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SUGAR BEET WEED CONTROL PROGRAMMES BASED UPON METAMITRON

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Summary Trials on mineral soils in 1977 confirmed the effectiveness of metamitron particularly when used as a two spray programme. No real advantage was found in using metamitron sequentially with other herbicides. Contact activity was enhanced by the addition of an adjuvant oil which resulted in improved control of older and less susceptible weed seedlings, such as *Polygonum convolvulus*. Metamitron was found to be the safest sugar beet herbicide even when tested under extreme conditions in an experiment in 1978. Selectivity, however, was found to be jeopardised when metamitron was used sequentially with other herbicides, in particular lenacil, and when applied mixed with oil especially at crop cotyledon stage. In preliminary studies metamitron had no adverse effect on crop growth and development.

Résumé Les épreuves sur les sols minérals en 1977 ont confirmé l'efficacité de metamitron, particulièrement quand on l'emploie comme une programme de deux pulvérisations. On n'a trouvé aucun avantage important en employant metamitron en séquence avec des autres herbicides. L'activité de contact était ameliorée par l'addition d'une huile adjuvante donnant de la lutte meilleure contre les mauvaises herbes de semis à une étage plus développée et moins prédisposées, par exemple *Polygonum convolvulus*. On a trouvé que metamitron, une herbicide pour les betteraves à sucre, soit le plus sûr, même quand on l'a éprouvé dans les conditions exceptionnelles dans une épreuve en 1978. La sélectivité pourtant était exposée au danger quand on a utilisé metamitron en séquence avec des autres herbicides, particulièrement lenacil, et quand on l'a appliqué mélangé avec l'huile adjuvante, particulièrement à la phase cotylédonne de la récolte. Dans les épreuves préliminaires, metamitron n'a montré aucun effet nuisible sur l'accroissement et la développement de la récolte.

INTRODUCTION

The intensive use of herbicides on the sugar beet crop emphasises the importance placed on weed control both to prevent weed competition and ease harvesting, thereby preventing yield loss. The discovery of metamitron led to experiments conducted to find the best way to use this compound and exploit its increased selectivity over currently available sugar beet herbicides (Morris *et al*, 1976). This herbicide offers the grower a new, simpler and highly effective weed control system. There are, however, circumstances when weed control will fall below optimum due to factors such as soil, climatic conditions, incorrect application timings or problem weeds such as *Polygonum convolvulus*. Trials in which metamitron was tested in mixture and in sequence with other herbicides showed that improved performance could be obtained (Hack and Schmidt, 1976). Further work comparing some of these treatments under British conditions is reported.

The factors that reduce herbicide selectivity are fairly well understood but weather is probably of overriding importance and in 1977 led to around 25% of the sugar beet crop being injured to some degree (Bray, 1977). The amount of damage can be exaggerated by mixtures of active ingredients and by the sequential usage of residual and contact materials. Often the symptoms are transitory; however, the significance in terms of the final yield is of major importance. Consequently experiments to examine the safety of metamitron were conducted.

METHOD AND MATERIALS

In all the experiments herbicide treatments were applied overall to small plots by means of pressurised knapsack sprayers fitted with Teejet fan nozzles using volumes of 250-300 l/ha at pressures of 2-3 bars. The herbicide formulations used were metamitron 70% w.p., isocarbamid 65% plus lenacil 13% w.p., lenacil 80% w.p., pyrazone 80% w.p., diallate 40% e.c., cycloate 72.7% e.c. and phenmedipham 11.4% e.c. All compounds were used at recommended rates which were varied according to soil type. A self-emulsifying adjuvant oil (Actipron) at 5 l/ha was mixed with metamitron to improve the contact action.

In 1977, 20 matrix trials were laid down on commercial crops to compare pre-emergence, post-emergence and sequential treatments. The post-emergence treatments were superimposed at right angles to the pre-emergence treatments to provide all combinations; untreated strips were left on either side of the pre- and post-emergence treatments thereby providing 4 untreated corner plots to enable a reliable estimate of weed population. Individual plot size was $36m^2$. Pre-emergence treatments were applied within a few days of drilling, and post-emergence treatments were applied when the untreated weeds were in the cotyledon to 1 true leaf stage which normally coincided with the crop cotyledon stage.

In the 4 incorporation trials treatments were duplicated in plots of $60m^2$. Pre-planting treatments were applied and incorporated immediately into the top 2.5cm of soil either with a rotovator or a harrow. Pre-emergence treatments were applied soon after drilling.

Herbicidal effectiveness was measured by making weed counts in 10 quadrats of $0.1m^2$ in each plot, approximately 3 weeks after the post-emergence applications had been made. Each weed species was recorded separately and the results for the total annual weeds and individual species of $>4/m^2$ were expressed as reductions compared with the untreated control. Plant stand counts were also made in 3 by 5m lengths of row per plot. The emergence figures were expressed as a percentage relative to the untreated control (100). Crop vigour reduction observed at the end of June was recorded visually on a percentage basis, the results being expressed as a proportion of sites where reductions were greater than 10%.

The areas where the sites were located are indicated by the trial numbers as follows; A - Elm Farm Trials Station, Suffolk, E - Norfolk and Suffolk, M - Lincolnshire and Nottinghamshire, N - Yorkshire and W - Shropshire and Hereford and Worcester. Soil samples from each site were analysed for both mineral fractions and organic matter content. The following abbreviations indicate the textural classification; LCS - loamy coarse sand, LS - loamy sand, CSL - coarse sandy loam, SL - sandy loam, FSL - fine sandy loam, ZyL - silty loam, ZL - silt loam, SCL - sandy clay loam and CL - clay loam. The majority of sites had organic matter levels of between 1 and 3%.

Two crop safety experiments were conducted in 1978 at Elm Farm Trials Station on a sandy loam soil. In the first a number of pre- and post-emergence treatments were examined in a matrix design. The crop was late sown, 31 May, and treatments were applied on 2 June and 10 June when the crop was in the early cotyledon stage. Approximately 10cm of irrigation was applied between the two application timings. Treatment effect was measured by counting the total numbers of plants surviving and the numbers grouped according to the type of symptom displayed on 16 June. Seedlings classed as chlorotic included those showing a general paling, those with a blotchy yellowing, a symptom typical of phenmedipham, and those with intraveinal chlorosis, a symptom associated with lenacil. Seedlings classed as cupped had upturned cotyledons, this symptom was very mild except where metamitron was used with oil when, in addition, some cotyledons exhibited apical necrosis. The visual appearance of the plots was also graded on a percent reduction in vigour basis. A final plant stand count was carried out on 4 July.

In the other experiment treatments were applied in a randomised block layout when the crop was approaching the two true leaf stage. Prior to treatments being applied weeds were eliminated using metamitron at 3.5 kg a.i./ha pre-emergence followed by hand weeding and the beet was thinned to 20cm spacing. Each plot was divided into sub-plots, the sub-plots being lifted at intervals to provide 10 plants for various growth analysis measurements. Since all the data have not been processed only the crop fresh weight is reported.

RESULTS

Herbicidal activity Above average rainfall during the spring of 1977 was reflected in the high levels of weed control with all pre-emergence materials (Table 1). Post-emergence applications of metamitron were slightly less effective and more variable (Table 2) due in part to late timing at some sites, but the addition of an adjuvant oil overcame this timing problem and improved effectiveness against *P. convolvulus* (Table 1). The combination of pre- and post-emergence treatments gave almost complete weed control, treatments differing mainly in their effectiveness against the *Polygonum spp*. (Table 1). Soil incorporation of metamitron offered little advantage in weed control over topical use, although when incorporated mixed with diallate or cycloate, control of *Avena fatua* was obtained (Table 3).

Crop tolerance In 1977, differences in plant population were small but where isocarbamid plus lenacil was used plant numbers tended to be slightly lower (Table 1). Chlorosis and reduced vigour were common features of the phenmedipham applications, also the addition of oil to metamitron reduced vigour, particularly when used in sequence with isocarbamid plus lenacil. Some leaf sticking symptoms, usually associated with diallate and cycloate, were observed where these chemicals were used with metamitron.

In the crop safety trial crop growth was rapid, the environmental conditions exaggerating some effects of residual and contact herbicides. Of the single applications, only lenacil obviously reduced plant population (Table 4). Surviving plants showed considerable damage with lenacil, phenmedipham and metamitron plus oil, but symptoms on other single treatments were considered very minor. The interaction between pre- and post-emergence herbicides was least where metamitron had been used pre-emergence but greatest where metamitron plus oil was used in sequence with lenacil.

In the growth analysis experiment the phenmedipham treatment caused a general chlorosis within one week. No real effect of metamitron could be detected but the addition of oil resulted in some scorch of the beet. The crop damage as manifested by the symptoms was reflected in the crop fresh weight (Table 5).

Table 1

Summary of weed control and crop safety results from the matrix trials 1977

Treatments	Rate kg a.i./ha	Median percent weed control: Total annual weeds	Chenopodium album	Poa annua	Polygonum aviculare	Polygonum convolvulus	Stellaria media	Tripleurospermum maritimum ssp. inodorum	Urtica urens	Veronica persica	Viola spp.	Crop safety: Median relative stand	Percent sites with vigour >10% reduced
Pre-emergence													
metamitron	3.5	94	100	100	88	37	96	100	97	99	90	100	0
isocarbamid/lenacil	1.6-3.9	86	96	100	87	71	100	100	82	89	45	96	5
pyrazone	1.4-4.0	79	91	100	68	66	89	100	80	90	29	103	5
Post-emergence													
metamitron	3.5	86	99	99	90	38	99	99	100	98	99	103	0
metamitron & oil (5 l/ha)	3.5	96	100	100	94	76	98	97	100	100	100	99	10
phenmedipham	1.14	81	96	68	66	86	98	91	92	97	85	96	30
Pre-emergence + Post-emergence													
metamitron + metamitron	3.5 3.5	99	100	100	100	85	100	100	100	100	100	98	5
isocarbamid/lenacil + metamitron	1.6-3.9 3.5	98	100	100	100	93	100	100	100	100	100	91	10
pyrazone + metamitron	1.4-4.0 3.5	95	100	100	98	72	100	100	100	100	100	99	5
metamitron + metamitron & oil (5 l/ha)	3.5 3.5	100	100	100	100	100	100	100	100	100	100	104	15
isocarbamid/lenacil + metamitron & oil (5 l/ha)	1.6-3.9 3.5	100	100	100	100	100	100	100	100	100	100	91	40
pyrazone + metamitron & oil (5 l/ha)	1.4-4.0 3.5	99	100	100	100	95	100	100	100	100	100	95	25
metamitron + phenmedipham	3.5 1.14	100	100	100	99	88	100	100	100	100	100	98	25
isocarbamid/lenacil + phenmedipham	1.6-3.9 1.14	99	100	100	100	100	100	100	100	100	100	93	25
pyrazone + phenmedipham	1.4-4.0 1.14	98	100	100	97	89	100	100	100	100	100	95	30
Untreated control													
Number per m^2 (m row)		201	34	24	48	31	15	10	23	73	12	(4.5)	-
Number of trials		20	10	8	11	7	10	6	4	6	6	14	20

Table 2

The effect of site and soil type on weed control in the matrix trials 1977

Treatments	Rate kg a.i./ha	Percent control of all annual weeds																				
		A/1 SCL	E/1 LS	E/2 CSL	E/3 SL	E/4 CL	E/5 LS	M/1 CSL	M/2 CL	M/3 SL	M/4 ZL	N/1 LS	N/2 LCS	N/3 SL	N/4 CSL	N/5 SL	N/6 CL	W/1 CSL	W/2 ZyL	W/3 FSL	W/4 ZL	Median
Pre-emergence																						
metamitron	3.5	94	100	99	93	80	93	97	85	69	92	88	92	98	99	60	72	99	100	96	93	94
isocarbamid/lenacil	1.6-3.9	87	92	91	80	87	83	63	90	85	70	35	0	93	68	58	83	97	94	95	96	86
pyrazone	1.4-4.0	88	88	88	69	68	87	57	80	60	75	31	57	71	89	55	65	78	94	88	95	79
Post-emergence																						
metamitron	3.5	92	100	93	88	50	99	81	63	44	58	97	37	93	99	83	41	100	81	95	3	86
metamitron & oil*	3.5	93	100	96	91	77	95	95	79	72	86	98	99	97	100	99	61	100	91	96	82	96
phenmedipham	1.14	73	95	83	78	88	91	48	63	76	68	57	98	53	95	94	64	85	67	98	60	81
Pre-emergence + Post-emergence																						
metamitron + metamitron	3.5 3.5	96	100	99	99	89	100	100	95	77	99	99	43	100	100	96	74	100	100	100	92	99
isocarbamid/lenacil + metamitron	1.6-3.9 3.5	96	100	97	100	97	100	100	98	91	94	98	0	100	100	96	98	100	100	100	96	98
pyrazone + metamitron	1.4-4.0 3.5	87	100	99	99	86	100	100	94	92	91	98	41	100	100	91	79	99	94	98	84	95
metamitron + metamitron & oil*	3.5 3.5	98	100	100	100	98	100	100	100	84	100	100	100	100	100	100	92	100	100	100	100	100
isocarbamid/lenacil + metamitron & oil*	1.6-3.9 3.5	98	100	99	100	97	100	100	97	93	97	100	100	100	100	100	97	100	100	100	99	100
pyrazone + metamitron & oil*	1.4-4.0 3.5	97	100	100	99	97	100	100	96	85	99	100	98	100	100	100	98	100	97	96	99	99
metamitron + phenmedipham	3.5 1.14	98	100	100	99	92	100	100	99	95	98	100	100	99	100	100	90	100	100	100	100	100
isocarbamid/lenacil + phenmedipham	1.6-3.9 1.14	93	100	99	99	93	100	100	100	91	95	100	98	100	99	99	96	98	100	100	99	99
pyrazone + phenmedipham	1.4-4.0 1.14	92	99	99	99	93	100	100	96	86	96	72	99	99	100	98	90	97	100	96	99	98
Untreated control																						
Number per m^2		194	258	266	215	114	109	93	124	648+	850	309	223	144	207	102	237	284	34	48	184	

* At a rate of 5 l/ha of product + per 0.5m^2

Table 3

Summary of weed control and crop emergence from the incorporation trials 1977

Treatments	Rate kg a.i./ha	Percent control broadleaved weeds A/2 SCL	E/6 CSL	E/7 CSL	M/5 CSL	Median	Percent control *Avena fatua* M/5 CSL	Median relative emergence
Pre-planting incorporation								
metamitron	3.5	91	97	100	85	94	29	105
metamitron + diallate	3.5 1.7	98	98	100	93	98	100	97
metamitron + cycloate	3.5 2.0-3.6	99	96	100	82	98	98	107
pyrazone + diallate	1.76 1.2	-	85	96	56	85	100	103
Pre-emergence								
metamitron	3.5	93	95	100	72	94	32	103
pyrazone	2.2-4.0	89	88	96	51	89	56	101
Untreated control								
Number per m^2 (per m row)		85	164	68	206	-	22	(4.4)

DISCUSSION

The results confirm that the effectiveness of metamitron can be improved in the post-emergence situation by the addition of an adjuvant oil which increased contact action, enabling more advanced and less susceptible weeds to be controlled. In less favourable seasons, this improvement may be greater. In 1977, two applications of metamitron gave over 95% control at 75% of the sites; consequently adjuvants were seldom justified. However, addition of oil to the second application increased weed control at some sites so that overall this was the most effective programme. There are no clear indications that an advantage could be obtained by using alternative herbicides in sequence with metamitron.

Under conditions conducive to crop damage metamitron treatments had the least effect on the beet. When metamitron was used in sequence with other residual herbicides selectivity was found to be reduced, particularly with lenacil, possibly due to the plant's inability to cope with two different photosynthesis inhibitors. The addition of oil to metamitron reduced the safety to sugar beet seedlings which may be due to more rapid foliar penetration overloading the detoxification process. The interaction of metamitron plus oil with other residual herbicides was, as a consequence, more severe (Table 4).

The phytotoxic effects caused by various herbicides would also be expected to have an effect on crop growth and final yield, although in some previous work this was not substantiated (Scott et al, 1976). In the experiment at Elm Farm in 1978 there were some indications that the check to crop growth by phenmedipham was maintained after visual differences had disappeared (Table 5). It has been reported, however, that yields are to a large extent pre-set by the weight of the

Table 4

The effect and interaction of herbicide treatments on sugar beet seedlings in a crop safety trial

Treatments	Rate kg a.i./ha	Number of surviving plants*	16 June 1978 Percent Plants Unaffected	Chlorotic	Cupped	Percent reduction in vigour	4 July 1978 Final plant stand*	Relative stand
Pre-emergence - 2 June 1978								
metamitron	3.5	123	90.6	0.8	8.5	0	121	104.3
lenacil	2.24	79	20.4	70.7	28.0	28	57	49.1
pyrazone	4.0	109	69.3	20.6	26.1	3	115	92.2
Post-emergence - 10 June 1978								
metamitron	3.5	105	70.5	5.7	26.2	3	107	92.2
metamitron & oil (5 l/ha)	3.5	101	16.9	51.7	64.2	13	114	98.3
phenmedipham	1.14	119	26.1	73.5	6.3	9	124	106.5
Pre-emergence + Post-emergence								
metamitron + metamitron	3.5 3.5	109	78.9	5.5	17.4	3	108	93.1
lenacil + metamitron	2.24 3.5	48	14.6	64.6	41.7	25	38	32.8
pyrazone + metamitron	4.0 3.5	83	61.4	19.3	33.7	5	89	76.7
metamitron + metamitron & oil (5 l/ha)	3.5 3.5	86	20.9	64.0	55.8	10	101	87.1
lenacil + metamitron & oil (5 l/ha)	2.24 3.5	14	28.6	50.0	50.0	90	18	15.5
pyrazone + metamitron & oil (5 l/ha)	4.0 3.5	72	13.5	79.2	73.6	25	90	77.6
metamitron + phenmedipham	3.5 1.14	113	24.8	67.3	19.5	13	113	97.4
lenacil + phenmedipham	2.24 1.14	49	12.2	87.8	51.0	35	50	43.1
pyrazone + phenmedipham	4.0 1.14	95	11.6	80.0	31.6	5	99	85.3
Untreated control								
Level on untreated		123	93.5	0	6.3	0	116	100

* Numbers of plants per 8m row

Table 5

The effect of post-emergence herbicides, applied on 26 May 1978 at the 2 leaf stage, on the growth of sugar beet

Treatments	Rate kg a.i./ha	Crop fresh weight g/plant May 26	June 1	June 8	June 14	June 22	July 6	August 3
metamitron	3.5	0.62	2.96	21.8	60.6	181	431	924
metamitron and oil (5 l/ha)	3.5	0.60	2.89	23.4	63.2	196	451	957
phenmedipham	1.14	0.59	1.75	13.8	44.5	127	387	812
Untreated	0	0.61	3.28	25.8	59.6	185	420	919
Statistical Significance			S	S	S	S	NS	NS
L.S.D. at 5% level			0.69	2.69	13.3	29		

metamitron at 3.5 kg a.i./ha was applied to all plots pre-emergence on 27 April 1978

storage root in July or as early as June (Scott and Jaggard, 1978); consequently the minimal effect of metamitron on growth and development should assist the crop in attaining its potential yield. Further careful work is required to evaluate the effect and interaction of herbicides under varying conditions on the growth and final yield of sugar beet. Only then can the value of attaining a weed free crop be weighed carefully against the possible implications of reducing crop selectivity.

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THE DEVELOPMENT OF 3,6-DICHLOROPICOLINIC ACID AS A TANKMIX AND/OR SEQUENTIAL APPLICATION FOR THE CONTROL OF ANNUAL AND PERENNIAL WEEDS IN SUGAR BEET

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Summary A programme of replicated trials carried out over a two-year period has demonstrated the utility of 3,6-dichloropicolinic acid as a post-emergence sugar beet herbicide in the UK.

Application of up to 200g ae/ha was safe to the crop from cotyledon to the eight leaf stage whilst later application caused transient leaf-curling effects. Tankmix with phenmedipham did not increase damage caused by phenmedipham alone.

Applications of 3,6-dichloropicolinic acid in tankmix with other post-emergence herbicide treatments (phenmedipham, phenmedipham/ lenacil, metamitron) improved the control of composite and polygonous weeds and permitted some dose reduction in the tankmix partner in certain situations.

150-200g ae/ha 3,6-dichloropicolinic acid gave good control of *Cirsium arvense* up to about 20cm tall while even better control was obtained by sequential applications of 100g ae/ha with a three week interval.

Résumé Un programme d'essais réalisés pendant deux ans a démontré l'utilité de l'acide 3,6-dichloropicolinique comme herbicide de post émergence de la betterave à sucre en Grande Bretagne.

L'application de quantités allant jusqu'à 200 g ae/ha se révéla sans danger pour la culture depuis le stade cotylédons jusqu'au stade 8 feuilles, alors qu'une utilisation plus tardive a causé des effets transitoires de frisottement des feuilles. Le mélange extemporané avec le phenmediphame n'a pas augmenté les dommages causés par le phenmediphame seul.

Les applications d'acide 3,6-dichloropicolinique en mélange extemporané avec d'autres traitements herbicides de post émergence (phenmediphame, phenmediphame/lenacile, metamitrone)

ont amélioré l'efficacité sur les mauvaises herbes des groupes des composées et de polygonacées et permis quelque réduction de la dose du partenaire dans certaines situations.

150-200 g ae/ha d'acide 3,6-dichloropicolinique ont bien maîtrisé Cirsium arvense d'une hauteur allant jusqu'à 20 cm. Mais une meilleure efficacite a été obtenue par des applications séquentielles de 100 g ae/ha à intervalle de 3 semaines.

INTRODUCTION

The chemical structure, physical and toxicological properties of 3,6-dichloropicolinic acid and its development as a broad-leaf herbicide in cereals under the code number DOWCO* 290 has been described by Haagsma (1975) and Brown and Uprichard (1976). Its activity against perennial weed species such as Cirsium arvense was first reported by Keys (1975), and its selectivity in sugar beet was reported by Vernie et al (1977). Although the spectrum of activity has been shown to be limited, the high level of efficacy against composite weeds suggested that it might well complement the spectrum of phenmedipham, besides having specific utility for the control of perennial weeds. Other development work in sugar beet on the continent has been reported by Jones and Bos (1977). Accordingly a UK field trial programme was initiated in 1977 to evalutate the efficacy of 3,6-dichloropicolinic acid as a tankmix and/or sequential application for the control of annual and perennial weeds in sugar beet in the UK This paper reports the results of these trials.

METHODS AND MATERIALS

3,6-dichloropicolinic acid was used throughout as the commercial product containing 100g ae/litre as the monoethanolamine salt. All other herbicides were used as their standard commercial formulations.

The primary trials were carried out during the period 1977-8 to evaluate 3,6-dichloropicolinic acid alone and in tankmix on annual broad-leaved weeds in sugar beet. These trials were all of randomised block design, with three or four replicates and a plot size of 30m^2. Three secondary trials were carried out to evaluate 3,6-dichloropicolinic acid alone, in tankmix and in sequential application for perennial broad-leaved weed control. These trials were of similar scale and design to the main trials except that only two replicates were used in the two 1977 trials and four replicates in the 1978 trials. Additionally two unreplicated timing trials were carried out in 1978 to investigate crop effects from application of 3,6-dichloropicolinic acid alone and in tankmix at four different crop growth stages.

Sites were selected primarily for heavy and varied post-emergence weed flora and included a range of soil types from very fine sandy loam to silt loam and including organic and peat soils. Pre-emergence treatments varied from nil to a range of standard sugar beet herbicides. Experimental post-emergence treatments were applied at annual weed growth stages of cotyledon to eight leaves and crop stages cotyledon to six leaves.

Application to perennial weed sites was made at stages indicated in Tables 3 & 4. All treatments were applied by Van der Weij sprayer using Delavan FJ11 fanjets and a pressure of 3.0 bars to give a spray volume of 220 l/ha.

Weed control was assessed approximately one month after spraying on a percentage basis, as was crop tolerance at intervals of 1-2 weeks and 4-5 weeks after spraying. Crop stand was determined by counting crop plants per 5 x 1 m rowlengths per plot, approximately one month after spraying. Selected treatments were harvested in late Autumn, by lifting, hand topping and weighing 20m rowlength per plot. Sugar content was determined by British Sugar Corporation Central Laboratories.

RESULTS

Table 1

Mean percent annual weed control (1977/8)

Treatment	Dose rate (g.ae/ha)	T.m.	P.c.	P.p	P.a.	C.a.	V.p.	S.m.
d	100	91	84	42	38	35	31	32
d	200	97	90	42	47	55	34	48
d+p	100+798	93	92	81	90	97	93	97
d+p	100+912	95	93	85	89	96	93	93
p	1140	81	91	86	86	97	95	98
d+p+l	100+798+560	95	92	87	92	97	93	98
p+l	798+560	76	85	82	93	97	91	97
d+m	100+2800	99	86	84	82	87	86	92
m	3500	93	58	84	89	86	93	92
Control	-	15	13	7	22	15	18	14
Mean no. of sites per species		3	3	3	4	9	4	2

Treatments

d = 3,6-dichloropicolinic acid

p = phenmedipham

m = metamitron

l = lenacil

Weed species

T.m. = Tripleurospermum maritimum ssp. *inodorum*

P.c. = *Polygonum convolvulus*

P.p = *Polygonum persicaria/lapathifolium* (mixed stand)

P.a. = *Polygonum aviculare*

C.a. = *Chenopodium album*

V.p. = *Veronica persica*

S.m. = *Stellaria media*

3,6-dichloropicolinic acid applied alone on annual weeds gave adequate control of T. maritimum only. Even on this species some larger plants were stunted but not killed, and visual scores at 1977 sites suggested a biomass reduction of about 85% and 95% at 100 and 200g ae/ha, whereas in terms of plant numbers, control levels were only 75% and 88% respectively. Similar effects were noted on P.convolvulus, P.persicaria and to a lesser extent on P.aviculare and C.album.

In addition to controlling T.maritimum, 3,6-dichloropicolinic acid alone gave a moderate degree of control of P.convolvulus, although not to a commercially acceptable level.

In mixture, 3,6-dichloropicolinic acid improved the control of T.maritimum, particularly when added to phenmedipham, and in all cases brought the level of control up to an acceptable level, which was not achieved by phenmedipham or phenmedipham/lenacil alone. 3,6-dichloropicolinic acid also improved the control of P.convolvulus when added to metamitron. Control of remaining weeds achieved by other herbicides was little affected by addition of 3,6-dichloropicolinic acid and this also appeared to be the case on Lamium purpureum, Lycopsis arvensis, Urtica urens, Thlaspi arvense and Viola spp., none of which were present on more than one site.

Table 2

Mean percent perennial weed control and crop damage (1977)

Treatment	Dose rate (g ae/ha)	Weed species & site: C.arvense Site 5	C.arvense Site 6	P.bistorta Site 6	crop* Site 5
d	100	88	40	20	1
d	150	93	40	40	1
d	200	95	75	40	5
Control		0	0	0	0
Perennial weed height at spraying (cm)		15-30	30-80	30-45	-
Crop stage (no.of leaves)		-	-	-	10-12

*Crop at site 6 eliminated prior to treatment by extreme weed competition.

Control of Cirsium arvense varied between the two sites sprayed in 1977 according to the weed growth stage. At site 5 thistles were at the late rosette stage, with some flowering shoots emerging but only up to 30cm tall. These shoots were not killed completely, but made no further growth, showed distortion and chlorosis in the established leaves, and die-back of the flowering shoots. At site 6 shoots were up to 80cm high and in full flower. Although 3,6-dichloropicolinic acid again caused leaf distortion and chlorosis, control was unsatisfactory at this growth stage. This response was confirmed in the 1978 trial where application early was more effective than late, although sequential application gave best results. The pattern was reversed on Sonchus oleraceus and Tussilago farfara where later applications caused greater suppression but neither weed was adequately controlled by any treatment.

Polygonum bistorta showed only slight leaf distortion and chlorosis, resulting in unsatisfactory control at this growth stage. Richardson & Parker (1976) found a high level of activity on *Polygonun amphibium* at 3-4 leaves, therefore early treatment may achieve better control.

Table 3

Mean percent perennial weed control and crop damage (1978)

Treatment early	late	Dose rate (g ae/ha)		C.arvense	S.oleraceus	T.farfara	crop
d+p	-	100+912	*	86	40	40	3.5
d+p	-	200+912	*	91	56	46	3.5
p	-	1140	*	22	15	5	6.0
Control		-	*	16	16	16	5.0
d+p	-	100+912		83	20	10	0.5
d+p	-	200+912		85	18	18	0.5
d+p	d	100+912+100		89	40	26	1.0
d+p	d	200+912+200		98	83	65	0.5
p	d	1140+100		56	36	26	2.5
p	d	1140+200		80	44	20	2.5
p	-	1140		5	0	0	8.5
Control		-		0	0	0	7.5

*Assessed 3 weeks after first application, second assessment (lower half of table) made 2 weeks after second application.
Growth stage 1st app: Crop 2 leaf, *Cirsium* 15-20 cm
Growth stage 2nd app: Crop 8 leaf, *Cirsium* 20-40 cm, flowering

Overall, most treatments applied in 1977 resulted in a consistently better crop stand than that in control plots. This may be attributed to the death of a few weak plants in the control plots due to weed competition.

3,6-dichloropicolinic acid alone caused no visible crop effects except for the 200g ae/ha rate at three sites in 1977 where a slight growth check was apparent at both times of assessment. This was less apparent in 1978. All treatments containing phenmedipham caused considerable scorch and a growth check which was still apparent one month after treatment. Early damage with the full rate of phenmedipham with or without 3,6-dichloropicolinic acid was unacceptable in at least some replicates at three sites in 1977. The addition of 3,6-dichloropicolinic acid, however, did not appear to increase the degree of damage caused by phenmedipham. Metamitron, alone or with 3,6-dichloropicolinic acid had little visible effect on the crop.

In the spray timing trials 3,6-dichloropicolinic acid gave only a slight growth check at the early cotyledon stage but otherwise had no significant effects on the crop. Later application at the 10-12 leaf stage for perennial weed control caused some curling of the leaf edges, and at 200g ae/ha a slight loss of turgor.

Table 4

Mean crop stand and crop tolerance (1977)

Treatment	Dose rate (g ae/ha)	Mean percent stand over all sites 1977	Mean percent damage at intervals after spraying: 1 week 1977	4 week 1977	2 week 1978	4-5 wk 1978
d	100	110	0.1	0.3	2.1	0.9
d	200	108	0.1	1.3	2.6	1.1
d+p	100+798	114	6.6	5.0	5.6	4.1
d+p	100+912	110	7.0	4.4	5.8	4.7
d+p	100+1140	110	7.6	5.6	-	-
p	1140	110	9.0	6.5	5.0	4.5
d+p+l	100+798+560	108	4.8	3.1	6.2	5.0
p+l	798+560	107	4.8	4.5	5.5	2.9
d+m	100+2800	112	1.5	0.4	2.8	2.4
d+m	100+3500	-	-	-	3.0	1.2
m	3500	106	0.3	1.0	3.0	2.1
control	-	100	0.4	0.3	1.4	1.4
L.S.D. 5%		8	-	-	-	-
No. of sites		4	4	4	5	5

Table 5

Crop tolerance over a range of growth stages (1978)

Treatment	Dose rare (g ae/ha)	mean percent damage at each crop growth stage: cot	2 lf	4 lf	6 lf
d	100	1.0	0.0	0.0	0.0
d	200	1.0	0.0	0.0	1.0
d+p	100+912	5.0	7.5	6.0	6.0
control	-	0.0	0.0	0.0	0.0

100g ae/ha of 3,6-dichloropicolinic acid had no significant effects on crop yield at any site while the double rate 200g ae/ha gave a significant yield increase at one site and some yield increase at the others. All mixtures gave significant or near significant yield increases over control at all sites, and yields from these treatments were also similar to or greater than phenmedipham alone but not significantly so. No treatment had any significant effect on beet sugar content.

Table 6

Mean yield of roots as percent of untreated (1977)

Treatment	Dose rate (g ae/ha)	Site 1	Site 2	Site 3	Mean
d	100	94	105	111	103
d	200	111	119	117	115
d+p	100+798	114	119	118	117
d+p	100+912	117	124	116	119
d+p	100+1140	108	128	125	120
p	1140	113	125	112	117
L.S.D. 5%		12	17	20	8
Control yield (t/ha)		39.9	35.2	29.9	

Table 7

Mean percent sugar contents in roots (1977)

Treatment	Dose rate (g ae/ha)	Site 1	Site 2	Site 3	Mean
d	100	17.2	17.3	17.7	17.4
d	200	16.9	17.2	17.9	17.3
d+p	100+798	16.6	17.2	17.7	17.2
d+p	100+912	17.0	17.3	17.9	17.4
d+p	100+1140	17.3	17.5	17.7	17.5
p	1140	17.3	17.1	17.5	17.3
control	-	16.6	17.1	17.7	17.1
L.S.D. 5%		N.S.	N.S.	N.S.	N.S.

DISCUSSION

Two potential areas of use for 3,6-dichloropicolinic acid have been identified following this development programme on sugar beet. The first is in tankmix with other post-emergence herbicides to widen the spectrum and improve levels of weed control. The second involves application either alone or in sequence for the control of perennial weeds and represents the first chemical solution to a long standing problem.

3,6-dichloropicolinic acid at 100g ae/ha has been shown to be consistently safe for use on sugar beet between the cotyledon and eight true leaf stages over a two-year period of contrasting spring weather conditions. It caused no reduction in crop stand, no visible damage symptoms, no yield reduction and no effect on sugar content. Tankmixing of 3,6-dichloropicolinic acid with phenmedipham does not appear to increase damage levels due to phenmedipham. 3,6-dichloropicolinic acid application to beet at a later stage for perennial weed control may cause slight leafedge curling at 200g ae/ha but this effect is transient and soon outgrown.

The benefit of tankmixing 3,6-dichoropicolinic acid with other post-emergence herbicide treatments (phenmedipham, phenmedipham/lenacil, metamitron) lies in the improved control of composite and polygonous weeds. 3,6-dichloropicolinic acid/phemedipham mixtures gave a moderate degree of dose response and a rate of 100g + 912g ae/ha was generally as good as or better than 1.14kg ai/ha phenmedipham alone and as good as a 100g + 1140g ae/ha tankmix evaluated in 1977 only. The best overall treatments were 3,6-dichloropicolinic acid/phenmedipham lenacil at 100 +798 +560g ae/ha, 3,6-dichloropicolinic acid/phenmedipham at 100+912g ae/ha, and, 3,6-dichloropicolinic acid/metamitron at 100 +3500g ae/ha (evaluated in 1978 only).

Whilst 150-200g ae/ha 3,6-dichloropicolinic acid applied alone offers good control of Cirsium arvense up to about 20cm tall, split sequential application of 100-200g ae/ha two to three weeks apart offers best control. The first of these applications may be made in tankmix with a post-emergence herbicide treatment.

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THE DEVELOPMENT OF METAMITRON FOR WEED CONTROL IN SUGAR BEET GROWN ON SOILS WITH MORE THAN 10% ORGANIC MATTER

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Summary. A treatment of metamitron as a single application pre- or post-emergence of weeds in sugar beet rarely provided adequate weed control on organic (>10% o.m.) soils. Two sequential post-emergence applications were safe to the crop and often produced good weed control but could be unreliable. Tank mixes of metamitron with an adjuvant oil increased the reliability of weed control. However, selectivity was reduced by these mixtures. The sequential use of two applications of metamitron plus oil was the most reliable effective treatment against weeds, although metamitron followed by metamitron plus oil produced similar weed control with less crop damage.

Résumé Un traitement de metamitron, c'est à dire, une seule application pré-émergente ou post-émergente des mauvaises herbes a montré un traitement herbicide suffisant dans les récoltes de betteraves à sucre sur les sols organiques (>10% matiere organique). Deux applications en séquence n'ont pas abîmé la recolte et ont souvent montré une bonne lutte contre les mauvaises herbes, mais une telle programme peut être d'un fonctionnement incertain. Liquides de pulvérisation de metamitron mélangés avec une huile adjuvante ont amélioré la sûreté d'un traitement herbicide. La sélection cependant était réduite par cas mélanges. L'utilisation, en séquence, de deux applications de metamitron avec l'huile adjuvante a prouvé d'être le traitement le plus efficace et le plus sûr contre les mauvaises herbes, mais une application de metamitron suivi par une application de metamitron avec l'huile adjuvante ont produit un traitement herbicide similaire et avec moins de dégâts causés aux récoltes.

INTRODUCTION

Weed control in soils with comparatively large proportions of organic matter (hereafter referred to as "organic" soils) is particularly difficult. These soils tend to contain large populations of weed seeds and provide a medium for vigorous plant growth. There is, therefore, a potential for severe weed competition and germination of significant numbers of weeds over a relatively long period after cultivation. In addition, residual herbicides have their activity markedly reduced by the organic matter in the soil. Thus many herbicides effective on mineral soils are of limited use on organic soils.

Metamitron has been shown to be a very safe and effective herbicide when used in sugar beet (Morris et al, 1976). It displays contact as well as residual activity so is suitable for use on organic soils. This paper considers the results obtained from the use of metamitron on beet grown in such soils.

METHOD AND MATERIALS

The metamitron used in the trials was formulated as a 70% wettable powder and phenmedipham as an 11.4% emulsifiable concentrate. The adjuvant oil used had the trade name Actipron, which is self emulsifying and produced by BP Oil Ltd.

The treatments in 1974 (1 trial) and 1975 (3 trials) were applied to small plots (20 to 24m^2) replicated three times. In 1977 (6 trials) the plots were 24 to 30m^2 and unreplicated. Applications to these trials were made by pressurised knapsack sprayers in 300 l/ha of water at 2.1 bars.

In 1976 the 7 trials were grower applied by commercial sprayers (normally as a band application along the row) in volumes from 220 to 400 l/ha of water at pressures ranging between 0.7 and 2.8 bars.

Assessments of weed control were made by seedling counts in quadrats, usually totalling 1m^2 per plot, 2-3 weeks after treatment. In 1975 assessments of weed cover for later applied treatments were made in early July.

The trials were carried out at various locations in the fenland of Eastern England (except for one in Yorkshire in 1977) on soils ranging from 14% to 73% organic matter.

RESULTS

An exploratory trial in 1974 confirmed that the residual activity of metamitron was much reduced in a soil containing 67% o.m. Much greater effectiveness was achieved by contact action when application was made to the seedling weeds.

Table 1

% Control of annual broadleaved weeds and Poa annua from trials in 1975

Treatment	Rate (kg a.i./ha)	No. of applications	Trial location: Weed stages at application	Queen Adelaide 48% o.m.	Thorney Dyke 21% o.m.	Woodwalton Fen 66% o.m.
metamitron	3.5	1	Cotyledon to 1 leaf	15	53	65
metamitron	4.9	1	Cotyledon to 1 leaf	46	63	65
metamitron	3.5	1	2-6 leaves	77	63	43
metamitron	4.9	1	2-6 leaves	80	74	54
metamitron	3.5	2	Cotyledon to 1 leaf of first and second weed flushes	97	92	75

Table 2

The effectiveness in % annual weed control of two sequential treatments of metamitron from trials in 1976

Treatment and rate (kg a.i./ha)	Trial location	Brandon Creek	Littleport	Bourne	Whittlesey
	% o.m. in soil	35	43	45	28
metamitron 3.5 + metamitron 3.5		41	41	19	73
phenmedipham 1.14		-	-	-	98*
+ phenmedipham 1.14		34+	57+	-	-
No. of weeds/m^2 on untreated		345	878	284	125

* Single application only

\+ Treatment following the pre-crop emergence use of a propham, chlorpropham and fenuron mixture

Table 3

% Control of all annual broadleaved weeds and Poa annua from individual trials in 1977

Treatments* at cotyledon-1 lf of weeds: At 1st weed flush	At 2nd weed flush	% o.m. in soil	Little Ouse	Burnt Fen	Feltwell	Bourne	Ramsey	Roecliffe	Median
			25	33	49	23	61	32	
A	A		99	81	68	33	84	69	75
A	B		100	86	80	84	85	84	85
B	B		99	89	86	93	90	96	92
C	C		97	84	66	84	82	82	83
No. of weeds/m^2 on untreated		—	273	349	463	524	458	249	404

* Treatment code: A = metamitron 3.5 kg a.i./ha
B = metamitron 3.5 kg a.i./ha + oil 5 l/ha
C = phenmedipham 1.14 kg a.i./ha

Table 4

% Control of most frequently occurring weed species from individual trials in 1977

Treatments* At 1st weed flush	At 2nd weed flush	Poa annua: Burnt Fen	Feltwell	Ramsey	Roecliffe	Median	Polygonum persicaria: Little Ouse	Burnt Fen	Feltwell	Bourne	Ramsey	Roecliffe	Median	Urtica urens: Little Ouse	Burnt Fen	Feltwell	Ramsey	Median
A	A	97	44	60	5	52	79	34(89)+	78	49	83	100	79	100	98	80	95	97
A	B	100	70	87	51	79	100	42(96)	86	61	88	100	87	100	98	74	94	96
B	B	97	87	80	100	84	71	60(93)	85	80	88	100	83	100	99	84	92	96
C	C	64	43	47	25	45	75	59(56)	76	38	79	98	76	100	96	82	86	91
No. of weeds/m^2 on untreated		35	126	15	29	32	14	81(82)	220	109	110	85	97	231	181	50	233	206

* Treatment code: A = metamitron 3.5 kg a.i./ha
B = metamitron 3.5 kg a.i./ha + oil 5 l/ha
C = phenmedipham 1.14 kg a.i./ha

+ Figures in brackets represent % weed control after a third application (second application repeated)

Table 5

Median % control of all weed species occurring in 1977 trials

Treatment* 1st weed flush / 2nd weed flush	A / A	A / B	B / B	C / C	No. of sites	Median untreated weed population (no./m^2)
Weed species						
Chenopodium album	41	86	91	90	2	112
Chenopodium rubrum	98	98	100	95	2	14
Galeopsis tetrahit + G. speciosa	98	100	100	100	2	14
Lamium purpureum	69	100	85	71	1	13
Poa annua	52	79	84	45	4	32
Polygonum aviculare	0	43	100	33	1	18
P. convolvulus	13	32	54	98	2	9
P. lapathifolium	94	100	100	94	1	17
P. persicaria	79	87	83	76	6	97
Stellaria media	86	75	77	72	2	33
Tripleurospermum maritimum ssp inodorum	84	84	95	87	1	19
Urtica urens	97	96	96	91	4	206
Viola arvensis	59	63	98	97	1	44

* Treatment code: A = metamitron 3.5 kg a.i./ha
B = metamitron 3.5 kg a.i./ha + oil 5 l/ha
C = phenmedipham 1.14 kg a.i./ha

The effectiveness of metamitron applied to emerged weeds in trials during 1975 is shown in Table 1. Poor weed control was ultimately seen with treatments applied at cotyledon to 1 leaf of the first flush of weeds. Treatments applied when the majority of weeds were at the 2 to 6 leaf stage also proved inadequate.

All single applications were considerably less effective than the sequential application of 3.5 kg a.i./ha applied at cotyledon - 1 leaf of the first flush of weeds, followed by the same treatment at the same stage of the second flush of weeds. However, these sequential applications produced rather variable weed control over the years 1975 to 1977 (Tables 1, 2 and 3).

In 1977 sequential applications were made involving the use of tank mixes of metamitron 3.5 kg a.i./ha plus adjuvant oil 5 l/ha. The aim was to increase the reliability of weed control compared with the use of metamitron alone. Results of these treatments from individual trials are shown for overall weed control (Table 3) and the most frequently occurring individual weed species (Table 4). Median % weed control figures for all species occurring on the trials in assessable numbers are shown in Table 5. A measure of reliability is provided by stating the number of trials from which data were obtained and the median weed population on which the results were based.

The results of crop tolerance assessments are shown in Table 6.

Table 6

Crop tolerance assessed between 7 and 20 days after second applications

Treatment*	A + A	A + B	B + B	C + C
1977 6 trials				
Mean % reduction in crop vigour	0	2	5	12
Number of sites where reduced vigour was seen	0	3	4	6
1976				
Mean % reduction in crop vigour	0	4	-	13
Number of sites where reduced vigour was seen	0(7)	1(1)	-	2(4)
(Figure in brackets represents the number of possible sites)				

* Treatment code: A = metamitron 3.5 kg a.i./ha
B = metamitron 3.5 kg a.i./ha + oil 5 l/ha
C = phenmedipham 1.14 kg a.i./ha

DISCUSSION

Pre-emergence treatments of metamitron were ineffective because the residual activity was so much reduced by the organic matter in the soil. Early post-emergence treatments, applied at cotyledon to 1 leaf stage of the earliest germinating weeds, were also poorly effective (Table 1). This was because the weeds emerging subsequent to treatment avoided the contact action of metamitron, whilst being protected from the residual activity by the organic matter in the soil. Later post-emergence treatments, applied at the 2-6 leaf stage of the weeds, brought metamitron into contact with the majority of weeds that were to emerge. However, these treatments were inadequate because the larger weeds were less susceptible to metamitron (Morris et al, 1976). Increased rates of 4.9 kg a.i./ha of metamitron were not markedly superior to 3.5 kg a.i./ha at these post-emergence timings (Table 1).

The use of metamitron as two sequential treatments at an early stage in the growth of the first two flushes of weeds frequently produced good weed control (Tables 1, 2 and 3). However, these treatments were not always reliable. These variable results were probably influenced by several factors. Accurate timing of post-emergence metamitron applications is important because weeds are most susceptible when they are small (Morris et al, 1976). This could be a particular problem under commercial conditions of beet herbicide treatment. The limited period of weed susceptibility is in turn affected by the species involved, since there are differences in species susceptibility. Weed germination subsequent to the second application could have been another factor involved. In such cases the ultimate weed control would not be adequate. The exceptional heat and drought during 1976 undoubtedly contributed to the high proportion of poor weed control results in that season. Weed growth and consequently foliar uptake of herbicides would have been affected, while any root uptake would have been severely reduced. The similarly poor results recorded in 1976 after treatment with the comparison standard herbicides tend to support this hypothesis.

In an effort to minimise some of these problems, tank mixes were included in the 1977 trials. The tank mixes used enhance the contact activity of metamitron, extending the period of susceptibility of weeds and increasing the susceptibility of some species (Hack and Schmidt, 1966). The results for overall weed control (Table 3) show an improvement in the reliability of treatments involving tank mixes compared with the applications of metamitron alone. It should be noted that metamitron alone was capable of achieving weed control comparable with the tank mix treatment at four of the six sites. In comparison with metamitron alone, increased susceptibility of Poa annua was evident where tank mixes had been used (Table 4). A similar condition was indicated for Chenopodium album, Lamium purpureum, Polygonum aviculare and P. convolvulus (Table 5). However, several species (notably Urtica urens, Table 4) were controlled similarly well by metamitron alone.

The problem of weed germination subsequent to treatment is demonstrated by the results against Polygonum persicaria from the site on Burnt Fen (Table 4). The population of P. persicaria on untreated plots at the time of the second applications was $56/m^2$. At assessment 17 days later, further germination had increased the population to $81/m^2$. A third herbicide application was made by repeating the "2nd flush of weed" treatment, resulting in the improved weed control shown (Table 4).

The weed control results from Tables 3 and 4 show very little difference in effectiveness between the treatments of metamitron followed by a tank mix and the sequential use of tank mixes. The details of species susceptibilities (Table 5) in general show a similar situation.

The crop tolerance results in Table 6 show that the enhanced weed control with tank mixes described above was only achieved with some loss in selectivity. Treatments of metamitron alone were consistently safe to the crop but the beet were not always tolerant of the tank mixes used. Where tank mixes were applied subsequently to metamitron alone, crop phytotoxicity was much less than where both applications were tank mixes.

The weed control and crop tolerance data suggest that for maximum and reliable weed control with minimum crop damage, the sequential use of metamitron plus oil would be most suitable. However, very little reduction in weed control occurs where the first application is of metamitron alone followed by the oil tank mix, while the crop phytotoxicity is reduced. This treatment appears to be a viable compromise.

Wherever possible, it would seem sensible to use metamitron alone sequentially to capitalise on its safety to the crop. Suitable situations for such a treatment might occur where Urtica urens, Galeopsis spp. and to some extent Polygonum persicaria are major species. These situations were not infrequently found in the trials conducted.

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