % control of these weeds, the doses of both compounds should be raised above the level given as an example (Table 3). Use of HOE 23408 in combination with metamitron resulted in improved activity against broad-leaved weeds only when Sun Oil 11E was included in the tank mix.

The tested tank mixes were not seen to cause any phytotoxicity or thinning, as demonstrated by the data presented in Tables 2 and 3. Only the tank mix in which HOE 23408 was combined with metamitron caused slight leaf symptoms at first, but these grew out later. Some surfactants also caused transient damage to the sugar beet plants.

Sequential applications Table 4 lists some sequential applications with metamitron. These are just a few of a very large number of tested sequential applications which, at not unduly high doses, gave reliable control of the major grass and broad-leaved weeds.

When Avena fatua is present, 0,8 kg/ha a.i. di-allate should be substituted by 1,2 kg/ha a.i. tri-allate in Treatment No. 1 for ppi application.

In Treatment No. 2, metamitron can be incorporated for example when conditions in spring are dry, thus giving good results at the first application.

The listed sequential applications guarantee very good effectiveness also against problem grass and broad-leaved weeds like Avena fatua, Echinochloa crus-galli, Gallium aparine, Polygonum aviculare and Polygonum convolvulus.

The sequential applications were not seen to cause any phytotoxicity or thinning.

Table 4

Weed control systems with metamitron for weed control in sugar beets

(rates in kg/ha a.i.)

Treatment No. 1: Metamitron 3.5 + diallate 0.8 ppi followed by metamitron 2.1 + phenmedipham 0.5 post emergence.
Treatment No. 2: Metamitron 3.5 pre, followed by metamitron 3.5 + Sun-Oil E11 5 l/ha* post emergence.
Treatment No. 3: Metamitron 3.5 pre, followed by metamitron 2.1 + phenmedipham 0.5 post emergence.
Treatment No. 4: CGA 24705 1.44 pre, followed by metamitron 3.5 + phenmedipham 0.5 post emergence.

	Treatment 1		Treatment 2		Treatment 3		Treatment 4	
Phytotox. %	(2)**	1	(7)	0	(6)	1	(3)	2
Thinning %	(2)	0	(7)	0	(6)	0	(3)	0
Alopecurus myosuroides	(2)	✹	(2)	✹	(1)	✹		
Avena fatua			(1)	●				
Echinochloa crus-galli					(2)	-	(2)	✹
Chenopodium album	(2)	✹	(7)	●	(6)	✹	(3)	✹
Galium aparine	(1)	✹	(4)	●	(4)	✹	(2)	✹
Lamium purpureum	(1)	✹	(3)	✹	(3)	✹	(2)	✹
Matricaria chamomilla	(1)	✹	(1)	✹	(1)	✹	(1)	✹
Polygonum aviculare	(1)	✹	(2)	✹	(2)	●	(1)	✹
Polygonum convolvulus	(1)	✹	(3)	◓	(3)	●	(2)	●
Raphanus raphanistrum	(1)	✹	(2)	✹	(1)	✹	(1)	✹
Stellaria media	(2)	✹	(3)	✹	(2)	✹	(2)	✹
Thlaspi arvense	(2)	✹	(4)	✹	(3)	✹	(2)	✹
Viola tricolor	(1)	✹	(1)	✹	(1)	✹	(1)	✹

-	○	⊜	◓	●	✹	
<35	36-59	60-74	75-89	90-97	98-100	% weed control

*) application rate of product

( )** number of trials

DISCUSSION

The results obtained with metamitron used both in tank mixes as well as in sequential applications with other herbicides show that the composition of the first herbicidal treatment is determined primarily by the grass weeds. Their occurrence can be predicted with considerable certainty. According to the sugar beet growing region, the following groups of grass weed species may be formed:

a) Alopecurus myosuroides, Apera spica-venti and Poa annua
b) Avena fatua, Avena ludoviciana
c) Echinochloa crus-galli, Digitaria sp. and Setaria sp.

It is only in a few cases that species of two different groups occur at the same location.

The expected composition of the weed flora cannot be predicted so clearly for broad-leaved weeds. However, this does not constitute any problems because metamitron has such a broad spectrum of activity against dicotyledons (Hack, 1975; Rieben, 1976) that there is less need for it to be mixed with other herbicides to obtain broad-leaved weed control.

In considering systems of sequential applications the first treatment should be so devised that, given favourable moisture conditions and non-occurrence of problem weeds, it will alone produce such a good level of herbicidal effectiveness that a follow-up treatment will not be necessary every year. This can reduce the costs for weed control on average over the years.

As it is not possible to foresee what pattern the weather will take during the first 4 to 6 weeks after sowing, which after all is an important phase for weed control, a programme of sequential applications must be so flexible that the scheduled follow-up treatments can still be changed at any time during the application period. In fact, this is very essential because it is only when a system of sequential applications is closely adapted to the conditions that it will give the best results at reasonable cost. It particularly depends upon the moisture status of the soil how much must be spent on herbicides and their application.

The results presented in this report show that metamitron, by virtue of its versatility of use and its extremely good crop tolerance, is especially suitable for chemical weed control in sugar beet both in tank mixes with other herbicides as well as in sequential applications.

Acknowledgements

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CONTROL OF WEED BEET IN CEREALS

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Summary Weed beet is an increasing problem in the intensive sugar beet areas of many countries and some land can no longer be used for beet cultivation. Only when the weed beet 'bolts' and flowers can it be distinguished from the cultivated crop and removed, but by this stage a dense population will have significantly reduced crop yield. A possible solution to the problem is to control the weed in other crops in the rotation, which are usually cereals. Preliminary glasshouse and field work with a number of herbicides indicated that good control of weed beet in cereals is possible. In thin or weedy cereal crops a herbicide mixture may be essential for effective control. Results so far indicate that farmers should be able to obtain good control of weed beet in cereals by use of appropriate herbicides, particularly the widely used broad leaved weed killers.

Résumé La betterave sauvage est un problème croissant dans les régions betteraves intensives dans beaucoup de pays, et dans quelques régions on ne peut même pas cultiver la terre. Seulement quand la betterave sauvage montée à graines et fleurit que l'on peut distinguer de la culture cultivée et éloignée, mais par ce point le rendement de la culture serait réduirte par une population épaise d'une manière significative. Une solution possible au problème est de controller les mauvaises herbes des autres cultures par assolement, qui sont normalement les céréales. Le travail preliminaire dans la serre et le champ avec plusieurs désherbants ont indiqué que dans les cereals la lutte contre à la betterave sauvage est faisable. Dans les cultures céréales qui sont maigres ou sales il se peut qu'un melange désherbant est essentiel pour controle effective. Jusqu'ici les résultats indiquent que peut-être les cultivateurs pourraient obtenir un contrôle la betterave sauvage dans les cultures céréals par l'usage des désherbants convenables en particulier ceux très utilisées contre les mauvaises herbes feuillus.

INTRODUCTION

Weed beet are annual forms of Beta vulgaris, B. maritima and B. macrocarpa and their hybrids. They have been recognised in arable crops since about 1969 and are now known to exist in many countries including Britain, Ireland, France, Belgium, Spain, Israel, U.S.A. (California), Holland, Denmark and Sweden. They have occurred because of hybridisation during seed production between the biennial cultivar and wild forms carrying the annual character as a dominant gene, and apparently by selection out of biennial cultivars because of changes in agricultural practices, including the narrowing of rotations, earlier sowing dates and reduced reliance on hand weed control. Increased mechanisation with associated reduction in hand labour in sugar beet crops has allowed early bolting beets to flower and produce seed prior to harvesting the crop. This seed will germinate readily and grow to give plants which bolt more easily than the parents. After a few generations of seed production in this way, annual types can be produced under polygenic control.

The problem appears to have increased in England since first noticed in the late 1960's and between 1973 and 1975 the proportion of sugar beet crop area infested rose from 0.17 to 1.4% (Longden 1976). Although the infestations are localised at present, the rate of spread could soon create a very serious problem, unless adequate control measures are taken. Weed beet could become as serious a problem to sugar beet growers as are wild oats for cereal farmers. Close rotations, as practised in East Anglia and North West Europe, clearly give maximum opportunity for weed beet multiplication with minimum opportunity for control.

Weed beet which appear in the sugar beet crop are difficult to recognise, particularly at early stages of growth. Being closely related to cultivated beet, they are resistant to chemicals normally used for weed control in the crop. By early July weed beet 'bolt' and the common recommendation is to remove them by hand pulling or cutting. This operation could perhaps be mechanised, but at a cost, as could the principle of applying a non-selective herbicide selectively to the taller plants (the 'bolters') (Longden 1974). July is a busy time on farms and even with apparently effective control some 'bolters' may produce seed. It is therefore essential that farmers ensure that weed beet do not multiply in subsequent crops in the rotation, thereby reducing the live seed population in the soil as much as possible before growing beet again. In most arable rotations winter wheat and spring barley are the principal alternative crops to sugar beet. In the light of this we initiated a study of the efficacy of various cereal herbicides on the control of young beet plants.

The authors acknowledge that it is unusal to publish results at such an early stage of development but it is felt that the weed beet problem is sufficiently serious to warrant the publication of preliminary data. However data for phenoxy-alkanoic acids can be accepted with some confidence based on previous experience with these broad leaved weed killers.

METHOD AND MATERIALS

Glasshouse test Seed from stocks of a wild annual, a cultivated biennial and a hybrid *B. vulgaris* were sown in 9cm diameter plastic pots and allowed to germinate in a glasshouse. When germination was complete plants were thinned to leave three per pot. At the three leaf growth stage four replicates were sprayed with the appropriate herbicide at 415 l/ha at a pressure of 2.75 bar. The spray nozzles were Tee-Jets No. 8003. After spraying plants were returned to the glasshouses, where day-length was extended to 16h using Philips warm white fluorescent tubes. Herbicidal efficacy was assessed two and four weeks after spraying based on a scale 0-10 where 0 represented no effect and 10 indicated complete plant kill. The chemicals used at 1,2 and 4 kg/ha formulated were:-

Chlortoluron (Dicurane 80 WP - 800 g a.i./kg)
Dicamba/benazolin/dichlorprop (Tri-Cornox Special - 613 g a.e./l)
Ioxynil (Totril - 250 g a.i./l)
MCPA-amine (Cornox M - 320 g a.e./l)

Field trial Treatments were randomised in three blocks in a crop of barley cv. Aramir which had been sown on 13 February 1976 at Orford, Suffolk. Each plot measured 2m x 10m and was sprayed with a knapsack sprayer delivering 264 l/ha at a pressure of 0.69 bar on 18 May when most beet seedlings had two to four leaves. Assessment of the herbicides was based on counts of beet seedlings in four 0.5m^2 quadrats per plot before spraying (14 May), 19 days after spraying (7 June) and immediately prior to harvesting the barley (12 July).

The chemicals used at recommended, three quarter and half rates were:-

2,4-D-amine (Cornox D - 320 g a.e./l)
Dicamba/benazolin/dichlorprop (Tri-Cornox Special - 613 g a.e./l)
Ioxynil/mecoprop (Actril C - 300 g a.i./l)
MCPA-amine (Cornox M - 320 g a.e./l)

RESULTS

The results from the glasshouse test were similar at the two assessments and those from the four week scorings (Table 1) show that the different seed stocks responded similarly. The substituted urea chlortoluron was clearly inferior to other compounds in controlling beet seedlings. All other compounds evaluated gave good control at the higher rate, but only the herbicide 'cocktail' dicamba/benazolin/dichlorprop gave acceptable control at the lowest rate.

Table 1

Response of three stocks of Beta vulgaris to cereal herbicides applied at the three leaf stage - assessments 4 weeks after spraying

B. vulgaris	Product	Rate (kg form/ha) 4	2	1
Annual	Chlortoluron	6*	4	1
	Dicamba/benazolin/dichlorprop	9	8	5
	Ioxynil	9	6	3
	MCPA-amine	9	8	5
Biennial	Chlortoluron	6	3	3
	Dicamba/benazolin/dichlorprop	8	8	7
	Ioxynil	10	8	4
	MCPA-amine	9	9	4
Hybrid	Chlortoluron	7	1	1
	Dicamba/benazolin/dichlorprop	9	9	9
	Ioxynil	10	8	2
	MCPA-amine	9	9	6

* each score is a mean of four replicates assessed on a scale 0-10 where 0 is no effect and 10 is complete kill.

Data from the field trial (Table 2) show that all compounds gave complete control at the highest rate but a significant proportion of the beet seedlings survived the 2,4-D-amine spray at the lowest rate.

Table 2

Effect of cereal berbicides sprayed onto weed beet in barley on 18 May 1976 at Orford, Suffolk

Herbicide	Rate (1 form/ha)	Seedling number/m^2			Kill percentage
		Before spraying (14 May)	After spraying (7 June)	Before combine harvesting (12 July)	
None	-	9.7	12.7	6.7	32
2,4-D	1.4	7.0	6.0	1.7	68
" "	2.1	6.0	1.3	NIL	100
" "	2.8	3.3	4.7	NIL	100
MCPA	2.8	5.3	3.0	NIL	100
"	4.2	11.7	7.3	NIL	100
"	5.6	9.0	0.7	NIL	100
Dicamba/ benazolin/ dichlorprop	2.8	2.7	2.7	0.3	93
" "	4.2	4.0	2.7	0.1	96
" "	5.6	3.7	2.0	NIL	100
Ioxynil/ mecoprop	3.5	2.0	2.0	NIL	100
" "	5.2	1.0	3.7	NIL	100
" "	7.0	3.7	1.7	NIL	100
S.E.		2.20	1.51	0.59	7.2

DISCUSSION

The glasshouse test was conducted to identify compounds which justified field evaluation. Chlortoluron was less effective than the others and a farmer using this for blackgrass (Alopecurus myosuroides) control could not expect complete removal of weed beet. As expected the phenoxy alkanoic acid and benzonitrile based herbicides gave good control at the two higher rates. However at the lowest rate acceptable control was given only by the "cocktail", (dicamba/benazolin/dichlorprop). This suggests that when the crop conditions favoured weed growth (e.g. thin crop, abundance of weeds) then only a more sophisticated herbicide treatment will give acceptable control.

This is supported by the field data. The reduction in weeds in the unsprayed plots shows that the crop itself competes with the weeds and even the poor crop used in this trial afforded some weed control. It must be emphasised that 1976 had a very dry growing season, both crop and weed were severely stressed, and it is possible that under more normal conditions some other compounds might have been more effective at the lower rate. The authors realise, however, that these data are the result of only one field trial using a limited range of herbicides and further work is planned. Nevertheless, the results may indicate a typical response by weed beet to these chemicals.

These data indicate differences in weed beet response to post-emergence application of cereal herbicides. This suggests that farmers with weed beet problems should use the more effective treatments available. Our experiments so far have indicated that the widely used post-emergence broad leaved herbicides should be effective at recommended rates in a healthy crop. If however the crop is weak or the weed abundant it is likely that effective control will be achieved only with a herbicide "cocktail" such as dicamba/benazolin/dichlorprop.

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INVESTIGATIONS INTO METHODS OF IMPROVING THE PERFORMANCE OF METOXURON AGAINST VOLUNTEER POTATOES

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Summary Control of volunteer potatoes in carrots with metoxuron is unreliable. Four experiments have been carried out to investigate methods of improving its efficacy. Comparisons between the flowable and wettable powder formulations produced similar results. Despite field reports to the contrary, the addition of linuron failed to improve the overall performance of metoxuron. Similarly the addition of ammonium sulphate, surfactant and self-emulsifying adjuvant oil all caused no enhancement.

Résumé Dans la lutte contre les pommes de terre adventices en cultures de carottes le métoxuron ne donne pas de résultats sûrs. Quatre expériences ont été installées pour étudier des moyens de rehausser l'efficacité de ce traitement. Des comparaisons entre les formulations "flowable" et poudre mouillable ont donné des résultats pareils. Malgré des indications du contraire en plein champ, l'adjonction du linuron n' a pas amelioré le comportement général du métoxuron. L'adjonction de sulphate d'ammonium, d'un mouillant ou d'une huile adjuvente n' a pas réussi non plus à l'améliorer.

INTRODUCTION

Metoxuron, a urea herbicide widely used in carrot crops, can show good activity against volunteer potatoes but the level of control is variable. Most of the earlier experiments with this herbicide at the Weed Research Organization resulted in poor control of potatoes (Lutman, 1976; Lutman & Davies, 1976).

The enhancement of herbicide activity with chemical additives such as ammonium salts, phosphates, surfactants and oil adjuvants has been attempted with varying degrees of success in recent years (Turner, 1976). As well as the addition of non-herbicidal materials, the mixing of certain herbicides can result in synergistic effects. For example, Griffiths and Lake (1974) have suggested that the mixing of linuron with metoxuron enhances the latter's performance against potatoes. The nature of the formulation of the herbicide can also affect its efficacy. Holmes (1972) found an increase in the reliability of wild oat control with barban when the formulation was changed from a 12% to a 25% emulsifiable concentrate.

The experiments described in this paper investigated a number of possible ways of improving metoxuron's performance against potatoes. These have included a comparison of two formulations; the addition of ammonium sulphate, surfactant or oil to the spray solutions; and the mixing of metoxuron with linuron.

METHOD AND MATERIALS

Field Experiments

General. All these experiments were planted with Scottish seed potatoes (4-6 cm in diameter) using a Packman 2 row potato planter. Each plot consisted of 2 rows 75 cm apart and 5 m long with the tubers 38-45 cm apart within rows. The herbicide treatments were all applied at a volume rate of 225 l/ha and a pressure of 2.1 bars, with a propane pressurised knapsack sprayer and 3 m boom fitted with 6 Teejet nozzles (No. 6502) held by two operators. The subsequent herbicide damage was recorded visually using a 1-7 scale (1 = dead; 7 = healthy), details of which have been given in a previous paper (Lutman & Davies, 1976). On some occasions the damage to the plants seemed to fall between two classes and these were scored as halves (eg. 3.5, 5.5). All the experiments were laid out in randomised blocks with 3 replicates except Experiment 1 which had only two.

Experiment 1. This experiment compared the activity of metoxuron (w.p.) at 3 and 5 kg/ha a.i. with that of a new fluid, water dispersable formulation (metoxuron flowable) at 2, 4 and 6 kg/ha a.i. Pentland Crown seed tubers were planted at the end of April 1975. On 17 June, when the plants were about 18-25 cm high, the metoxuron treatments were applied. Herbicide damage was assessed 10, 17, 28 and 38 days after application. At the end of September the central 2 m of the 2 rows of each plot was harvested and the number and fresh weight of tubers/m of row were determined (Table 1).

Experiment 2. In this experiment mixtures of metoxuron (flowable) with linuron (e.c.) at 3 + 0.5, 3 + 1 and 5 + 1 kg/ha a.i. respectively were compared. In addition metoxuron (flowable) was applied as a split application of 3 + 3 and 5 + 5 kg/ha a.i. The mixtures and the first of the split applications were applied on 17 June and the second of the split applications 14 days later. Damage was assessed 10, 17, 28, 38 and 49 days after the first application, and during September 2 x 2 m samples were dug from each plot to determine tuber numbers and fresh weight (Table 2).

Experiment 3. The activity of metoxuron (w.p.) alone at 2, 4 and 6 kg/ha a.i. was compared with mixtures of metoxuron (w.p.) and linuron (e.c.) at 3 + 0.5 and 5 + 0.5 kg/ha a.i. respectively. King Edward seed tubers were planted at the end of March 1976. The metoxuron treatments were applied on 27 May, when the plants were 18-25 cm high and on 4 June when they were somewhat larger. The damage caused was assessed 12 and 20 days after spraying, and on 19 July the haulm present in the central 2 m of the 2 rows of each plot was harvested and the fresh weight in 4 m of row recorded (Table 3).

Pot Experiment

Experiment 4. Metoxuron (w.p.) at 4 kg/ha a.i. was compared with a similar dose of the flowable formulation, and with a mixture of metoxuron (flowable) and linuron (e.c.) at 4 + 1 kg/ha a.i. respectively. The effect of three additives; 1% surfactant (Agral 90*), 5% self-emulsifying adjuvant oil (Actipron†) and ammonium sulphate (16 kg/ha) on the performance of metoxuron, again at 4 kg/ha a.i. was also studied. Potato tubers of 9 varieties were planted (4/pot) during April 1975. Details of the growing conditions and treatment methods employed have been described elsewhere (Lutman & Davies, 1976). All the plants were sprayed with the WRO laboratory pot sprayer, at a volume rate of 197 l/ha and at a pressure of 2.1 bars, when they were approximately 25 cm high. Varieties Arran Pilot, Maris Peer, Majestic, Pentland Dell and Red Craigs Royal were treated 28 days after planting and the slower growing varieties (King Edward, Maris Piper, Pentland Crown and Record) eight days later. The damage caused was assessed 9, 14, 21, 28 and 35 days after treatment, and the dry weight of haulm from each pot was recorded at harvest, 68 days after planting (Table 4).

*Manufactured by Plant Protection Division, Imperial Chemical Industries.
†Manufactured by B.P. Trading Ltd.

RESULTS

xperiment 1. All the metoxuron treatments caused some damage to the otato plants which was reflected by a significant decrease in the weight of tubers/m resent at harvest (Table 1). There was, however, no marked decrease in the number f tubers. The two formulations achieved similar levels of control, but the overall erformance of the metoxuron treatments was poor.

Table 1

The damage caused to potato plants by several doses of two formulations of metoxuron and their effects on tuber production

Formulation	Dose kg/ha a.i.	Damage scores* (Days after treatment) 10	17	28	38	No. of tubers /m	Wt. (kg) tubers /m
Flowable	2	5.0	5.0	6.2	6.5	21.3	1.28
	4	5.0	5.0	5.8	6.0	24.6	1.16
	6	5.0	5.0	6.0	6.0	26.2	1.29
Wettable powder	3	5.0	5.0	6.0	6.2	28.5	1.29
	5	5.0	5.0	5.8	4.5	29.9	0.85
Control		7.0	7.0	7.0	7.0	31.9	2.06
Standard error						2.7	0.15

* 1-7 scale 1 = dead : 7 = healthy

Table 2

The damage caused to potato plants by mixtures of metoxuron with linuron and split applications of metoxuron, and their effects on tuber production

Herbicide	(kg/ha a.i.)	Damage scores Days after 1st application 10	17	28	38	49	No. of tubers /m	Wt. (kg) of tubers /m
Mixtures								
Metoxuron (flowable) + linuron (e.c.)	3 + 0.5	4.7	5.0	6.0	6.5	5.8	20.2	1.21
	3 + 1	4.7	5.0	5.7	6.3	5.7	26.2	1.14
	5 + 1	4.5	4.7	5.2	4.2	4.5	18.3	0.71
Split applications								
Metoxuron (flowable)	3 + 3	5.5	5.0	4.0	4.2	5.0	27.6	0.74
	5 + 5	5.5	5.0	3.2	2.0	1.5	10.5	0.18
Control		7.0	7.0	7.0	7.0	7.0	27.6	1.76
Standard error							2.44	0.16

Experiment 2. The mixture of metoxuron (5 kg/ha) + linuron (1 kg/ha) severely damaged the potatoes, reducing the weight of tubers by 60% (Table 2). The remaining two mixtures caused only slight injury but still reduced the weight of tubers. The split application of 5 + 5 kg/ha metoxuron was the most effective treatment, almost killing the plants and reducing the final number of tubers by 60% and their weight by 90%. The other split application (3 + 3 kg/ha) was much less effective.

Experiment 3. The results showed that the second application was more effective than the first (Table 3). For example, the 6 kg/ha dose applied on the 27 July achieved a similar level of control to that of the 4 kg/ha dose applied on 4 June. Comparisons between the metoxuron and linuron mixtures and metoxuron alone indicate that the linuron failed to improve metoxuron's performance. Best results were obtained from the 6 kg/ha dose sprayed on 4 June, which reduced haulm fresh weight by 85%. The other treatments were much less effective although all reduced the weight of haulm compared to that of the untreated controls.

Table 3

The damage caused to potato plants by metoxuron alone and mixtures with linuron, all applied at 2 dates, and their effects on tuber production

Herbicide	Dose kg/ha a.i.	Application 27 May: Damage scores (Days after treatment) 12	Application 27 May: Damage scores (Days after treatment) 20	Application 27 May: Fresh wt. haulm (kg) /4m of row	Application 4 June: Damage scores 12 days after treatment	Application 4 June: Fresh wt. haulm (kg) /4m of row
Metoxuron (wettable powder)	2	5.2	6.3	5.39	4.9	4.06
	4	4.8	5.7	3.82	3.7	2.59
	6	4.5	5.1	2.83	2.8	1.11
Metoxuron (w.p.) + linuron (e.c.)	3 + 0.5	5.0	5.9	4.94	4.4	3.77
	5 + 0.5	4.5	5.3	3.73	3.2	1.76
Control		7.0	7.0	8.00	7.0	7.52
Standard error				0.52		0.52

Experiment 4. As there were no interactions between the 6 treatments and the varieties, the data presented are the averages of the results obtained for the 9 varieties. The overall level of control was poor, none of the treatments resulting in damage scores lower than 3.7 (Table 4). The addition of ammonium sulphate, surfactant and emulsifiable oil did not significantly improve the degree of control attained by metoxuron (w.p.) alone. Similarly the addition of linuron had little effect. However, the flowable formulation was somewhat better than the wettable powder.

DISCUSSION

The overall level of control in the 4 experiments was rather poor and failed to approach the levels that have been achieved in practice. It is difficult to explain this, but it may be related to the vigour of the potato plants used in these experiments. The tubers used were all between 4 and 6 cm in diameter, whereas most volunteer potato tubers are between 1 and 4 cm (Lutman, 1977). The plants from the seed tubers would therefore be much more vigorous than those from groundkeeper tubers

Table 4

The damage caused to potato plants by the 6 metoxuron treatments and their effects on the dry weight of haulm (mean of 9 varieties)

Formulation	Dose (kg/ha a.i.)	Additives Type	Additives Rate	Damage scores (Days after treatment) 9	14	21	28	35	Dry wt. (g) haulm /pot
Wettable powder	4	None		5.8	5.4	4.9	4.2	4.6	18.9
Flowable	"	None		5.8	5.4	4.7	3.7	4.0	14.4
Wettable powder	"	$(NH_4)_2SO_4$	16 kg/ha	5.8	5.4	5.1	4.2	4.8	17.0
" "	"	Agral 90 (surfactant)	1%	5.4	5.3	5.2	4.3	4.4	15.5
" "	"	Actipron (emulsifiable oil)	5%	5.1	5.2	5.2	4.7	5.3	19.3
Flowable	"	Linuron (e.c.)	1 kg/ha	5.7	5.1	4.8	4.2	4.4	17.3
Standard error									1.20

and thus provided a more rigorous test of metoxuron's performance than would probably occur in practice. However it seems unlikely that the influence of the formulations and additives on metoxuron's performance would be substantially different under field conditions. If anything it could be argued that this relatively poor performance of metoxuron provided a better background for such examinations.

The comparisons between the flowable formulation and the wettable powder indicated that there were no important differences between them, although in the pot experiment the flowable formulation was marginally more active than the wettable powder. The improvement in metoxuron's performance attained by the addition of linuron reported by Griffiths and Lake (1974) and Farm Protection (1976) was not demonstrated in these experiments, even though the doses used were comparable. A number of studies have shown that the addition of ammonium sulphate improves the activity of foliar applied herbicides (Turner & Loader, 1975; Blair, 1975). Similarly the addition of surfactants and adjuvant oils can also increase herbicide activity (Turner, 1976). However, in the pot experiment the level of control achieved by metoxuron (w.p.) was not improved by the addition of ammonium sulphate, surfactant or self-emulsifying adjuvant oil.

Considering the four experiments together, the best control was achieved by the split application of 5 + 5 kg/ha of metoxuron in Experiment 2. The success of this treatment was mainly due to the effects of the second application on the regrowth resulting from the first, partially successful one. Regrowth of the apex and the axillary buds of the lower leaves and of the nodes below the soil surface is typical of the sub-lethal doses of metoxuron.

Hence the main conclusion from these experiments is that there is little reason to change the nature of the metoxuron treatments already in common agricultural use, except perhaps consideration of the use of split applications.

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HERBICIDE USAGE ON MAINCROP POTATOES IN GREAT BRITAIN

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Summary The annual survey of maincrop potato production techniques carried out by the Potato Marketing Board provides much information on technical aspects of potato production including weed control.

In 1963 control of weeds in potatoes was still effected almost entirely by ploughing and, after planting, by mechanical cultivations. By 1975 68% of maincrop potato acreage in Great Britain was treated with chemicals. Herbicides are now the accepted standard control for weeds. Regional differences reflect different climatic conditions with the wetter west using most. If growers are grouped according to size of potato holding the proportion using herbicides increases noticeably from the small growers to the largest.

The commercial development of effective post-emergence sprays is likely to further increase the overall use of herbicides to some extent, but the area of potatoes in Great Britain which can be sprayed with herbicides is approaching its maximum.

Resumé Le rapport annuel de la comission d'étude des marchés de la pomme de terre, au sujet des techniques de production de la récolte principe de celle-ci, fournit beaucoup d'informations sur les orientations techniques de sa culture, y compris le désherbage.

En 1963, le désherbage des pommes de terres etait toujours presque entièrement fait par le charrue, puis une fois la plantation effectuée mécaniquement. Au cours de l'année 1975, 68% de la superficie cultivée en pommes de terre étaient traités par herbicides chimiques. Les herbicides sont actuellement le moyen généralment reconnu contre les mauvaises herbes. Des particularités regionales montrent différentes conditions climatiques tellesque l'Ouest, plus humide ayant des besoins plus grands. Si les cultivateurs étaient groupés selon la taille des exploitations de pommes de terre, la proportion de ceux qui utilisent les herbicides augmenterait sensiblement des petits aux plus grands exploitants.

Le développement commercial des pulvérisations, après la levée effective des pousses, est souhaitable, pour développer plus tard l'utilisation totale des herbicides a une plus grande étendue, mais la superficie de pommes de terre cultivée qui peut être pulverisée avec des herbicides est entrain d'atteindre son maximum.

INTRODUCTION

The Potato Marketing Board (PMB) has published four reports on Maincrop Potato Production in 1958, 1963, 1968 and 1973. A report is to appear on the 1975 crop based on the PMB crop production survey which has been run annually since 1970. The material in this paper is largely based on this survey supplemented by data from Crop Check Weighing Reports from earlier years.

The frame from which the 1975 survey sample was drawn consisted of the planting returns of all maincrop potatoes made by registered producers in Great Britain who grew more than three acres of any maincrop variety. The eligible records were then sorted by administrative area and variety and within these groupings by the total potato area on the whole farm. From these sorted lists, farms to be included in the survey were selected to give a representative sample covering all potato varieties and sizes of potato enterprises within each PMB administrative area.

In all cases, the producers included in the survey were visited by PMB field officers to obtain information on the herbicides that were used on the selected crops, along with all other production input data.

The number of farms surveyed in relation to the number of registered producers and the total area of maincrop potatoes in each PMB division are shown in the following table.

Table 1

PMB Administrative division	Total number of registered producers in 1975	Total area of maincrop potatoes in hectares	Number of farms surveyed
South West	3470	6806	87
South East	3193	4542	108
West Midland	5343	16076	101
East Midland	6094	29680	192
East Anglia	6019	29017	207
Northern	5930	24438	158
Scottish	5429	25019	150
Total	35478	145578	1003

RESULTS

The expansion of herbicide usage The increasing proportion of acreage covered by herbicides must be seen against the declining area under maincrop potatoes. Indeed, Scotland which shows the largest proportional increase in herbicide usage has suffered a greater proportional decline in total maincrop potato plantings than England and Wales.

Figure 1

Regional pattern of herbicide usage 1975

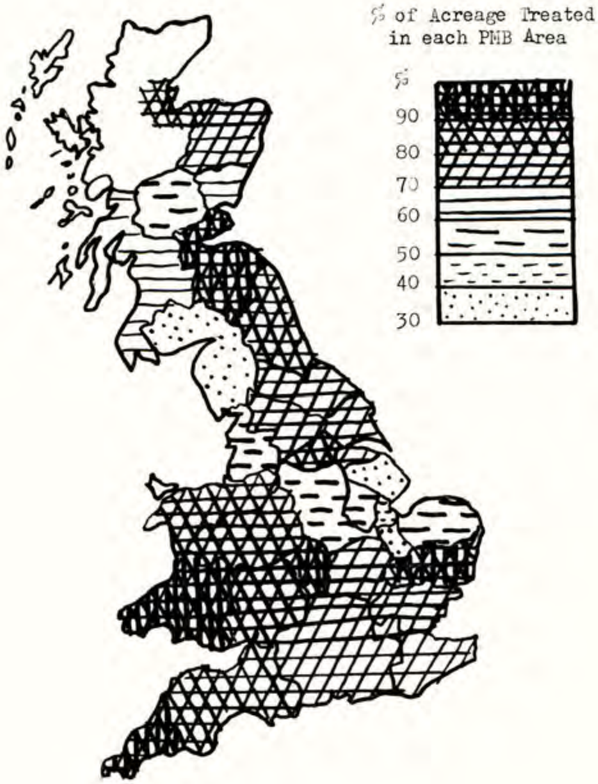

Table 2

Herbicide usage at two year intervals since 1965

	England & Wales			Scotland		
Crop Year	Total maincrop area in hectares	Area treated in hectares	% of crop treated	Total area in hectares	Area treated in hectares	% of crop treated
1965	164634	26341	16	44213	3095	7
1967	164800	54384	33	40697	15058	37
1969	139790	64303	46	31298	14397	46
1971	147901	81346	55	30805	17251	56
1973	133793	89641	67	25967	18177	70
1975	120272	79380	66	22791	16637	73

The apparent levelling off in total usage in England and Wales in 1975 is undoubtedly related to the very late planting season and subsequent dry conditions, both of which tended to restrict weed growth. But the time must soon come when all those who can readily be persuaded will be using herbicides. Manufacturers will then have to concentrate more on selling the special qualities of their products rather than maximising volume in an expanding total market.

Regional variations in herbicides usage As in earlier years a greater proportion of potato area was treated in the West than elsewhere with the smallest proportion covered in the intensive potato areas of the East. An interesting exception is the PMB administrative area of Suffolk and Cambridge which also has a much larger proportion of irrigated crops than elsewhere (Figure 1).

Intensity of usage is more or less the reverse of the order of importance as maincrop production areas. This may be because weed levels are low in the intensive arable areas of the East. On the other hand weed growth is perhaps more certain in the wetter West.

Variations in usage on different holding sizes There is clear evidence that small acreage growers use less herbicides.

Table 3

Herbicide usage by holding size-group in Great Britain

Size of holding in hectares	% of crop grown by this group that is treated with herbicide
0 - 2.0	44
2.1 - 4.0	52
4.1 - 8.0	65
8.1 -14.0	68
14.1 -30.0	76
over 30	72

Herbicide usage on different potato varieties Varietal differences in usage are to be expected depending upon such factors as differences in habit, growth rate, maturity date and, of course, geographical distribution. All of these have a bearing on the comparative competitiveness of different varieties against weeds. In addition there is the socio-economic factor of new varieties being taken up more rapidly by the more technologically appreciative growers. Whatever the pattern of associations the pattern of usage distribution by variety remained the same in 1975 as in other years.

Table 4

Herbicide usage by variety in Great Britain 1975

Variety	Total plantings in hectares	Herbicide treated in hectares	% treated
Desiree	13547	9346	69
King Edward	25177	16035	58
Majestic	4939	2568	52
Maris Piper	21327	12156	57
Pentland Crown	30443	21615	71
Pentland Dell	14150	10613	75
Pentland Ivory	7321	4686	64
Record	14475	12448	86
Others	11685	8833	69
All maincrops	143064	98300	67

Types of herbicides used on maincrop potatoes in 1975 When herbicides were classified by their mode of action the following usage pattern occurred with different type preferences showing between England & Wales on the one hand and Scotland on the other.

Table 5

Usage of different herbicide types

	England & Wales		Scotland	
Action type	Treated area as % of crop	Estimated hectares	Treated area as % of crop	Hectares
Contact	25	29492	43	10659
Translocated	1	1591	0	0
Soil acting	8	9517	2	474
Mixed action				
Trans + Soil	19	23249	8	2004
Contact + Soil	1	1454	0	0
Trans + Soil + Contact	17	20554	22	5386

Use of particular chemical types Notable features were the continued pre-eminence of paraquat followed by paraquat/urea mixtures, and the rise in popularity of metribuzin. In 1975 this accounted for 10% of sprayed area in England and Wales (in 1973 it was 3%) and 6% in Scotland (in 1973 it was 4%).

Table 6

Chemical type usage expressed as sprayed area

Chemical types (ranked by usage)	England and Wales: Sprayed hectares	England and Wales: % of total sprayed area	Scotland: Sprayed hectares	Scotland: % of total sprayed area
All chemicals	87340	100	18524	100
Paraquat alone	29548	34	10659	58
Paraquat with monolinuron	12976	15	335	2
Paraquat with linuron	5963	7	5052	27
Metribuzin	9098	10	1194	6
EPTC	4834	6	474	3
Linuron	4672	5	471	3
Monolinuron	4209	5	-	-
Linuron + trietazine	2804	3	841	2
Terbutryne + terbuthylazine	2683	3	-	-
Others	10569	12	-	-

DISCUSSION

Two dry seasons 1975 and 1976 inimical to weed growth have halted the expansion of total overall herbicide usage on maincrop potatoes in Great Britain. However, it seems likely that it was reaching a peak anyway as the number of growers still unconvinced has declined to the hard core of resisters.

Future developments in herbicide use on potatoes will now probably take the form of refinements in management of applications and more specific use of particular chemicals to suit particular varieties or conditions. Competition between manufacturers in a more restricted market may be expected to cut out all but a few specialist products and companies. It might be expected that this will act as a spur to competitive development of new products and methods of control. Against this must be held the soaring cost of research and development and especially of increasingly strict product approval trials. These considerations may well restrict new developments for a crop that still represents only a very small part of agricultural production both in Britain and world wide.

Acknowledgements

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