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THE EFFECT OF SOWING DATE ON THE CRITICAL PERIOD FOR WEED CONTROL IN SUGAR BEET

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Summary In both early (24 March) and late (7 May) sown crops grown at Sutton Bonington in 1973 there was a distinct critical period during which it was essential to handweed but not earlier or later than this, when weeds could grow without affecting final yield. In the March sown crop this period extended from mid May until mid June (4-8 weeks after crop emergence), while in the May sown crop in which events occurred rapidly, it was from mid-late June (4-6 weeks after emergence).

In a parallel series of treatments, combinations of pre- and post-emergence herbicides were applied overall to the March sown crop in an attempt to achieve particular weed control regimes from the handweeded series. Used alone, pyrazone's (pre-em.) effect was equivalent to handweeding for between 2 and 4 weeks, and phenmedipham's (post-em.) effect, handweeding until 4 weeks. A further two weeks effective control was achieved when either herbicide was supplemented with 2-ethoxy-2, 3, dihydro-3, 3-dimethyl-5-benzoyl methanesulphonate (ethofumesate) or when pre- and post-emergence herbicides were applied sequentially.

Résumé Dans les récoltes ensemencées à Sutton Bonington en 1973 l'une précoce (24 Mars), l'autre tardive (7 Mai), il y eut une période critique très distinct durant laquelle il fut essentiel de désherber à la main mais ni avant après le moment où les mauvaises herbes pourraient pousser sans affecter la récolte finale. Pour la récolte de Mars cette période, s'est étalee de la mi-Mai à la mi-Juin (4 a 8 semaines après l'emergence du grain) tandis que pour celle de Mai au cours de laquelle tout s'est passé rapidement, elle a commencé la seconde moitié de Juin (4 à 6 semaines après émergence).

Dans une série parallèle de traitements, un mélange d'herbicides avant et après émergence fut essayé integralement pour la récolte ensemencée en Mars afin de réaliser certains régimes de contrôle des mauvaises herbes à partir de la série des désherbages a la main. Utilisé seul, l'effet du pyrazone (avant émergence) fut equivalent à un désherbage à la main pour une durée de 2 à 4 semaines, et l'effet du phenmedipham (après émergence) à un désherbage à la main durant jusqu'à 4 semaines. Un contrôle effectif de deux semaines supplémentaires fut réalisé lorsque les deux herbicides furent accompagnés de 2-éthoxy-2, 3, dihydro-3, 3-diméthyl 1-5-benzoyl méthanesulphonate ethofumesate ou lorsque les herbicides pour avant et après l'émergence furent utilisés à intervalles consécutifs.

INTRODUCTION

Field experiments at the University of Nottingham between 1970 and 1972 (Scott and Moisey, 1972) tested when during the life of the sugar beet crop weed control was essential and when weeds could be allowed to grow without affecting yield. In each year crops in which hand weeding ceased six weeks after crop emergence yielded as well as those weeded throughout. Moreover, crops in which weeding did not commence until four weeks after emergence also achieved full yield potential. Thus for these April sown crops there was a relatively short "critical period" for weed control during late May and early June. The present experiment, in 1973, tested how sowing date affected the picture. Crops sown on 24 March and 7 May were given a series of handweeding treatments. In a parallel experiment, also sown on 24 March these effects were compared with a series of herbicide treatments intended to reproduce particular weed control regimes from the hand-weeded series.

METHOD AND MATERIALS

The experiments accompanied commercial beet crops at the usual point in the all arable rotation of the University farm. Crop and weed development was followed by sampling from an area of $1.55m^2$, 2, 4, 6, 8, 10, 14, 18, 22 and 24 weeks after 50% crop emergence. Final harvest samples of both crops were taken on two occasions, each from approximately $5.5m^2$ on 15 October and 12 November. This enabled us to look for any advantage that might be gained from delaying harvesting of weedy crops, thereby giving the opportunity of making some recovery during the period of rapid weed senescence. Table 1 shows the range of herbicide treatments given and also indicates the target period of active weed control at which the herbicide treatments were aimed. Pyrazone and phenmedipham when used alone or in sequence were applied at dose rates currently recommended in commercial practice. When applied as mixtures with ethofumesate only half the normal rate of phenmedipham was used. Dose rates in the herbicide mixtures used do not necessarily correspond to those commercially recommended. On the same date that post-emergence herbicides were applied, further plots received a once and for all hoeing which had proved remarkably effective in 1970 - a dry year. Since the herbicide experiment was adjacent to the other experiments and sown on the same day as the early sowing, data are directly comparable.

Table 1

Details of the herbicide experiment

Crop sown 24 March 1973 — 50% crop emergence 18 April 1973

Treatment kg a.i./ha Pre-em.	Post-em.	Date of application	Target period of weed control
Pyrazone 2.5	-	26 March	until 2 or 4 weeks
Pyrazone 1.5 + ethofumesate	-	26 March	until 6 or 8 weeks
-	Phenmedipham 1.0	6 May	between 4 and 6 weeks
-	Phenmedipham 0.5 + ethofumesate	6 May	between 4 and 6 weeks
Pyrazone 2.5	Phenmedipham 1.0	26 March/6 May	until 6 or 8 weeks
Pyrazone 1.5 + ethofumesate 1.5	Phenmedipham 0.5 + ethofumesate 1.0	26 March/May	until 26 weeks
-	hoed once	6 May	between 4 and 6 weeks

RESULTS

Experiment 1

Weed development

Frequent heavy rainfall during May, June and July encouraged vigorous weed growth leading to a maximum dry weight of weeds of $1000 g/m^2$, the heaviest so far recorded in this series of experiments. Chenopodium album predominated and accounted for 94% of the weight of weeds in both sowings. Its growth was so prolific that other species were progressively suppressed. The number of C. album fell drastically after short periods of weeding in both crops, but those plants which germinated after four weeks of weeding in the early crop and after two weeks of weeding in the late crop, grew extremely vigorously. With their rapid growth and erect habit individual C. album plants became much branched and very large. Unlike C. album, Polygonum aviculare, Polygonum convolvulus and Aethusa cynapium were less prevalent in the late sown crop and became progressively less frequent and individual plants progressively less vigorous as weeding was longer continued. In the case of P. aviculare this was almost certainly due to dormancy induced by warm conditions towards the end of May, (Courtney, 1968). A similar mechanism may have been operative for P. convolvulus and A. cynapium. Similar numbers of established seedlings of P. convolvulus and P. aviculare existed initially, but P. convolvulus was better able to avoid shade and survive by entwining around tall C. album stems, while the more prostrate plants of P. aviculare were effectively shaded out.

Cultivations during May always caused a flush of emergence of Tripleurospermummaritimum ssp. inodorum. Seedbed preparations for the early May sowing resulted in three times as many T. maritimum ssp. inodorum seedlings being present by mid-June in the late crop than in the early crop. Similarly, T. maritimum ssp. inodorum was more frequent where the early sowing was last hoed on 14 May (until 4 weeks) or 28 May (until 6 weeks) than where no hoeing or only two weeks of hoeing was done. These extra seedlings lacked vigour and were very much suppressed by the development of the crop and other weed species. When hoeing was continued into June and July this species became less frequent.

Groundkeeper potatoes were a significant component of the weed flora in 1973. They developed from small complete tubers and pieces of tuber which survived the two mild winters since potatoes were grown in 1971. They were more frequent in late sown beet; their early growth was vigorous in the warm soil whilst other annual weeds were still small. Similar periods of weeding were more effective in the late than in the early crop, as events occurred more rapidly. Many weeds quickly emerged from the warm soil, enabling a greater number of weeds to be destroyed at each hoeing. Moreover, crop leaf development was accelerated and leaf cover was soon effective in suppressing weed growth.

Crop responses

Crop responses to weeds in 1973 confirmed previous observations. Failure to control weeds resulted in large depressions of final crop weights, 95% in both early and late sowings. Weeds developing after two weeks of hand weeding depressed crop dry weight of early and late sown crops by 86% and 37% respectively. Extending the weeding to four weeks restricted losses to 51% and 6%. Six weeks of weeding was sufficient to eliminate any effects of weeds in the late sown crop, whilst a loss of 20% final dry weight resulted in the early crop. Weeds restricted root growth more than shoot growth, reminiscent of the morphological response of beet plants to growth in dim light. The canopy of C. album produced deep shade.

Weeds present for the first four weeks after emergence in both early and late sowings had no effect on final dry weights provided that crops were subsequently kept clean. In the late sown crop there was a temporary check to development after the first weeding at four weeks but this was subsequently outgrown. Further delays to the start of weeding had more permanent effects, but the early sown crop was more tolerant to the presence of weeds during the earliest stages than the late sown crop.

Sugar yields

In regularly weeded crops the penalty for delaying sowing from 24 March to 8 May was a loss of 2 tonne/ha of sugar. However, yields of both early and late sown crops were reduced to 0.3 t/ha when weeds were not controlled. Losses from weeds were due to the production of smaller roots with low sugar contents; sugar contents of weedfree and weedy crops were 17.1 and 13.3% when early sown and 16.6 and 14.7% when late sown. Table 2 gives sugar yields of early and late sown crops averaged over the two harvesting dates. Extending the initial weedfree period progressively increased sugar yields until they equalled those of continuously weedfree crops. This was achieved by weeding the early sown crop until eight weeks after crop emergence but only six weeks for the late sown crop.

Table 2

The effect of time of weed infestation on sugar yield (t/ha) (Mean of two harvest dates)

Weeds controlled	Early sowing Date	Early sowing Yield	Late sowing Date	Late sowing Yield
Throughout the season		10.50		8.53
No weed control		0.34		0.29
Until 2 weeks	30 April	0.98	1 June	4.82
Until 4 weeks	14 May	4.42	15 June	7.71
Until 6 weeks	28 May	7.82	29 June	8.17
Until 8 weeks	11 June	9.94	13 July	8.18
Until 10 weeks	25 June	10.35	27 July	8.21
After 2 weeks	30 April	10.47	1 June	9.02
After 4 weeks	14 May	10.48	15 June	8.71
After 6 weeks	28 May	9.38	29 June	5.25
After 8 weeks	11 June	8.05	13 July	3.33
After 10 weeks	25 June	5.47	27 July	2.46
Between 2 and 4 weeks		-	1 June - 15 June	7.21
Between 4 and 6 weeks	14 May - 28 May	6.95	15 June - 29 June	8.25
Between 4 and 8 weeks	14 May - 11 June	9.68		-
Standard error		±0.310		±0.310

In both sowings the start of weed control measures could be safely delayed until four weeks after crop emergence provided crops were subsequently kept clean. Further delays to the start of weeding resulted in yield losses which were more substantial in the late sown crop. Combining this information, it appears that the critical period for weed control in the early sown crop extended between four and eight weeks after crop emergence i.e., between mid-May and mid-June. The 'critical period' for weed control in the late sowing was shorter, between four and six weeks after emergence, from the middle to the end of June. Table 2 shows how successful limited periods of "mid-season" weeding were in achieving maximum sugar yields in early and late sown crops.

The indication of a smaller yield from the early sown crop weeded between four and eight weeks than where weeding was continued throughout is entirely due to data from the second harvest when there happened to be many bolters in the harvest area of the mid season weeded treatment. At the first harvest yields of these two treatments were clearly not different. In the main, crop responses to the periods of weeding were similar irrespective of harvest dates. There was one exception; whilst the late sown crop weeded until four weeks after emergence did not produce as much sugar as the regularly weeded crops when harvested early, it was able to do so by 12 November. This yield improvement was the result of increased root size and slightly higher sugar concentrations.

Experiment 2 - A comparison of herbicide treated and handweeded crops

Few passes were required to produce a fine seedbed suitable for the even distribution of pre-emergence herbicides. However, no rain fell during eighteen days prior to drilling and pre-emergence spraying and the soil remained dry. Appreciable rain did not occur until eleven days after spraying so that some weeds may have emerged before pre-emergence herbicides reached the zone from which they germinated. Frequent heavy rainfall during May, June and July stimulated growth of weeds which had evaded control and further infestation occurred whilst the residual activity of pre-emergence herbicides waned. The major weed species occurring over the site were C. album, Poa annua, T. maritimum ssp. inodorum, P. convolvulus, A. cynapium, P. aviculare and S. tuberosum. C. album was the most important species evading control by all the herbicides used. Even the most effective herbicide combination failed to control it to the extent that yield was reduced to 75% of the weedfree control (Table 3). In Table 3 data from Experiment 1 are from the 14 October harvest, coincident with the harvest of the herbicide experiment.

Pyrazone was completely effective in controlling T. maritimum ssp. inodorum but many C. album plants (approximately 70% of untreated) infested the pyrazone treated crop, and formed 96% of the total weed burden in early August. Final weed weights were similar to those from crops handweeded for four weeks, but the course of weed development throughout the season was intermediate between that in crops handweeded for two and four weeks. Sugar yield was also intermediate between that from crops handweeded for two and four weeks.

Pre-emergence application of a pyrazone/ethofumesate mixture gave more persistent control. The pyrazone effectively controlled T. maritimum ssp. inodorum, a species which is resistant to ethofumesate. The amount of weed which developed in this treatment was intermediate between crops handweeded for four and six weeks and sugar yields were related accordingly. The increased persistency and lower dependence on soil moisture of ethofumesate was valuable in controlling later germinating weeds and gave much improved control of C. album in particular.

A single post-emergence dose of phenmedipham gave completely effective control of C. album and P. convolvulus present at the time of application. Control of P. aviculare was good, except in the case where P. aviculare plants had developed beyond the first true leaf stage. Control of T. maritimum ssp. inodorum and Poa annua was poor and groundkeeper potatoes survived the treatment. Many more weeds became established subsequent to spraying. This treatment did, however, effectively postpone the entry of fresh infestations of C. album for a longer period than pyrazone whilst the crop became better able to suppress weed growth. Crop and weed yields were similar to where handweeding was done for four weeks.

Table 3

The performance of herbicide treated and handweeded crops

Treatment	Crop dry weight g/m^2	Weed dry weight g/m^2	Sugar yield t/ha
Full weed control	2184	-	10.13
No weed control	92	1012	0.29
Weeded until 2 weeks	287	923	0.84
Weeded until 4 weeks	886	567	3.50
Weeded until 6 weeks	1633	181	6.95
Weeded until 8 weeks	2120	19	9.39
Weeded after 4 weeks	2119	-	9.77
Weeded 4-6 weeks	1635	239	6.36
Weeded 4-8 weeks	2234	6	9.99
Pyrazone (pre-em.)	386	550	1.36
Pyrazone/ethofumesate (pre-em.)	1271	328	4.99
Hoed once	255	782	0.75
Phenmedipham (post-em.)	826	471	2.98
Phenmedipham/ethofumesate (post-em.)	1433	271	6.13
Pyrazone (pre-em.) + phenmedipham	1692	117	7.15
Pyrazone/ethofumesate (pre-em.) + phenmedipham/ethofumesate (post-em.)	1805	98	7.53
Standard error	±89.9	±68.8	±0.463

Crops treated with a combination of phenmedipham and ethofumesate post-emergence, produced twice the amount of sugar as those receiving phenmedipham alone. This treatment combined the contact herbicidal effect of phenmedipham and ethofumesate with the residual effect of ethofumesate. This extended the period of control of C. album, improved control of P. annua, and severely checked groundkeeper potatoes. T. maritimum ssp. inodorum on the other hand was quite resilient. The overall effect on crop performance resembled handweeding between four and six weeks. A single post-emergence application of phenmedipham to crops which were treated with pyrazone pre-emergence gave weed control and sugar yields markedly higher than either of the herbicides alone. By restricting the stages of weed growth and weakening established weeds, pyrazone paved the way for more effective action by phenmedipham. C. album was controlled well, but some late germinators infested the crop, particularly between rows. The very much lower densities of C. album in this treatment enabled groundkeeper potatoes to thrive. The surrounding commercial crop received this herbicide treatment and several days of handweeding were required to remove the potatoes. The combination of pyrazone pre-emergence and phenmedipham post-emergence resulted in weed control, and sugar yields similar to those of crops handweeded for six weeks.

The combination of pyrazone/ethofumesate pre-emergence and phenmedipham/ethofumesate post-emergence gave the most complete weed control and the highest sugar yields of herbicide treated crops. Similar numbers of C. album infested this and the pyrazone + phenmedipham treated crop but the use of ethofumesate affected their appearance. Mature plants consisted of a single main stem, heavy with dark coated seeds which remained on the stem until final harvest. Potato groundkeepers, although temporarily severely stunted by the treatment, outgrew the check, and thrived in the presence of few other weeds.

A single hoeing, coinciding with the application of phenmedipham to other treatments, led to very heavy weed infestations. Existing weeds were moderately well controlled but soil disturbance brought more weed seeds to the surface and caused a flush of weed emergence, with the whole weed spectrum represented.

Pre-emergence herbicides did not appear to depress crop vigour. Adverse effects were most marked (Table 4) in crops to which the sole treatment was a post-emergence application of phenmedipham/ethofumesate, more so than where this followed pyrazone/ethofumesate pre-emergence. Fresh and dry weights of roots, crowns and leaves were all depressed. Leaf number was not affected, but leaves were smaller and thicker than those of handweeded controls. Leaf distortion and fusion along leaf margins was particularly noticeable when ethofumesate was used in a post-emergence mixture but symptoms completely disappeared by mid-season.

Table 4

The effect of post-emergence herbicides on crop and weed dry weight (g/m^2)

Treatment	21 May Crop dry wt	21 May Weed dry wt	5 July Crop dry wt	5 July Weed dry wt
Handweeded	2.30	-	673	-
Phenmedipham	1.71	4.24	307	481
Phenmedipham/ ethofumesate (post-em.)	1.23	2.31	461	156
Pyrazone (pre-em.) + phenmedipham (post-em.)	1.67	1.21	538	79
Pyrazone/ethofumesate (pre-em.) + phenmedipham/ethofumesate	1.50	0.01	504	81
Standard Error	±0.168	±0.608	±33.2	±67.1

Table 5 shows evidence that over a six week period the growth checks were overcome to a certain extent, except apparently where phenmedipham was used. By the second sampling, however, weeds which escaped control by the herbicides were exerting competitive effects.

DISCUSSION

Hull and Webb (1970) observed that late-sown sugar beet had fewer annual weeds. Presumably preliminary cultivations to work in fertilisers caused weeds to germinate which were subsequently destroyed during seedbed preparation. In the present experiment winter ploughed ground remained unworked until the day of the late sowing and few weeds had established on the plough mould, which had become dry and consolidated. The few autumn established T. maritimum ssp. inodorum and S. media plants which did exist were more difficult to kill than when in a more juvenile stage in March. The hazard of commencing cultivations at an early stage to eradicate part of the weed flora prior to sowing is that seedbed conditions are formed prematurely which can be difficult on some soils to maintain, or recreate, in the event of heavy rain.

As in previous experiments data from the handweeded treatment demonstrated that control measures need not commence until four weeks after emergence, irrespective of sowing date. The implication is that it may be desirable to aim for universally effective post-emergence herbicides and dispense with pre-emergence treatment. If this were to be done then it is likely that a sequence of post-emergence doses would be needed, timed to coincide with each flush of weed emergence during the critical period. Experience in 1973 suggests that this may be more difficult to achieve in early sowings where weeds emerge over a prolonged period so that by the time sufficient seedlings are evident to warrant treatment the earliest germinators are already beyond the susceptible stage. By dealing with these and restricting the range of growth stages which subsequent treatments have to cope with pre-emergence herbicides pave the way for effective use of post-emergence herbicides. In later sowings, where events are more concentrated, reliance exclusively on post-emergence control may be a more realistic proposition. This is just as well for it is in warm dry soil that weeds may be expected to escape the action of soil applied herbicides. The year 1973 was an exception but usually these conditions are more frequent when sowing late. The 1973 experiment suggests a potential hazard in relying on a sequence of post-emergence applications. If each brings a check to growth then the accummulated effect may be more serious in the long term than the checks from single doses, which previous experiments have shown to be largely outgrown. This may be particularly important if supplemented by other adverse effects, e.g. pest and disease attack.

It may be desirable to control weeds which establish after the critical period if they impede harvest or produce seed which creates problems in subsequent crops. Both in early and late sown crops, such C. album and T. maritimum ssp. inodorum. plants which were present at harvest had completely senesced and were very brittle. They were readily dealt with in the surrounding commercial crop by a standard "bolter slasher". On the other hand P. aviculare remained green and tough, especially where gaps existed and would undoubtedly have been capable of entwining itself in elevators, cleaner loaders or factory equipment. In past experiments weedy treatments have increased the amount of seed in the soil. Counts in succeeding crops have shown that where crop establishment has been good and growth vigorous standard herbicide treatments to cereals, potatoes or leys have masked any carry-over effects but in fallow, headlands or patchy areas the legacy of exceedingly weedy treatments as long ago as 1968 is still obvious.

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EXPERIMENTS TO DISCOVER THE EFFECT OF SEQUENTIAL APPLICATION OF DIFFERENT HERBICIDES ON THE GROWTH OF SUGAR BEET

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Summary The effect of herbicides on the growth and yield of sugar beet was measured in three trials carried out from 1971 to 1973. In the absence of serious weed competition there were adverse effects on the beet from the use of phenmedipham used post-emergence in 1971; and from TCA pre-drilling in 1972 and 1973. No evidence was obtained of any damage to the crop from normal or reduced applications of the residual pre-emergence herbicides lenacil, pyrazone or propham/chlorpropham/fenuron.

There was no evidence of any adverse interaction between any of the herbicides on the growth of the beet.

INTRODUCTION

The shortage of labour for hand hoeing sugar beet has made imperative the need for a virtually complete control of weeds by the use of herbicides. Because no single herbicide can yet achieve consistent control of a wide spectrum of weed species there has been increasing interest in the sequential use of different herbicides (Baldwin and Armsby 1970, Norfolk Agricultural Station 1970, Griffiths and Swalwell 1970, Short 1972). While this leads to improved weed control, the effect of a multiplicity of herbicide treatments on the beet themselves has not received much attention, and could become a factor of importance as weed populations decline and herbicide toxicity to the crop becomes proportionally more serious than the effect of weed competition.

The aim of these experiments was to measure the effect of various combinations of herbicide treatments on the development and yield of sugar beet in the absence of weeds, or at least in situations where competition from weeds was not likely to become an over-riding limitation to crop development.

There was an obvious practical limit to the number of herbicide interactions that could be included as treatments, but in view of current trends it was thought essential that pre-drilling, pre-emergence and post-emergence applications should be in the trials. Phenmedipham was the obvious choice for the post-emergence treatment as no other reasonably effective herbicide was available.

TCA was chosen for the pre-drilling treatment rather than di-allate, because the interaction between di-allate and various pre-emergence herbicides had already been examined (Bray and Hilton 1968) while the position with regard to TCA and any possible interactions had not been fully investigated. Residual pre-emergence herbicides included in the trial were pyrazone, lenacil and a propham/chlorpropham/fenuron mixture. The rates of these materials have to be adjusted to soil type, and can prove critical to the safety of the crop. Because of this and the suggestion that rates may be reduced where a post-emergence herbicide follows (Norfolk Agricultural Station 1970, Griffiths and Swalwell 1970), it was decided to include both a full commercial rate and a reduced rate of each of the three pre-emergence residual herbicides.

METHOD AND MATERIALS

The trials were situated in commercial crops of sugar beet in Cambridgeshire and there were three replications at each site. Herbicides were applied using a Van der Weij plot sprayer fitted with the 6 ft boom of an Oxford Precision Sprayer.

The materials were applied to plots 12 ft x 16 ft at a volume of 20 gal/acre and pressure of 32 lb/in^2 using 00 jets (Allman).

Visual assessments were made of crop and weed vigour before the applications of the phenmedipham and measurements were made of crop plant diameter during the growing season.

The trials were harvested by hand and plant populations were assessed at this time.

The roots were washed and sugar percentages measured in a tare house.

Site Details

	1971	1972	1973
Soil type	Org ZyCL	Calc SL	Calc SL
Organic matter (%)	5.2	3.2	3.6
pH	7.6	7.5	7.6
Row width	20 in.	21 in.	21 in.
Variety	Bush Mono	Sharpe's Polybeet	Sharpe's Polybeet
Seed spacing	4½ in.	5½ in.	5½ in.
Date TCA applied	11 March	16 March	14 March
Cultivations (before TCA applied)	None	Spring tine harrow twice Dutch harrow Roll Light harrow	One light spring tine (Lilla Harrie)
Cultivations (after TCA applications)	Spring tine harrow Dutch harrow	Dutch harrow Roll Light harrow	One light spring tine (Lilla Harrie)
Drilled	8 April	22 March	19 March
Pre-emergence applications	14 April	23 March	26 March
Crop emerging	3 May	11 April	25 April
Post-emergence applications	18 May	10 May	14 May
Beet counts and growth assessments	18 May 18 May 4 June	9 May 9 May 19 May 19 June	14 May 14 May 25 June
Hand singling	7 June	Nil	Nil
Harvest (plot size 4 rows x 12 ft)	15 October	5 October	15 October

Treatments

	Control untreated
Pre-drilling	TCA 13.8 lb a.i./ac
Pre-emergence (All applied after TCA)	Lenacil 2 lb a.i./ac " 1 lb a.i./ac Pyrazone 3.6 lb a.i./ac " 1.6 lb a.i./ac Propham chlorpropham fenuron 8 pints/ac) of proprietary mixture " " " 4 pints/ac) containing 2.25 lb/gal a.i.
	All the above treatments were with and without
Post-emergence	Phenmedipham 1.0 lb a.i./ac

Yields clean beet (tons/acre)

Treatments	1971 Phenmedipham 1.0 lb a.i./ac		1972 Phenmedipham 1.0 lb a.i./ac		1973 Phenmedipham 1.0 lb a.i./ac		Mean Phenmedipham 1.0 lb a.i./ac	
	Without	With	Without	With	Without	With	Without	With
Untreated Control	18.39	17.26	12.54	12.03	14.41	16.04	15.11	15.11
TCA 13.8 lb a.i./ac	19.69	15.61	8.88	10.68	14.24	14.56	14.27	13.61
TCA + lenacil 2 lb a.i./ac	18.77	17.20	10.10	10.43	14.34	14.77	14.40	14.13
TCA + lenacil 1 lb a.i./ac	18.63	17.86	9.61	10.80	14.39	15.51	14.21	14.72
TCA + pyrazone 3.6 lb a.i./ac	19.49	17.48	11.26	10.12	15.52	13.32	15.35	13.64
TCA + pyrazone 1.8 lb a.i./ac	18.08	17.14	9.76	10.56	14.59	14.67	14.15	14.13
TCA + PCF* 8 pints/ac	19.20	16.88	10.73	9.90	14.32	15.18	14.75	13.99
TCA + PCF* 4 pints/ac	18.68	17.59	10.31	9.49	14.02	14.63	14.34	13.90
SE	± 0.60		± 0.63		± 0.72		± 0.416	
Mean	18.87	17.13	10.40	10.50	14.45	14.84	14.57	14.15
SE	± 0.21		± 0.22		± 0.25		± 0.15	

* PCF = proprietary propham/chlorpropham/fenuron

Sugar content (%)

Treatments	1971 Phenmedipham 1.0 lb a.i./ac Without	1971 With	1972 Phenmedipham 1.0 lb a.i./ac Without	1972 With	1973 Phenmedipham 1.0 lb a.i./ac Without	1973 With	Mean Phenmedipham 1.0 lb a.i./ac Without	Mean With
Untreated control	19.6	19.1	17.7	17.4	16.2	17.1	17.8	17.9
TCA 13.8 lb a.i./ac	19.5	19.3	17.1	17.2	16.7	16.4	17.8	17.6
TCA + lenacil 2 lb a.i./ac	19.3	18.8	17.3	17.5	16.4	15.1	17.6	17.4
TCA + lenacil 1 lb a.i./ac	19.3	19.3	17.2	17.2	16.3	16.5	17.6	17.7
TCA + pyrazone 3.6 lb a.i./ac	19.2	19.2	17.2	16.9	16.4	16.2	17.6	17.5
TCA + pyrazone 1.8 lb a.i./ac	19.6	18.9	17.1	17.3	16.8	16.8	17.8	17.7
TCA + PCF* 8 pints/ac	19.3	18.9	17.0	17.1	16.5	16.7	17.6	17.6
TCA + PCF* 4 pints/ac	19.2	19.2	17.3	17.1	15.7	16.2	17.4	17.5
SE	± 0.20		± 0.18		± 0.27		± 0.14	
Mean	19.4	19.1	17.2	17.2	16.4	16.5	17.7	17.6
SE	± 0.07		± 0.06		± 0.10		± 0.05	

Sugar yield (cwt/acre)

Treatments	1971 Without	1971 With	1972 Without	1972 With	1973 Without	1973 With	Mean Without	Mean With
Untreated control	72.2	65.8	44.4	42.0	46.8	54.8	54.4	54.2
TCA 13.8 lb a.i./ac	76.8	60.2	30.4	36.8	47.8	47.8	51.7	48.3
TCA + lenacil 2 lb a.i./ac	72.2	64.6	35.0	36.4	47.0	47.6	51.4	49.5
TCA + lenacil 1 lb a.i./ac	71.6	69.0	33.2	37.2	46.8	51.2	50.6	52.5
TCA + pyrazone 3.6 lb a.i./ac	74.6	67.1	38.8	34.2	50.2	43.2	54.6	48.2
TCA + pyrazone 1.8 lb a.i./ac	70.6	64.9	33.4	36.6	49.0	49.2	51.1	50.2
TCA + PCF* 8 pints/ac	74.1	63.7	36.4	33.8	47.4	50.8	52.6	49.4
TCA + PCF* 4 pints/ac	71.6	67.6	35.8	32.6	44.2	47.6	50.6	49.3
SE	± 2.42		± 3.38		± 2.58		± 1.64	
Mean	72.9	65.4	36.0	36.2	47.4	49.0	52.1	50.2
SE	± 0.85		± 0.85		± 0.92		± 0.58	

* PCF = proprietary propham/chlorpropham/fenuron

Plant populations at harvest ('000s/acre)

Treatments	1971 Phenmedipham 1.0 lb a.i./ac		1972 Phenmedipham 1.0 lb a.i./ac		1973 Phenmedipham 1.0 lb a.i./ac	
	Without	With	Without	With	Without	With
Untreated control	27.1	27.1	29.0	30.2	26.4	29.3
TCA 13.8 lb a.i./ac	28.8	26.4	27.1	31.1	25.0	26.4
TCA + lenacil 2 lb a.i./ac	28.4	22.9	33.7	28.0	27.0	26.3
TCA + lenacil 1 lb a.i./ac	28.2	30.2	31.4	30.1	26.1	28.8
TCA + pyrazone 3.6 lb a.i./ac	29.8	29.0	32.1	31.8	28.7	28.7
TCA + pyrazone 1.8 lb a.i./ac	27.1	25.6	29.9	32.0	28.5	29.7
TCA + PCF* 8 pints/ac	29.2	25.3	31.8	31.3	26.8	27.7
TCA + PCF* 4 pints/ac	28.8	24.6	31.4	32.3	26.4	29.0
Mean	28.9	26.4	30.8	30.8	26.9	28.2

Average number of true leaves in June

Untreated control	6.0	5.0	10.8	9.5	11.8	11.6
TCA 13.8 lb a.i./ac	6.2	4.4	9.4	10.3	12.3	11.2
TCA + lenacil 2 lb a.i./ac	6.0	4.5	9.3	9.6	12.4	11.6
TCA + lencail 1 lb a.i./ac	6.5	4.6	9.5	8.9	11.8	12.7
TCA + pyrazone 3.6 lb a.i./ac	5.6	4.2	10.2	9.1	12.2	11.6
TCA + pyrazone 1.8 lb a.i./ac	6.0	4.3	8.6	9.7	12.1	11.3
TCA + PCF* 8 pints/ac	5.7	4.7	10.4	9.5	10.2	11.4
TCA + PCF* 4 pints/ac	5.7	4.7	11.1	9.2	11.3	12.1
Mean	5.9	4.6	9.9	9.5	11.8	11.7

* PCF = proprietary propham/chlorpropham/fenuron

Average plant span (inches)

Treatments	1971 Phenmedipham 1.0 lb a.i./ac		1972 Phenmedipham 1.0 lb a.i./ac		1973 Phenmedipham 1.0 lb a.i./ac	
	Without	With	Without	With	Without	With
Untreated control	9.1	6.3	12.5	10.8	17.6	19.6
TCA 13.8 lb a.i./ac	9.2	5.9	9.5	10.5	19.6	18.1
TCA + lenacil 2 lb a.i./ac	9.4	5.0	9.9	10.6	18.4	17.8
TCA + lenacil 1 lb a.i./ac	9.3	5.4	10.6	9.5	19.5	19.1
TCA + pyrazone 3.6 lb a.i./ac	8.2	5.4	10.4	9.7	20.4	20.3
TCA + pyrazone 1.8 lb a.i./ac	9.1	5.5	8.7	9.4	18.7	17.3
TCA + PCF* 8 pints/ac	8.5	5.5	10.7	9.5	17.0	18.6
TCA + PCF* 4 pints/ac	8.9	5.8	9.6	10.0	17.1	20.4
Mean	8.9	5.6	10.2	10.0	18.5	18.9

* PCF = proprietary propham/chlorpropham/fenuron

RESULTS

The use of phenmedipham resulted in an obvious check to the growth of the sugar beet in 1971, probably due to abnormal periods of high temperatures following application. This check persisted until the end of June and was reflected in reduced yields of beet and a slightly depressed sugar content.

In 1972 and 1973 TCA, applied rather closer to the time of drilling than is normally recommended, was also responsible for a significant yield reduction. In 1973 a dry, cold period of weather delayed crop growth in the early stages and may have accentuated the damage. The pre-emergence herbicides did not have any obvious damaging effects on yield.

DISCUSSION

Though the aim was primarily to measure the effects of the herbicides on the beet, there were complications due to the presence of weed, because this could not always be removed soon enough or completely enough to be sure that no competition had occurred: there were indications for example that grass weeds competed with the crop on the control plots in the first year. In spite of this, the mean yield from the untreated control treatment was among the highest. There was a tendency for the use of the higher rates of the pre-emergence herbicides to lead to increased yields where phenmedipham had not been used. This was presumably due to more weed competition where reduced rates of pre-emergence herbicides were used. Where phenmedipham was applied, weed control was adequate in any case and the use of higher rates of pre-emergence herbicides did not show to advantage.

Though the presence of small amounts of weed slightly confused the picture, it appeared that there was no evidence of adverse interactions between herbicides on crop development or yield. There were, however, instances of adverse effects from certain herbicides on the yield of the crop and it would therefore appear wise to restrict herbicide applications to the minimum necessary to achieve control of the weeds present or expected.

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NOTES

Proceedings 12th British Weed Control Conference (1974)

THE EFFICIENCY OF HERBICIDES BASED ON PYRAZONE, ETHOFUMESATE, LENACIL AND PHENMEDIPHAM, USED ALONE OR IN COMBINATION, IN SUGAR BEET GROWN UNDER ROMANIAN CONDITIONS

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Summary Trials were conducted in 1972 and 1973 in 5 regions of Romania to investigate the efficiency of herbicides based on pyrazone, ethofumesate, lenacil and phenmedipham on the differing soils. Both grass and broad-leaved weeds occurred, and results obtained from herbicides used alone were unsatisfactory with many species uncontrolled. Mixture of herbicides, or sequential treatments were required for satisfactory weed control, and the best results were obtained using the herbicide ethofumesate associated either with lenacil or phenmedipham.

INTRODUCTION

Our first experiments on herbicides for use in sugar beet crops were effected in 1964. From the analysis of results obtained on different soil types, conclusions were drawn similar to those advanced by Holmes (1966) and Eddowes (1966). On the chernozem soils, lenacil efficiency was higher than that of pyrazone (Sarpe et al., 1967, 1969). Satisfactory results have been obtained during recent years, with our research having been directed to combinations of herbicides belonging to different chemical groups. A broadened weed control spectrum with satisfactory control of both monocotyledon and dicotyledonous weeds was thereby achieved. (Sarpe et al 1973). In this report are presented some of the results obtained.

METHOD AND MATERIALS

The herbicides used in these trials were as follows:-

pyrazone:- 5-amino - 4 - chloro-2-phenylpiridazin - 3(2H)-one

lenacil:- 3-cyclohexyl - 6,7-dihydro-1H-cyclopentapyrimidine-2,4-(3H,5H) dione

ethofumesate:- 2-ethoxy - 2,3-dihydro-3,3-dimethylbenzofuran-5-yl methylsulphonate

phenmedipham:- 3-(methoxycarbonylamino) phenyl N-(3'-methylphenyl)carbamate

The experiments were laid out as latin squares, replicated 4 times. Plot size was 25 m^2. The herbicides were applied before sowing and incorporated to a depth of 6 - 8 cm with the help of a moto-cutter. Assessments of herbicidal efficiency were carried out during the season and the results were expressed in EWRC scale units. Immediately prior to crop harvest, the weight of weeds present was determined after selection into three groups, annual monocotyledonous, annual dicotyledonous and perennial weeds.

The experiments were effected in 5 localities, representing different zones of Romania.

RESULTS

In Table 1 are presented the results obtained at Fundulea, Lovrin and Turda, all situated on chernozem soils with 3.5 - 5.8% humus and 34 - 58% clay. The main weeds in order of numerical importance, were Setaria spp., Sinapis arvensis, Raphanus raphanistrum, Echinochloa crus-galli, Amaranthus retroflexus, Polygonum spp., Hibiscus ternatus, Chenopodium album, Thlaspi arvense, Stachys annua, Cirsium arvense, Sonchus spp.

In 1972, 20 days of unsettled weather followed pre-emergent application of herbicides, the quantity of precipitation being 28 mm at Fundulea, 7.4 mm at Lovrin and 20 mm at Turda. In these conditions pyrazone showed only a very slight herbicidal effect on the chernozem soils. Lenacil was better, especially against dicotyledonous weeds but the sugar yield in the lenacil plots was unsatisfactory due to the presence of resistant and uncontrolled monocotyledonous species.

The results obtained using ethofumesate, in the first year's trial researches corroborated reports from other countries (Pfeiffer, 1969; Pfeiffer and Holmes, 1972).

The herbicide ethofumesate used at the rate of 2 - 4 kg a.i./ha showed good effect against the following weeds: Setaria spp., E. crus-galli, A. retroflexus and a very slight effect upon the species H. ternatus and T. arvense. Again due to the presence of resistant species of weeds, the sugar yield was considerably reduced from this treatment.

On the chernozem soils, the best results were obtained from plots treated with ethofumesate + lenacil, applied pre-sowing. The tank-mix of ethofumesate plus pyrazone was less effective, because pyrazone at a dose of 3 kg/ha fails to control weed species resistant to ethofumesate. The sequence:- ethofumesate followed by phenmedipham, showed a satisfactory control of monocotyledonous and dicotyledonous weeds.

At Brasov and at Tirgu Mures (see Table 2) different results were obtained. At Brasov on a soil containing 2.8 - 3% humus good results were obtained using lenacil and very unsatisfactory results using pyrazone. At Tirgu Mures, on soil containing only 1.7% of humus, pyrazone and lenacil gave similar results. Ethofumesate had a reduced overall effect due to the prevalence of the following broad-leaved weeds:- R. raphanistrum, S. arvense, C. album, Veronica spp., H. ternatus and Polygonum convolvulus. The monocotyledonous weeds Setaria spp. and E. crus-galli were less numerous than at other sites. For all that, at these experimental stations the best results were obtained in plots treated with the herbicide mixtures ethofumesate + lenacil or phenmedipham, while on soils poorer in humus content ethofumesate + pyrazone gave similar control.

In 1973 many combinations with ethofumesate were investigated. The combinations studied and the results obtained are shown in Tables 3 and 4. On the chernozem soils of Fundulea, Lovrin and Turda the best results were obtained in plots treated before sowing and soil incorporated with ethofumesate + lenacil (ppi) or with ethofumesate (ppi) + phenmedipham (post-emergence). Post-emergence applications of ethofumesate + phenmedipham also appear interesting, but this technique needs further study, because at Brasov and at Tirgu Mures (Table 4) unsatisfactory results were obtained

DISCUSSION

Because of the soil types, and the large number of weed species, both dicotyledon and monocotyledonous, which occur in the sugar beet growing regions of Romania, satisfactory weed control cannot be obtained with any single currently available herbicide. Only combinations, either as tank mixes or as sequential treatments, have given satisfactory results.

Pre-emergence (surface) treatments give good results only under wet (abnormal) spring conditions. Reliability is improved under normal conditions by shallow (4 - 6 cm) incorporation of herbicides pre-sowing. The use of ethofumesate and lenacil pre-sowing has in these conditions proved the most effective, giving control of mono and dicotyledons superior to that achieved by ethofumesate and pyrazone.

Good results were also obtained by the sequential treatment of ethofumesate (ppi) followed by phenmedipham (post-emergence).

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Table 1

Weed control and yield data - 1972 trials

Treatment			Fundulea			Lovrin			Turda		
Herbicides[x]	Dose kg/ha a.i.	Time of application	Weeds t/ha	Sugar beet t/ha	Sugar beet %	Weeds t/ha	Sugar beet t/ha	Sugar beet %	Weeds t/ha	Sugar beet t/ha	Sugar beet %
Control I-hoed 3 times			0	53.2	100	0	33.7	100	0.8	38.2	100
Control II-not hoed			24.0	10.2	19	20.5	2.5	7	5.3	17.8	47
Pyrazone	4.5	pre-em.	23.2	12.4	23	19.5	5.2	15	2.9	22.2	58
Lenacil	0.8	ppi	15.5	17.3	32	19.4	6.5	19	2.5	25.5	67
Lenacil	2.4	ppi	11.1	18.7	35	17.5	14.6	43	1.0	33.5	88
Ethofumesate	2.0	ppi	18.8	10.4	19	22.0	12.8	38	2.1	26.3	69
Ethofumesate	3.0	ppi	15.5	21.6	41	16.3	10.6	31	2.2	26.5	69
Ethofumesate	4.0	ppi	10.6	25.4	48	10.7	10.9	32	1.8	31.0	81
Phenmedipham	1.0	post-em.	22.9	12.5	23	14.5	11.4	34	3.1	26.0	68
Ethofumesate + lenacil	2.6 + 1.6	ppi + ppi	4.6	32.2	61	6.7	20.2	66	1.0	37.4	98
Ethofumesate + pyrazone	2.0 + 3.0	ppi + ppi	10.7	20.7	39	20.0	7.9	23	1.8	33.9	89
Ethofumesate + phenmedipham	2.0 + 1.0	ppi + post-em.	7.2	27.8	52	3.9	29.0	86	2.1	31.7	83
			LSD 5%	10.8			7.8			7.6	
			1%	14.4			10.4			10.1	
			0.1%	18.6			13.5			13.3	

x The plots treated with herbicides were not hoed.

Table 2

Weed control and yield data - 1972 trials

Treatment			Brasov			Tirgu Mures		
Herbicides[x]	Dose kg/ha a.i.	Time of application	Weeds t/ha	Sugar beet t/ha	Sugar beet %	Weeds t/ha	Sugar beet t/ha	Sugar beet %
Control I-hoed 3 times			0	34.2	100	0	36.0	100
Control II-not hoed			18.1	6.9	20	16.0	10.7	30
Pyrazone	4.5	pre-em.	17.8	6.5	19	3.2	29.0	80
Lenacil	0.8	ppi	0.5	25.8	75	0.8	33.5	93
Lenacil	2.4	ppi	0.5	34.9	102	0.5	34.3	95
Ethofumesate	2.0	ppi	8.1	20.1	59	9.0	22.8	63
Ethofumesate	3.0	ppi	5.3	20.4	60	8.2	22.9	63
Ethofumesate	4.0	ppi	3.9	23.9	70	4.0	26.8	74
Phenmedipham	1.0	post-em.	3.4	25.3	74	3.5	29.2	75
Ethofumesate + lenacil	2.6 + 1.6	ppi + ppi	0.5	33.5	98	0.3	37.7	104
Ethofumesate + pyrazone	2.0 + 3.0	ppi + ppi	3.8	28.4	83	0.6	33.4	93
Ethofumesate + Phenmedipham	2.0 + 1.0	ppi + post-em.	1.0	31.4	92	0.9	33.4	93
			LSD 5%	5.6			6.5	
			1%	7.4			8.7	
			0.1%	9.6			11.2	

x The plots treated with herbicides were not hoed.

Table 3

Weed control and yield data - 1973 trials

Treatment			Fundulea			Lovrin			Turda		
Herbicides[x]	Dose kg/ha a.i.	Time of application	Weeds t/ha	Sugar beet t/ha	Sugar beet %	Weeds t/ha	Sugar beet t/ha	Sugar beet %	Weeds t/ha	Sugar beet t/ha	Sugar beet %
Control I-hoed 3 times			0.5	25.2	100	0.2	33.1	100	0	43.2	100
Control II-not hoed			5.0	1.3	5	2.6	4.7	14	8.3	5.7	13
Pyrazone	4.5	pre-em.	3.0	4.3	17	2.0	8.6	26	3.9	26.7	60
Lenacil	2.4	ppi	4.2	7.8	31	1.2	26.1	79	2.3	34.2	79
Ethofumesate	2.0	ppi	3.7	3.2	13	1.9	11.4	34	5.8	18.6	43
Phenmedipham	1.0	post-em.	4.1	5.5	22	1.8	12.5	38	6.1	16.3	38
Ethofumesate + lenacil	2.0 0.7	ppi ppi	4.1	3.8	15	1.2	24.1	73	2.6	34.3	19
Ethofumesate + lenacil	2.0 0.7	pre-em. pre-em.	5.1	8.7	34	1.9	13.7	41	3.5	25.7	59
Ethofumesate + lenacil	2.6 1.6	ppi ppi	2.4	15.4	61	0.8	25.4	77	2.5	35.8	81
Ethofumesate + pyrazone	2.0 3.0	ppi ppi	4.5	3.4	13	1.8	15.7	47	3.2	33.3	77
Ethofumesate + phenmedipham	2.0 1.0	ppi post-em.	1.5	25.3	100	1.2	25.2	76	1.6	35.9	83
Ethofumesate + phenmedipham	1.0 1.0	post-em. post-em.	1.9	25.0	100	0.8	27.6	83	4.3	17.6	41
		LSD 5%		5.3			6.5			7.7	
		1%		7.0			8.7			10.5	
		0.1%		9.1			11.3			13.2	

x The plots treated with herbicides were not hoed.

Table 4

Weed control and yield data - 1973 trials

Treatment			Brasov			Tirgu Mures		
Herbicides[x]	Dose kg/ha a.i.	Time of application	Weeds t/ha	Sugar beet t/ha	Sugar beet %	Weeds t/ha	Sugar beet t/ha	Sugar beet %
Control I-hoed 3 times			0	30.8	100	0.8	20.8	100
Control II-not hoed			4.7	2.1	7	9.1	0.8	4
Pyrazone	4.5	pre-em.	2.0	8.7	28	4.1	9.3	44
Lenacil	2.4	ppi	1.3	22.9	74	3.0	12.0	57
Ethofumesate	2.0	ppi	2.9	7.4	24	7.9	2.6	12
Phenmedipham	1.0	post-em.	1.8	13.5	44	7.0	3.5	17
Ethofumesate + lenacil	2.0 0.7	ppi ppi	1.4	17.7	56	8.3	5.7	28
Ethofumesate + lenacil	2.0 0.7	pre-em. pre-em.	1.5	18.8	61	8.7	3.8	18
Ethofumesate + lenacil	2.6 1.6	ppi ppi	1.2	19.6	64	3.7	11.0	53
Ethofumesate + pyrazone	2.0 3.0	ppi ppi	1.8	10.9	35	6.9	8.1	39
Ethofumesate + phenmedipham	2.0 1.0	ppi post-em.	1.2	20.9	68	8.7	5.2	28
Ethofumesate + phenmedipham	1.0 1.0	post-em. post-em.	1.3	13.0	42	9.5	1.7	8
			LSD 5%	13.0			5.8	
			1%	17.4			7.8	
			0.1%	22.6			10.0	

x The plots treated with herbicides were not hoed.

NOTES

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THE ACTIVITY OF LENACIL ON PEAT SOILS FOR WEED CONTROL IN SUGAR BEET

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Summary An examination has been made of the use of lenacil soil incorporated on fen peat soils. Various methods of incorporation were tested and a surface application was also made.

All levels of lenacil and the various methods of incorporation appeared safe to the crop.

Incorporation of lenacil by rotovator gave better and more consistent weed control than any other incorporation technique, particularly where the seedbed had been levelled by a heavy roller prior to spraying. The use of a rotovator however is not very popular with some fen farmers because of the loosening and drying effect it produces.

INTRODUCTION

High organic matter soils, in particular, fen peats present weed control problems because of their high adsorptive characteristics, and certain herbicides are not recommended because of the prohibitive rates which would be required. Experimental work has shown that mixtures of chlorpropham and fenuron exhibit activity on peat soils (Bray, 1968) but weed control in the past has been based mainly on mixtures of propham, chlorpropham and fenuron (Bracey, 1967) of which there are now several commercial formulations, and also on a mixture of propham and medinoterb (Bartlett and Emery, 1966; Bartlett and MacDonald, 1967). However lenacil, which has already been widely investigated on mineral soils by Cussans (1964), Caldwell and Eddowes (1966), Forrest et al (1966), Holmes (1966), Marks (1966), Bray and Cussans (1968), Bray (1970), gave promising results when used on organic peat soils (Ramand et al 1970 a & b). Through incoroporation into the surface of the peat was essential because no activity was observed with surface application even after heavy rain (Ramand, 1969).

In 1970 a trials series was started to examine the effect of different methods of incorporation at three different dosage rates. In this year little was known about the rates needed for adequate activity, and as a result all levels were below those eventually recommended. Subsequent commercial recommendations were based on organic matter content. In 1971 and 1972 three levels were tested, the middle one being based on organic matter content and applicable to the site in question, and rates of approximately 25 per cent above and below this level.

In each year the work was undertaken at two sites for which in general the optimum rate of application on inspection was thought to be 1.5 lb a.i./ac. On the six sites over the three years the lowest rate used was 1.0 lb and the highest rate was 3.0 lb a.i./ac. In each year rotovation was used as a means of incorporation at all sites. This was tested against an alternative method, which in most cases was one or two passes of a springtined cultivator depending upon the degree of incorporation achieved. At Methwold Hythe in 1970 an ingenious home-made incorporator was used. This consisted of a revolving cylinder with ribs of angle iron which churned up the soil and was geared to twice ground speed. At all sites the two methods of incorporation were tested against a straightforward surface application using the same three rates of herbicide and an untreated control to evaluate the physical effect of incorporation. All sites were drilled as soon after incorporation as possible.

Table 1

Site details

Year and location	Soil types	Drilled	Sprayed	Rain after spraying (in.) 1 week	4 weeks
1970					
A. Methwold Hythe, Norfolk	light peat	21 Apr	21 Apr	0.65	1.17
B. Conington, Peterborough	light peat	26 Apr	22 & 27 Apr	0.25	1.32
1971					
C. Burnt Fen, Suffolk	light peat	1 Apr	1 Apr	0.00	1.08
D. Conington, Peterborough	light peat	22 Apr	20 & 23 Apr	1.44	2.06
1972					
E. Newborough, Peterborough	light peat	21 Mar	21 Mar	0.15	1.23
F. Burnt Fen, Suffolk	peaty loam	4 Apr	29 Mar & 7 Apr	0.65	1.33

METHODS AND MATERIALS

The investigations were undertaken on commercial crops of sugar beet. The layout was fully factorial and the treatments replicated four times. The plot size used for spraying was 1/200 ac.

Chemicals were applied overall in a water volume of 50 gal/ac by an Oxford Precision Sprayer fitted with Birchmeier Helico Sapphire 1.6-673a-1.3 nozzles operating at a pressure of 25 or 30 lb/in^2.

The lenacil used was an 80 per cent wettable powder formulation.

Records

1. Pre-singling: Twelve random quadrat (4 x 18 in.) counts were taken on each plot, the number of beet and the dominant weed species recorded individually. Also visual assessments of crop and weed vigour were taken on a scale 0-10.

2. Post-singling: A mid-season count of the beet in the centre two rows of each plot was made for the assessment of final population.

3. Yield. Where possible the same beet that had been counted in mid-season were hand lifted, washed, weighed and then analysed for sugar content.

Table 2

Pre-singling assessments on sugar beet seedling numbers (% of untreated)

Dose (% recommended) — Site and methods of incorporation

1970	Methwold Hythe (A) Surface (nil)	Roto-vation	Rotating cylinder	Mean	Conington Fen (B) Surface (nil)	Roto-vation	Springtine 1 pass	Mean
0	100 (27.4)*	104	71	92	100 (71.1)*	90	90	94
35	106	108	93	103	95	100	98	98
60	107	88	99	98	97	101	102	100
75	99	100 (±8.6)	101	100 (±5.0)	92	92 (±4.5)	98	94 (±2.6)
Mean	103	100 (±4.3)	91		96	96 (±2.2)	97	

1971	Burnt Fen (C) Surface (nil)	Roto-vation	Springtine 1 pass	Mean	Conington Fen (D) Surface (nil)	Roto-vation	Springtine 1 pass	Mean
0	100 (69.1)*	103	103	102	100 (59.2)*	101	85	95
75	110	102	107	106	80	81	97	86
100	101	98	101	100	79	79	104	87
125	107	102 (±4.2)	100	103 (±2.4)	97	86 (±9.1)	105	96 (±5.3)
Mean	104	101 (±2.1)	103		89	87 (±4.6)	98	

1972	Burnt Fen (E) Surface (nil)	Roto-vation	Heavy springtine 2 passes	Mean	Newborough (F) Surface (nil)	Roto-vation	Springtine 1 pass	Mean
0	100 (60.5)*	97	98	98	100 (42.8)*	105	101	102
75	100	102	110	104	101	109	104	104
100	91	101	97	96	100	100	102	101
125	102	100 (±6.5)	110	104 (±3.8)	106	110 (±7.6)	112	110 (±4.4)
Mean	98	100 (±3.3)	104		102	106 (±3.8)	105	

* '000/ac on untreated

RESULTS

Effect on sugar beet: Pre-singling assessments on the crop (Tabel 2) showed that none of the treatments significantly reduced beet seedling numbers. There was a hint however of a slight but not significant loss at Conington in 1971. The low figure in 1970 at Methwold Hythe with the home-made incorporator in the absence of lenacil was almost certainly due to the high weed population on this particular treatment.

At Methwold Hythe 8 in. seed spacing was employed and the resulting plants were left untouched whilst at all other sites the seeds were spaced closer (3-4 in. depending on centre) and were subsequently hand singled. Although slight differences in seedling numbers were recorded before singling all sites had adequate final beet numbers for fen peat soils when assessed in July.

Table 3

Summary of pre-singling assessments on total annual weed numbers (% of untreated)

Dose (% recommended)	Methods of incorporation Surface	Rotovation	Other	Mean
	1970 - mean of 2 sites			
0	100	98	120	106
35	92	76	101	90
60	75	97	91	87
75	81	72	62	72
Mean	87	86	94	
	1971/72 - mean of 4 sites			
0	100	108	104	104
75	106	58	63	75
100	86	48	62	65
125	75	30	52	52
Mean	92	61	70	

Table 4

Pre-singling assessments on total annual weed numbers (% of untreated)

Dose (% recommended)	Method of incorporation Surface	Roto-vation	Other	Mean	Surface	Roto-vation	Other	Mean
1970	Methwold Hythe (A)				Conington Fen (B)			
0	100 (1365)*	101	140	114	100 (1202)*	94	98	97
35	92	74	120	95	92	78	78	84
60	80	117	102	100	68	74	78	73
75	84	72	65	74	77	73	58	69
		(±17.5)		(±10.1)		(±8.7)		(±5.0)
Mean	89	91	107		84	79	79	
		(±8.7)				(±4.3)		

Table 4 (continued)

Dose (% recommended)	Method of incorporation: Surface	Roto-vation	Other	Mean	Surface	Roto-vation	Other	Mean
1971	Burnt Fen (C)				Conington Fen (D)			
0	100 (508)*	113	100	104	100 (1136)*	134	83	106
75	106	106	53	89	115	41	58	72
100	101	76	68	82	110	36	60	69
125	124	32 (±12.2)	50	69 (±7.0)	87	37 (±18.4)	75	66 (±10.6)
Mean	108	82 (±6.1)	68		103	62 (±9.2)	69	
1972	Burnt Fen (E)				Newborough (E)			
0	100 (488)*	76	116	98	100 (2073)*	100	114	105
75	74	48	72	64	108	57	66	77
100	63	47	65	58	73	48	60	61
125	50	42 (±12.8)	44	45 (±7.4)	61	23 (±14.6)	41	42 (±8.4)
Mean	72	53 (±6.4)	74		86	57 (±7.3)	70	

* '000/ac on untreated

Yield assessments were taken at sites A, C, D, E, F. The only significant effect on sugar yield was caused by rotovation at site C (Burnt Fen) where the mean yield was reduced inexplicably by 5.3 cwt/ac when compared with the 73.9 cwt/ac from one pass of a springtined cultivator.

Effect on weeds: A summary of pre-singling assessments of total weed population is shown in Table 3. In 1970 the rates used were too low and poor weed control resulted. In the succeeding trials weed control was variable but rotovation tended to give more reliable results than any other method. Rotovation at the recommended rate of lenacil gave more than 50 per cent control of total weeds at sites D, E and F, and at Newborough in 1972 control in excess of 75 per cent was achieved with the rate higher than that recommended. At this site a high population of over two million weed seedlings per acre was recorded on the untreated controls (Table 4).

Polygonum proved troublesome on most sites and only slight control was recorded (Table 5). There were even cases of these weeds exceeding those of the untreated plots where competition had been reduced by the excellent control of the more susceptible weeds such as *Urtica urens*, *Chenopodium album* and particularly *Stellaria media*. The exception to this was by rotovation at Newborough in 1972 where control of *Polygonum spp.* in excess of 60 per cent was obtained with the recommended rate of lenacil and 85 per cent control with the highest dose used (Table 6). The control of *S. media* and *C. album* by both rotovation and tined cultivator was adequate at the recommended rate of lenacil at those sites where these weeds occurred with the exception of 1970, but the rotovation appeared to give better control of *C. album*. *U. urens* occurred at Conington in 1971 and was controlled better by the rotovation treatments than by springtine cultivator.

Table 5

Summary of pre-singling assessments on total numbers of Polygonum spp. (% of untreated)

Dose (% recommended)	Surface (nil)	Rotovation	Other	Mean
		1970 - mean of 2 sites		
0	100	119	129	116
35	92	102	162	119
60	84	179	138	134
75	103	136	94	111
Mean	95	134	131	
		1971/72 - mean of 3 sites		
0	100	91	116	102
75	106	61	64	77
100	73	47	61	60
125	67	21	40	43
Mean	87	55	70	

DISCUSSION

This series of trials has given useful information over a number of seasons on the use of lenacil on fen peat soils. Lenacil was safe, even with slight over-dosing, and gave reasonable control of most of the weeds experienced on these soil types, with the possible exception of Polygonum spp.

Table 6

Pre-singling assessments on total numbers of Polygonum spp. (% of untreated)

Dose (% recommended)	Methods of incorporation Surface	Roto-vation	Other	Mean	Surface	Roto-vation	Other	Mean
1970	Methwold Hythe (A)				Conington (B)			
0	100 (370)*	134	148	127	100 (160)*	84	86	90
35	102	103	200	135	71	100	74	81
60	92	228	171	164	66	65	67	66
75	108	151	97	119	92	102	85	93
		(±51.4)		(±29.7)		(±15.6)		(±8.9)
Mean	101	154	154		82	88	78	
		(±25.7)				(±7.8)		

Table 6 (continued)

Dose (% recommended)	Surface	Roto-vation	Other	Mean	Surface	Roto-vation	Other	Mean
1971		Burnt Fen (C)						
0	100 (256)*	94	91	95				
75	90	118	70	93				
100	98	94	91	94				
125	118	51 (±12.4)	70	80 (±7.1)				
Mean	102	89 (±6.2)	80					
1972		Burnt Fen (F)				Newborough (E)		
0	100 (67)*	97	143	113	100 (1853)*	90	114	101
75	125	67	125	106	108	53	61	74
100	60	93	93	81	70	39	56	55
125	93	67 (±22.4)	60	73 (±13.0)	60	15 (±14.2)	36	37 (±8.2)
Mean	94	81 (±11.2)	104		84	49 (±7.1)	67	

*'000/ac on untreated

Incorporation of the herbicides by rotovator appeared to give the best results. At Newborough in 1972 the seedbed was rolled prior to spraying and incorporation. This gave a more uniform incorporation, thus eliminating the problems of dilution of herbicides by too deep incorporation and inadequate mixing by too shallow working. However, some growers prefer not to use rolls on this soil type claiming that it breaks up small clods which may help to prevent wind erosion. Similarly, implements such as rotovators which loosen the surface may also render the soil more liable to 'blow' and consequently are not very popular on fen peats. This could preclude the wide acceptance of this technique.

A useful adaptation is suggested by Ramand (1970) where lenacil was band sprayed and incorporated with an inter-row hoe. As well as the saving in cost of material, the resulting weeds between the rows may help to prevent wind erosion and can be removed later by inter-row cultivation or spraying.

Lenacil soil incorporated lends itself more to specialised techniques which are the province or larger growers and agricultural contractors. Because the incorporation of lenacil by rotovation did not produce outstanding control its acceptance will depend upon the performance of other herbicides and weed control techniques.

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PRE-EMERGENCE AND POST-EMERGENCE USE OF ETHOFUMESATE IN SUGAR BEET

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Summary Since 1972 an experimental programme on the use of ethofumesate alone and in mixtures in pre- and post-emergence applications has been in progress in Britain, France, Austria and Greece. In pre-emergence applications a high degree of crop safety was confirmed; long-term control of a wide range of grass and broad-leaved weeds was obtained by the use of ethofumesate in mixtures with pyrazone or lenacil or by a pre-emergence treatment followed by phenmedipham. Studies on the crop safety of ethofumesate + phenmedipham applied post-emergence have shown growth stage of the beet to be of major importance. Excellent weed control was obtained with this post-emergence treatment.

INTRODUCTION

By the end of 1972 extensive testing by sugar beet specialists throughout Europe and in the USA had shown ethofumesate to be a herbicide of marked promise for use in sugar beet with a high degree of crop safety and a weed spectrum complementary to that of other herbicides. (Pfeiffer, 1969; Pfeiffer and Holmes, 1972; Sullivan, Fagala and Ross, 1972)

In 1973 and 1974 the authors carried out research programmes in Britain, France, Austria and Greece to make a closer study of the performance of ethufumesate alone and in mixtures for both pre- and post-emergence use. This report gives an outline of the results obtained with selected treatments and considers some findings of particular interest. Results from similar work in 1972 are included where relevant.

METHOD AND MATERIALS

In each year a standard experimental design was used in all countries. The location and numbers of experiments are shown below:

Country	Year	Area	No. of expts. and application time	
			Pre-emergence	Post-emergence
Britain	1973	Eastern counties	13	13
	1974	Eastern counties	-	3
France	1973	Nord and Alsace	12	12
	1974	Loiret	-	3
Austria	1973	Eastern and NW Austria	10	6
	1974	Eastern Austria	-	3
Greece	1973	Thessaloniki area	3	3
	1974	Thessaloniki area	-	2

Pre-emergence experiments in 1973

Ethofumesate alone was tested at doses from 0.75 to 6.0 kg/ha and at 0.75 to 2.0 kg/ha in mixtures with pyrazone or lenacil. Plot size was $24m^2$ with phenmedipham applied post-emergence on $8m^2$ of each plot. There were 3 replications. Visual assessments on crop growth and weed control were made at least twice during the season. Counts of beet were made on 2 rows x 12m of each plot, i.e. 72m of row per treatment. Leaf deformities were counted on the same areas.

Post-emergence experiments in 1973

Ethofumesate and phenmedipham were used alone and in mixtures at 0.75, 1.0 and 1.5 kg/ha ethofumesate and 0.66 and 1.0 kg/ha phenmedipham. Plot size was $16m^2$ with 2-4 replications. Weed control and crop response were assessed visually.

Post-emergence experiments in 1974

In each country complex experiments were carried out to test the safety of ethofumesate + phenmedipham applied at different growth stages and in different environmental conditions. In each experiment 3 drillings of beet were sprayed with 3 mixture doses at 6 application times. Other variables were also included and the total number of treatment combinations was 216. Plot size was $20m^2$ with 2 replications. Weed control and crop growth were assessed visually. Beet stand was assessed by counting sample areas of 10 rows x 1m per plot before and after treatment. Leaf deformities were counted on the same areas.

Ethofumesate was used throughout as a 20% emulsifiable formulation.

RESULTS

Pre-emergence experiments

(a) Crop safety

In the pre-emergence experiments in 1973 the effect of ethofumesate at doses up to 6 kg/ha was assessed on stand of beet, vigour of growth, incidence of leaf deformity and, in 4 experiments, on yield.

Counts of beet plants were made in all experiments, and the results for 5 treatments are shown in Table 1.

Table 1

% stand of sugar beet in 4 countries

	Dose of ethofumesate (E), pyrazone (P) and lenacil (L) in kg/ha					
	E 1.5	E 6.0	E 1.5 P 2.0	E 1.5 L 0.5	P* rec.	L* rec.
Britain	111	110	111	111	107	106
France	103	99	103	105	98	106
Austria	102	98	100	101	105	95
Greece	106	103	106	98	99	-

* pyrazone and lenacil alone were used at locally recommended doses, usually 3.2 kg/ha pyrazone and 0.8 kg/ha lenacil.

There was a tendency for treated plots to give higher figures than untreated controls, particularly in Britain where it was thought to be due to an early-developing and very heavy weed infestation.

Much work has been carried out on the occurrence of deformity of beet leaves which is sometimes observed after use of ethofumesate. At the completion of these studies the results and conclusions are as follows:

(a) At an ethofumesate dose of 1 kg/ha the frequency of major deformity was less than 1% in 88% of the trials; 1-2% in 6% of the trials; over 2% in 6% of the trials.

(b) Recovery of the plants was rapid. In northern Europe in 1973 deformity had largely disappeared by the end of June on plants treated with 1 kg/ha ethofumesate. At higher doses, deformity disappeared more slowly, but by harvest time only a negligible proportion of plants showed any sign of abnormal growth, even after treatment with doses as high as 6 kg/ha.

(c) The effect of leaf deformity during the season on root weight at harvest was examined on individual marked plants. The significance of the results is low because of the low frequency of deformity and thus the small number of affected plants available. The results indicate however that minor deformity did not affect root weight, but, as would be expected, the occasional marked deformity resulted in reduced weight of roots. As has been shown above, the frequency of such major deformity is extremely low, and the effect on yield per hectare is therefore negligible.

(d) Adding pyrazone or lenacil to ethofumesate or following ethofumesate treatment with phenmedipham did not increase the effect in any consistent manner.

(e) In laboratory studies on the occurrence of deformities at 2 temperatures (15°C and 24°C), the frequency of deformity was lower at the low temperature, but the effect persisted longer because of the slower growth in cool conditions.

(f) An indication of differences in susceptibility was found between different strains of sugar beet.

Sugar beet yields in 22 experiments in 1972/73 are given in Table 2. Root weights are expressed as percentages of weights for the standard pyrazone treatment. All plots were hoed.

Table 2

Mean root weight as % of pyrazone

	No.of expt.	Dose of ethofumesate kg/ha 2	4
1972 - Britain	7	100.3	100.1
Austria	5	102.2	103.6
France	6	99.7	92.7
1973 - Britain	4	96.9	-

The yield figures illustrate the wide margin of selectivity of ethofumesate considering that doses giving effective weed control are in the range of 1 - 1.5 kg/ha.

(b) Weed control

The overall weed control given by pre-emergence treatments in 33 experiments is shown in Table 3. The results are for 4 doses of ethofumesate alone and in mixtures with pyrazone or lenacil. All pre-emergence treatments were tested with and without a subsequent application of phenmedipham.

Table 3

Mean % weed control in 33 experiments in 1973

Other pre-emergence herbicide	Not followed by phenmedipham					Followed by phenmedipham 1.0 kg/ha				
	Dose of ethofumesate kg/ha					Dose of ethofumesate kg/ha				
	0	0.75	1.0	1.5	2.0	0	0.75	1.0	1.5	2.0
0	0	50	62	72	80	70	89	90	93	95
Pyrazone 2 kg	73*	77	81	88	88	91*	92	93	96	97
Lenacil 0.5 kg	63*	73	78	85	89	88*	91	94	95	97

* Pyrazone and lenacil alone were used at locally recommended doses, usually 3.2 kg/ha pyrazone and 0.8 kg/ha lenacil.

Weed populations included grasses as well as a wide range of broad-leaved species and the results show the advantage of combining ethofumesate with another pre-emergence herbicide to extend the spectrum of both components. The best results were obtained by using phenmedipham after a pre-emergence treatment.

The above table shows the weed control observed during May; late-season (July) assessments were made at 14 sites, and the results are summarised in Table 4.

Table 4

% weed control in May and July

		Dose of ethofumesate (E), pyrazone (P), lenacil (L), in kg/ha					Phenmedipham
		E 1.5 -	E 1.5 P 2.0	E 1.5 L 0.5	P rec.	L rec.	1.0
Not followed by phenmedipham	May	81	92	83	73	69	-
	July	54	83	78	60	64	
Followed by phenmedipham	May	98	99	97	92	91	72
	July	92	95	96	87	86	53

The results show the very high level of long-term weed control which can be obtained by making two herbicide applications, one pre-emergence and one post-emergence. The 14 experimental sites included 5 with serious infestations of grass weeds, mainly *Alopecurus myosuroides* and 2 with *Avena fatua*. The most common broad-leaved weed was *Chenopodium album*; other weeds causing serious infestations included *Amaranthus retroflexus*, *Galium aparine*, *Sinapis arvensis*, *Polygonum* spp. and *Matricaria* spp.

In a few experiments it was possible to make counts of weeds which had emerged late in the season. This information is limited, but it indicates that 1.5 kg/ha ethofumesate + pyrazone or lenacil gave about 90% control of Solanum nigrum (1 experiment) and Mercurialis annua (2 experiments). In both cases assessments of the young plants were made in early July.

The percentage control given by pre-emergence treatments on 26 weed species is shown in Table 7.

Post-emergence experiments

(a) Crop safety

The complex experimental programme carried out in 1974 was designed primarily to study the crop safety of mixtures of ethofumesate and phenmedipham applied post-emergence. In each experiment beet at three growth stages was sprayed at 6 different times in order to compare the treatment effects under conditions of varying temperature and light intensity.

As expected the beet was most sensitive if sprayed when it was small. Table 5 gives figures for plant stand on fixed sampling areas where the beet were counted before and after treatment. The figures are means of 10 experiments.

Table 5

% stand of beet sprayed at 3 growth stages

Crop growth stage	Untreated	Ethofumesate + phenmedipham 0.6+ 0.5	1.0+* 0.8	1.5+ 1.2	Phenmedipham 1.2
Cotyledons	98	99	88	78	94
2 leaves	101	100	97	89	100
4 leaves	100	103	100	97	100

* suggested optimum experimental dose

Growth stages in each experiment were variable owing to irregular emergence, but the figures suggest that even the highest dose had little effect at the 4-leaf stage whereas at the cotyledon stage only the lowest dose of the mixture was safe.

It was clear from the results that safety was influenced by other factors as well as growth stage. High temperature and light intensity are probably of considerable importance: for instance in Greece where spraying temperatures were as high as 30°C the medium dose reduced stand by over 40% at the cotyledon stage whereas some of the experiments in Britain and France showed no reduction at the same dose and growth stage. Nevertheless, even in Greece plant stand was not reduced by this dose when applied at the 4-leaf stage.

The treatments sometimes caused scorch and frequently checked the growth of the beet. In some experiments and at certain times of application a marked reduction in size was visible 1-2 weeks after spraying, but the plants recovered rapidly and after another 2-3 weeks growth appeared normal. Leaf deformities were occasionally observed, but the incidence at the doses tested was very low. At the dose of 1.0 kg/ha ethofumesate + 0.8 kg/ha phenmedipham the incidence of marked deformity was not more than 0.5% in any experiment, and most experiments showed only occasional minor leaf adhesions.

(b) Weed Control

In 1973 ethofumesate was tested post-emergence at doses of 0.75, 1.0 and 1.5 kg/ha in mixtures with phenmedipham at 0.66 and 1.0 kg/ha. Doses in the main experiments in 1974 were slightly different, nevertheless some comparison can be made of the results obtained in the two years. In Table 6, 1973 results are given only for the doses which are nearest to those tested in 1974.

Table 6

% weed control with post-emergence treatments in 1973 and 1974

	Dose of ethofumesate (E) and phenmedipham (Ph) in kg/ha									
	1973 Results						1974 Results			
	E1.5	Ph 1.0	E+Ph 0.75 +0.66	E+Ph 1.0+ 0.66	E+Ph 1.0+ 1.0	E+Ph 1.5+ 1.0	Ph 1.2	E+Ph 0.6+ 0.5	E+Ph 1.0+ 0.8	E+Ph 1.5+ 1.2
Britain	56	65	76	78	85	88	53	76	85	87
France	61	65	87	92	94	95	84	94	98	99
Austria	53	64	60	82	85	95	75	78	91	92
Greece	55	73	85	90	93	98	83	90	93	94

The stage of growth of the weeds at spraying varied, but as a broad indication the majority of plants were in the 2-6 leaf stage. The experiments were assessed 2 to 3 weeks after spraying. Table 6 shows that, as previously found, ethofumesate applied post-emergence was not effective when used alone, though it caused marked suppression of the growth of some weeds. Average figures for phenmedipham alone are also low owing partly to the presence of resistant weeds and partly to the time of application which in a number of experiments was too late for optimum results with this herbicide. In both years and in all four countries, combinations of the two herbicides gave high levels of weed control. Differences between the countries are probably due to prevalence of certain weeds in the areas in which the experiments were carried out, for instance, in Britain Polygonum aviculare was one of the more important weeds and one which was difficult to control completely. Ethofumesate + phenmedipham was more effective on this species than phenmedipham alone, but timing of the application at a moderately early growth stage was still important.

Results on a number of weeds indicated that timing of application with the mixture was less critical than with phenmedipham alone so that a longer period was available for effective spraying. For instance, on Polygonum convolvulus phenmedipham gave excellent control when the majority of the plants were in the 1-leaf stage but by the time laterals were developing the plants were no longer so suceptible. The mixture of ethofumesate 1.0 and phenmedipham 0.8 kg/ha gave at least 95% control from the time of emergence up to the 4-5 leaf stage.

The susceptibility of 21 weed species to 3 mixtures of ethofumesate and phenmedipham and to phenmedipham alone is shown in Table 8. The number of experiments from which results were obtained is shown in the first column. Application was at a relatively early growth stage, but on some species was later than is recommended for phenmedipham alone. Information on these weeds is limited, but the table indicates a satisfactory weed spectrum for the medium-dose mixture.

Table 7

% control of 26 weeds with pre-emergence treatments in 1973

Dose in kg/ha

Weed species	No. of expts.	Ethofumesate 1.0	1.5	2.0	3.0	Ethofumesate + pyrazone 1.0+ 2.0	1.5+ 2.0	2.0+ 2.0	Ethofumesate + lenacil 1.0+ 0.5	1.5+ 0.5	2.0+ 0.5	Pyrazone rec.	Lenacil rec.
Aethusa cynapium	1	72	72	76	90	93	92	93	97	91	98	91	89
Alopecurus myosuroides	5	89	97	98	99	94	97	98	93	96	98	55	53
Amaranthus lividus	1	40	90	100	100	85	90	100	80	90	90	35	35
Amaranthus retroflexus	3	88	92	96	97	89	94	98	95	97	97	66	44
Anagallis arvensis	1	35	20	88	90	75	98	85	60	80	75	85	40
Atriplex patula	3	87	91	94	95	93	90	93	96	93	93	83	96
Avena fatua	11	61	76	83	91	57	76	86	63	76	84	22	20
Chenopodium album	18	76	81	92	95	88	91	93	83	87	91	79	82
Chenopodium hybridum	2	59	75	94	95	84	88	94	78	80	86	74	70
Echinochloa crus-galli	2	45	48	53	55	48	50	60	33	45	50	0	3
Fumaria officinalis	4	71	91	95	99	97	97	74	71	75	75	70	63
Galium aparine	5	81	87	96	97	84	91	96	82	90	93	45	28
Galeopsis tetrahit	1	93	95	95	95	95	100	100	100	100	100	100	100
Lapsana communis	1	0	0	25	30	50	92	95	-	-	80	100	70
Melandrium album	2	77	88	98	100	97	98	98	98	98	97	75	71
Myosotis arvensis	2	12	53	65	82	100	100	99	41	98	93	94	97
Polygonum aviculare	5	71	67	67	96	96	96	97	96	87	98	95	87
Polygonum convolvulus	10	69	79	85	94	88	91	96	76	89	93	78	63
Polygonum persicaria	7	59	66	74	78	82	86	93	76	81	86	86	73
Sinapis arvensis	6	24	32	51	61	83	88	90	69	80	83	84	78
Solanum nigrum	2	80	84	92	95	83	80	95	77	89	89	69	40
Stellaria media	6	97	98	99	99	97	98	100	100	100	100	86	86
Thlaspi arvense	2	50	55	65	78	98	100	99	84	97	95	100	90
Tripleurospermum maritimum	7	37	46	65	71	97	84	99	92	79	97	99	96
Veronica agrestis	4	76	95	94	87	100	99	100	96	90	98	100	76
Viola arvensis	5	46	49	65	72	88	96	76	63	71	69	88	31

Table 8

% control of 21 weeds with post-emergence treatments in 1974

Weed species	No. of expts.	Dose of ethofumesate + phenmedipham kg/ha 0.6+ 0.5	1.0+* 0.8	1.5+ 1.2	Phenmedipham 1.2 kg/ha
Alopecurus myosuroides	1	48	73	83	10
Amaranthus retroflexus	3	84	91	94	67
Anagallis arvensis	5	98	99	100	95
Avena fatua	2	22	73	79	9
Chenopodium album	8	95	98	98	84
Chenopodium hybridum	1	81	93	100	67
Fumaria officinalis	2	95	98	99	94
Galium aparine	2	68	82	89	47
Mercurialis annua	2	68	74	85	5
Poa annua	1	76	93	96	0
Polygonum aviculare	4	72	82	92	43
Polygonum convolvulus	6	97	99	99	65
Setaria spp.	2	91	96	98	74
Sinapis arvensis	3	96	96	98	81
Solanum nigrum	2	98	99	99	91
Sonchus oleraceus	1	99	100	100	97
Stachys annua	1	43	50	64	15
Stellaria media	1	98	100	100	79
Tripleurospermum maritimum	1	12	25	70	30
Veronica hederifolia	1	100	98	99	75
Viola arvensis	2	98	100	100	92

*Dose suggested for experimental use.

Growth stage at spraying was in general within the 2 to 6 leaf stages.

DISCUSSION

It is clear from the weed control tables that considering the broad-spectrum weed control now essential in sugar beet production ethofumesate used alone either pre- or post-emergence would usually prove inadequate. It is equally clear that because of its weed spectrum, crop safety and adaptability of use, ethofumesate has much to contribute towards achieving a high standard of weed control by means of relatively simple herbicide programmes.

The experimental results suggest three main types of herbicide programme in which ethofumesate could be used:

Pre-emergence in mixtures with pyrazone, lenacil or other proven residual herbicides

Pre-emergence followed by phenmedipham

Post-emergence in mixtures with phenmedipham

A number of variations on these basic systems are of course possible, and can be developed to suit local requirements.

In pre-emergence use the crop safety of ethofumesate has in general proved to be of a very high order even in cases of heavy overdosing. In the post-emergence use of ethofumesate + phenmedipham, safety is dependent on temperature and other environmental factors as well as on the growth stage of the beet. This treatment will therefore need care in the timing of the application.

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Proceedings 12th British Weed Control Conference (1974)

ETHOFUMESATE BEHAVIOUR IN THE SOIL

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Summary This paper summarises the results of 5 years' experiments carried out in Europe and the USA on the behaviour of ethofumesate in the soil. Ethofumesate is not usually leached below 5-10 cm in the soil; this restricted leaching pattern may be explained partly by its low solubility and partly by its adsorption onto the soil complex. The disappearance of ethofumesate from the soil is almost entirely due to the action of micro-organisms. The effect of possible residues on succeeding crops has been investigated in considerable detail. The safety of ethofumesate at recommended rates to the following crop of wheat was clearly established.

INTRODUCTION

Numerous experiments have been carried out on the soil behaviour of ethofumesate by the authors and co-operators over the last 5 years in Europe and the USA. This paper summarises the results available to date covering: the effect of soil type on ethofumesate activity, leaching, sorption in the soil, decomposition and the safety of ethofumesate to the soil microflora.

RESULTS

1. Effect of soil type on the activity of ethofumesate

Experiments were carried out on soil types ranging from high organic to sandy soils. In a representative greenhouse study, 4 widely different soils were compared at 3 rates of ethofumesate using *Panicum miliaceum*, *Setaria italica*, *Papaver rhoeas* and *Matricaria tripleurospermum* as test plants with varying susceptibility. The results in Table 1 are shown as averages of the 4 species.

Table 1

% growth reduction of four species

Ethofumesate rate (kg a.i./ha)	Sandy soil	Coarse sandy loam	Loam soil	Organic sandy clay loam
2.00	92	77	74	67
0.66	76	69	52	35
0.22	46	12	5	0
Average	71	53	44	34
Soil composition				
% organic matter	1.08	1.49	2.36	8.79
% clay (fractions < 50 μ)	11.22	38.41	50.49	48.66
% total sand	87.70	60.10	47.15	42.55

The table shows the dependence of the percentage growth reduction on the dose rate. A correlation of dose rate with soil type was found, to the extent that a sandy soil required less and both a loam and an organic soil required more ethofumesate than a coarse sandy loam, in order to obtain the same percentage of growth reduction. The extremes are that an organic soil required about 4 times and a loam about 3 times as much chemical as did a sandy soil, and the need to vary the dose by soil type as with other soil herbicides is strongly implied.

2. Movement in the soil

2.1 Evaporation

The vapour pressure of ethofumesate is 6.45×10^{-7} mm Hg at 25°C. Vapour pressures of three other well known herbicides are: Atrazine 3.0×10^{-7} mm Hg at 20°C, pyrazone 7.4×10^{-2} mm Hg at 40°C and EPTC 1.0×10^{-1} mm Hg at 24°C. This shows that the value for ethofumesate is relatively low and although most of the ethofumesate remains in the top 5–10 cm of the soil, no significant losses by evaporation are expected. This also implies that ethofumesate is taken up from the soil water solution, and does not act through the vapour phase. This has been fully confirmed by biological experiments.

2.2 Leaching

The amount of leaching of ethofumesate is governed by the following factors: the solubility (110 ppm at 25°C in H_2O), the degree of adsorption onto the soil constituents and the amount of precipitation occurring and its distribution with time. In soils with a low or normal organic matter content, adsorption will occur, but it will be of a low order when compared with other herbicides, as referred to in paragraph 3. The low solubility of ethofumesate limits its movement in the soil, and in most fields leaching is not likely to exceed 10 cm in any one season. The degree of leaching as influenced by the low solubility of ethofumesate and by the degree of adsorption has been assessed under a range of conditions, of which the following are representative examples:

(i) Soil columns were filled with either low organic compost soil or a coarse sandy loam to which a top layer of 6.3 mm of sand mixed with ethofumesate, trietazine or EPTC was added. A total of 200 mm irrigation was applied either during an

8 day period or during 1 day. The degree of leaching was assessed by bio-assay using wheat sown over the length (20 cm) of the soil profile. The results are shown in Table 2.

Table 2

Herbicide	Soil type	Dose kg a.i./ha	Period over which water was applied days	Depth of maximum activity cm	Greatest depth of activity cm
Ethofumesate	Low organic compost	4.4	8	2.5	7.5
Ethofumesate	Coarse sandy loam	4.0	8	7.5	12
Ethofumesate	Coarse sandy loam	4.0	1	9.5	14
Trietazine	Coarse sandy loam	4.0	8	5	10
EPTC	Low organic compost	4.4	8	3.7	15

This experiment demonstrates the restricted leaching of ethofumesate.

(ii) A similar experiment was carried out in the open air. Pots filled with a coarse sandy loam or a loamy fine sand received a 6.3 mm top layer which contained 4 kg ethofumesate a.i./ha. All pots were placed outside for 8 weeks from mid-December to mid-February and received 30 mm natural precipitation, except in a series of pots which was protected from any precipitation. Additionally some pots received a further 37 mm irrigation. A bio-assay of wheat, sown in 1 cm slices of the soils showed the following maximal depths of leaching.

Table 3

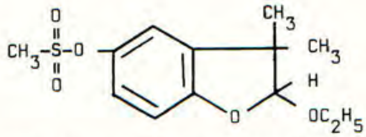
Maximal depth of leaching under various conditions

Treatment	Total precipitation mm	Soil type: Coarse sandy loam cm	Soil type: Loamy fine sand cm
Natural precipitation	30	3	2
Protected from precipitation	0	2	not assessed
Natural precipitation + additional irrigation	67	6	not assessed

In this relatively prolonged experiment, the loss of ethofumesate due to microbial breakdown was minimal due to the low temperatures involved. (see also paragraph 4)

It can be concluded from these findings that ethofumesate is not likely to leach below a depth of 10 cm in the soil under normal agricultural conditions.

3. Sorption in the soil



The molecular structure of ethofumesate suggests the availability of negative charges for ionic binding as well as the possibility of hydrogen bonding and van der Waals-London interactions with the soil complex. In practice relatively few positive charges are present in the soil complex whereas negative charges are abundant (Burns, 1972).

This leaves the much weaker hydrogen bonding and the van der Waals-London interactions. The first is likely to occur both with the clay and organic colloid, whereas the van der Waals-London interactions are likely to be restricted to the organic colloid. This is suggested by the molecular structures occurring both in the clay and the organic, and by the molecular structure of ethofumesate (Hamaker and Thomoson, 1972).

The adsorption, which represents partition between solid surface and solution can be described by the empirical Freundlich equation and which contains an equilibrium constant K_D (Hamaker and Thompson, 1972). K_D is expressed as the amount adsorbed per unit weight of soil (µg/g)/concentration in solution at equilibrium (µg/ml) (Graham-Bryce, 1972). Reisler (1973) established a value 6.5 for the K_D of ethofumesate and the value for 1/n was 1.0, under conditions which show a K_D value of 22 for diuron. The soil is described as containing 3.3% organic matter, 7% clay (fractions < 16 µ) and 90% sand.

It is known that small amounts of herbicide are adsorbed from the soil by weeds and the crop. In the case of ethofumesate only a single degradation product, the conjugated 2-ketometabolite* is likely to be present at harvest in the crop in detectable amounts (Whiteoak, 1974) . At recommended dosage rates, total residue levels in mature crops are usually below 0.1 ppm in the roots and 0.2 ppm in the tops as measured by analytical methods sensitive up to 0.02 ppm (Whiteoak, 1974) This suggests that only minute quantities of ethofumesate (0.5 to 0.8% of the normal dose rate) are likely to be absorbed and removed from the soil by the major species in a sugar beet field.

4. Decomposition processes

The molecular structure of ethofumesate suggests some proneness to chemical or enzymatic hydrolysis in the soil. In practice however neither the related 2-keto* nor the 2-hydroxy** compounds have as yet been detected in the numerous soil samples analysed. It must be concluded that under normal conditions of pH, temperature and moisture ethofumesate is relatively stable to chemical or enzymatic decomposition.

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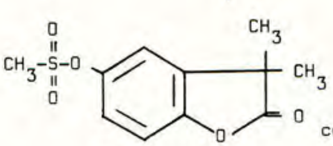

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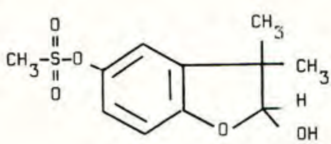

Experimental work indicates that ethofumesate is predominantly broken down by soil organisms. For example in soil samples kept frozen at -17°C for up to 9 months, the level of residues did not decrease.

Experiments were also carried out comparing the rate of ethofumesate breakdown in soil under wet or dry conditions and under low or high temperatures. The conditions were of dry soil at 2-5°C and 21°C and wet soil at similar temperatures.

Table 4 presents the mean results of this study for two different soil types (coarse sandy loam and organic clay), two rates (1 ppm and 3 ppm) and two bio-assay plants (wheat and mustard). The results are expressed as % loss of herbicidal activity as determined by bio-assay after 7 or 14 weeks, in comparison with standards using soil treated with ethofumesate and kept frozen at -17°C during the exposure period.

Table 4

Average loss in %

Weeks exposure	Conditions			
	Dry-cold	Wet-cold	Dry-warm	Wet-warm
7 weeks	13	36	40	69
14 weeks	15	40	59	90

Wheat grew normally in soil treated with 3 ppm (corresponding to about 3 kg ethofumesate a.i./ha) after 14 weeks of exposure to wet-warm conditions. However, when soil was sterilised by heat before exposure to wet-warm conditions or kept frozen at -17°C for 6 weeks no breakdown occurred, as shown in Table 5.

Table 5

% reduction of test plants under various conditions of soil storage

Species	Frozen - 17°C		Wet-warm Unsterilised		Wet-warm Sterilised	
	3 ppm	1 ppm	3 ppm	1 ppm	3 ppm	1 ppm
Wheat	100	100	60	0	100	100
Mustard	75	50	35	0	70	50

The complete elimination of breakdown by sterilisation of the soil suggests that the disappearance of ethofumesate was due to soil micro-organisms.

5. Decomposition in the field and safety to succeeding crops

A detailed study on the disappearance of residues in soil was made in relation to winter wheat, the crop most sensitive to ethofumesate, and a crop most likely to be sown after sugar beet. From 1972 to 1974 the stand of wheat or barley following sugar beet trials was assessed with regard to stunting, thinning and crop vigour. Table 5 shows the absolute rates of ethofumesate a.i./ha which were tolerated on any field in that country and in that year, under practical farming conditions. The number of trials is given in brackets.

Table 6

Maximum rate of ethofumesate (kg a.i./ha) tolerated by a following crop of wheat or barley

Year of assessment	UK	USA	France	Austria	Belgium
1972		4.5 kg (7)			
1973	4 kg (10)	3.5 kg (7)	2.5 kg *	4 kg (5)	
1974	3 kg (8)		3 kg (8)	6 kg (4)	2 kg (18) *

* No higher rates used

Farmers carried out cultivation by ploughing in most cases. But the above results include some sites where only superficial soil cultivation preceded the drilling of the cereals.

Higher doses (6 kg a.i./ha) of ethofumesate were used in 31 other trials. However, even at this high rate (3-4 times the recommended rates) only in 4 cases could damage be detected. Although stunting was observed early in the season on one trial in France, yield determinations at harvest showed no statistically significant difference from untreated plots. After treating beet pre-emergence in 1973 with rates of up to 6 kg a.i. ethofumesate/ha, the subsequent winter wheat crop was harvested at 4 locations in France according to official protocol. Statistical analysis showed no significant differences in comparison with control plots, even though on two locations the farmer had carried out only very shallow seedbed preparations following the sugar beet crop.

In view of the above and the proposed label recommendations to plough after beet sprayed with ethofumesate has been harvested, the safety margin to a following crop of winter wheat is adequate. Wheat is the most sensitive crop known to date.

6. Effects of ethofumesate on soil micro-organisms

Concentrations up to 15 ppm ethofumesate, corresponding to 10-15 times the recommended rate of application, proved to have no effect on the rate of nitrification of ammonium nitrogen or on the total microbial activity as measured by the evolution of carbon dioxide. This work suggests that ethofumesate at recommended dosage rates is most unlikely to adversely affect soil micro-organisms.(Whiteoak, 1973)

7. Conclusions

From the evidence of the glasshouse and field trials referred to, it may be concluded that the depth of leaching of ethofumesate in soils will normally be less than 10 cm. As with most residual herbicides, soils with high clay or organic content are shown to require higher dosage rates than those needed for loamy sand soils. Glasshouse tests suggested an increase of 3-4 fold, but massive field evidence from many countries has shown that a factor of 2 is sufficient to cover the likely needs of sugar beet soils.

The decomposition of ethofumesate in soil is believed to be almost entirely due to the action of soil micro-organisms. It is therefore much more rapid in warm moist soils than in cold dry soils. All field results to date show that even the highest dosage rates likely to be used in Europe of ethofumesate decompose sufficiently during the sugar beet growing season to leave the soil completely safe for winter wheat sown after ploughing. The activity of soil micro-organisms is not adversely affected by ethofumesate, even at 10 times the soil concentrations likely in practice.

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NOTES

H-22234, A NEW PRE-EMERGENCE HERBICIDE FOR SUGAR BEETS

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Summary N-Chloroacetyl-N-(2,6-diethylphenyl)-glycine ethyl ester (H-22234) has been extensively tested in Europe and the U.S.A. for selective weed control in sugar beets. H-22234 controls many annual grass weeds and some broadleaf weeds occurring in beets. Herbicidal activity is strongest, in most cases, when applied pre-emergence. Under arid conditions a shallow pre-sowing incorporation performs best. Broad-spectrum weed control has been attained using H-22234 pre-emergence and subsequently treating post-emergence with phenmedipham; or by mixing H-22234 with pyrazone or lenacil for pre-emergence application. Sugar beet tolerance is excellent, and only a temporary stunting has been observed with excessive rates.

Résumé N-Chloroacétyl-N-(2,6-diéthylphényl)-glycine éthyl ester (H-22234) était testé sur une grande échelle en Europe et aux Etats-Unis comme hericide sélectif dans les betteraves sucrières. H-22234 donne une bonne destruction des graminées annuelles et des diverses mauvaises herbes à larges feuilles qui se trouvent dans les cultures bettaravières. L'action herbicide est la meilleure dans la plupart des cas en traitement pré-émergence. Dans les régions à climat sec une incorporation peu profonde, avant semis, donne des résultats les meilleurs. Un contrôle à spectre large des mauvaises herbes est obtenu en utilisant H-22234 en pré-émergence et ensuite phenmedipham en post-émergence ou par des mélanges de H-22234 avec pyrazone ou lenacil pour des traitements de pré-émergence. La sélectivité vis-à-vis les betteraves est excellente, seulement un freinage temporaire était observé avec des dosages excessifs.

INTRODUCTION

N-Chloroacetyl-N-(2,6-diethylphenyl)-glycine ethyl ester (H-22234) is a new pre-emergence herbicide that has been extensively tested in Europe and the U.S.A. during the last three years. Weed control results and sugar beet tolerance have been very promising, and development is in advanced stages.

General biological, chemical and toxicological properties of H-22234 have been reported elsewhere (Lehman 1972, Lehman 1974, Veegens and Vergracht 1974). Time and space does not permit a complete review of results in this report. Results have been selected that are representative and indicative of what can be expected with H-22234. The purpose of this report is intended as a progress report to describe results that have been obtained.

METHOD AND MATERIALS

H-22234 is formulated as an emulsifiable concentrate containing 480 g a.i./l. Rates applied have ranged from 0.5 to 8.6 kg/ha, with the most common rates approximately 2.0 to 4.0 kg/ha. Trials were conducted under conditions that included a wide range of soil types and climatic conditions. Trial results for this report were selected to include trials conducted in Belgium, France, Germany, Holland and the U.S.A. The method and materials used in the trials reported here are generally known and common to weed control researchers. The descriptions that follow are brief and give specific details unique to the individual trial or series of trials.

Germany Four logarithmic trials were conducted on four soil types, each at a different location. Soils were: (A) a sandy soil with 4.6% organic matter, (B) a clay soil, (C) a clay loam soil, and (D) a sandy loam soil low in organic matter. H-22234 was applied in 1000 l./ha water with a propane log sprayer. Pre-sowing treatments were incorporated 4-5 cm. Treatments were applied in April or May, 1973, and evaluated during June.

Belgium Three trials reported here were conducted in Belgium. In one trial near Glabbeek, H-22234 was applied at constant dosage rates on a sandy loam soil. Plots were 20 m^2, and each treatment was replicated three times. Treatments were applied March 26 and 28, 1973. Pre-sowing treatments were incorporated 2-3 cm. Weed counts were made May 7, 1973.

Two trials were conducted near Gembloux, on a sandy loam soil with 1.5% organic matter. In these tests H-22234 was evaluated as component in various weed control systems that were compared with standard systems. Plots in each trial were 32.4 m^2, and all treatments were replicated 6 times in randomized blocks designs. Herbicides were applied in 400 l./ha water on March 19, 1973. Evaluations were made May 11, immediately prior to application of post-emergence treatments, and again May 22.

Holland A trial was established March 16, 1973 near Abbenes to evaluate H-22234 + pyrazone for Alopecurus myosuroides control in sugar beets. Soil at this trial site was a clay loam containing 35% clay and 4.0% organic matter. Weed counts were made June 8, 1973.

U.S.A. One trial is reported here in which H-22234 + pyrazone combination ratios were evaluated. The trial was conducted on the Hercules Incorporated research farm near Wilmington, Delaware, on a silty clay loam soil with 2.0% organic matter. Treatments were applied May 5, 1972, and were evaluated during July.

France A series of trials were conducted in France during 1973, to evaluate efficacy of H-22234 against weeds in sugar beets, and in particular, activity against Avena fatua. Results on A. fatua are presented here from 6 trials. These trials were initiated during March and April, 1973, and were evaluated two months after treatment. Depth of incorporation with pre-sowing treatments varied among trials from 5-10 cm. with most made at 5-6 cm. Soils at trials sites ranged from sandy loams to clays. In general, dry weather conditions prevailed following treatment.

RESULTS

Extensive tests with H-22234 in Europe and the U.S.A. have defined the spectrum of susceptible weeds. H-22234 is not a broad-spectrum herbicide; it controls most annual grasses, but it is limited in the number of broadleaf weeds controlled. The data in this report demonstrate the activity of H-22234 against some of the weeds listed in Table 1.

A. myosuroides control with H-22234 was very good, as shown by results in Tables 2, 3, 4 and 5. Rates of 2.0 to 3.0 kg/ha were required for consistent results when H-22234 was applied alone. In combination with pyrazone, 2.0 kg/ha H-22234 gave very good control. It should be noted that in two trials control was equally good with pre-sowing incorporated or pre-emergence treatments (Tables 2 and 3), but in a third trial, results were much better with pre-emergence treatments (Table 6).

Table 1

Weeds susceptible to H-22234

Monocots	Dicots
Alopecurus myosuroides	*Amaranthus* spp.
Cynodon dactylon	*Capsella bursa-pastoris*
Digitaria sanguinalis	*Euphorbia maculata*
Echinochloa crus-galli	*Matricaria chamomilla*
Eleusine indica	*Matricaria matricarioides*
Eragrostis spp.	*Physalis* spp.
Lolium multiflorum	*Portulaca oleracea*
Panicum dichotomiflorum	*Solanum nigrum*
Poa annua	*Sonchus* spp.
Setaria spp.	*Thlaspi arvense*
	Veronica spp.

Table 2

Sugar beet tolerance and weed control with H-22234 applied pre-emergence in 1973 on four soils at different locations in Germany. Ratings are on EWRC Scale

		Dosage (kg a.i./ha)						
Species	Soil 1/	8.6	6.7	3.8	2.0	1.0	0.5	0.35
Sugar beet	A	2	1	1	1	1	1	1
	B	1	1	1	1	1	1	1
	C	4	3	2	1	1	1	1
	D	2	2	1	1	1	1	1
Alopecurus myosuroides	B	1	1	1	1	3	5	6
	C	1	1	2	2	4	5	6
Poa annua	A	1	1	1	2	3	6	7
	D	1	2	2	2	4	5	6
Matricaria chamomilla	B	1	2	2	2	3	4	5
	C	1	1	1	1	2	6	7
	D	2	2	2	4	5	6	7
Stellaria media	A	1	3	5	8	9	9	9
	B	5	6	8	9	9	9	9
	D	3	4	4	4	4	4	6
Capsella bursa-pastoris	B	4	4	4	6	7	7	8
	C	1	1	1	1	1	3	4
Polygonum aviculare	A	1	2	2	3	6	7	7
	B	1	2	3	4	6	7	7
	D	1	2	4	4	5	6	7

1/ Soils: A - organic sand; B - clay; C - loess; D - sandy loam

Table 3

Average sugar beet tolerance and weed control with pre-emergence and pre-sowing incorporated treatments of H-22234 from tests conducted in Germany during 1973. Ratings are on EWRC Scale

Species	Method	No. of locations	Dosage (kg a.i./ha) 8.6	6.7	3.8	2.0	1.0	0.5	0.35
Sugar beets	pre-em.	4	2.2	1.8	1.2	1.0	1.0	1.0	1.0
	preinc.	4	2.7	1.8	1.2	1.0	1.0	1.0	1.0
Alopecurus myosuroides	pre-em.	2	1.0	1.0	1.5	1.5	3.5	5.0	6.0
	pre-inc.	2	1.0	1.0	1.5	1.5	3.0	4.5	5.5
Poa annua	pre-em.	2	1.0	1.5	1.5	2.0	3.5	5.5	6.5
	pre-inc.	2	2.0	3.0	4.5	5.5	7.0	9.0	9.0
Matricaria chamomilla	pre-em.	3	1.3	1.6	1.6	2.3	3.3	5.3	6.3
	pre-inc.	3	2.8	2.8	5.0	6.3	7.3	8.3	8.7
Polygonum aviculare	pre-em.	3	1.0	2.0	3.3	4.3	5.7	7.0	7.7
	pre-inc.	3	4.3	5.3	7.0	7.8	8.0	8.8	9.0

Table 4

Weed control in sugar beets with pre-sowing incorporated and pre-emergence application of H-22234 from tests conducted at Glabbeek, Belgium, during 1973

Herbicide	kg a.i./ha	Method	Weed Counts 1/ Mc	Pc	Pp	Sm	Vt	Ca	Am	Beet Stand
H-22234	1.80	pre-inc.	80	48	209	45	54	150	12	110
	4.32	"	66	34	118	45	60	111	14	115
H-22234	1.56	pre-em.	6	52	82	40	31	50	16	110
	2.04	"	4	26	41	135	40	0	18	104
	3.12	"	0	34	9	45	6	0	21	87
	4.32	"	0	21	36	85	12	11	2	82
H-22234 + pyrazone	1.8+3.6	pre-em.	0	15	32	5	23	0	4	82
	3.6+7.2	"	1	2	4	0	0	0	1	87
	2.0+3.6	"	0	13	4	15	10	5	6	94
Cycloate	2.73	pre-inc.	84	41	141	100	52	61	16	112
Avadex	1.4	pre-inc.	145	60	150	120	69	139	26	98
Control	-	-	336	46	22	20	48	18	96	100

1/ Mc = Matricaria chamomilla; Pc = Polygonum convolvulus; Pp = Polygonum persicaria; Sm = Stellaria media; Vt = Viola tricolor; Ca = Chenopodium album; Am = Alopecurus myosuroides.

Table 5

Schedule of treatments (kg/ha) applied to sugar beets in 2 trials at Gembloux, Belgium
Trial I consisted of treatments A-H, and Trial II of treatments I-P

Treatment	Pre-sowing inc. March 19		Pre-emergence March 20		Post-emergence May 11	
A	H-22234	1.44	-		phenmedipham	1.2
B	"	1.92	-		"	1.2
C	"	2.88	-		"	1.2
D	"	3.84	-		"	1.2
E	H-22234 + lenacil	1.44+0.4	pyrazone	3.2	-	
F	" "	2.88+0.8	"	6.4	-	
G	di-allate+lenacil	1.2+0.4	"	2.0	-	
H	cycloate+lenacil	2.16+0.4	"	2.0	-	
Control	-	-	-	-	-	-
I	-		H-22234	1.44	phenmedipham	1.2
J	-		"	1.92	"	1.2
K	-		"	2.88	"	1.2
L	-		"	3.84	"	1.2
M	-		H-22234+pyrazone	1.44+3.2	-	
N	-		"	2.88+6.4	-	
O	di-allate	1.4	pyrazone	4.0	phenmedipham	1.2
P	cycloate	2.88	"	4.0	"	1.2
Control	-	-	-	-	-	-

Table 6

Weed control and sugar beet response to schedules of herbicide treatments in Table 5

	Weed Control						Crop Injury May 22		Beet Yield at harvest	
	Weeds/m^2				EWRC Rating					
	May 11		May 12		May 22		EWRC Rating		Relative	Relative
Treatment	dicot	mono	dicot	mono	dicot	mono	Vigor	Stand	no./ha	yield
A	52.8	8.6	7.9	7.4	4.7	4.7	2.3	1.0	105.0	96.9
B	49.4	3.6	8.6	5.5	3.0	4.3	1.8	1.0	104.1	105.8
C	28.4	1.8	2.1	1.6	3.0	4.0	2.3	1.0	99.8	98.5
D	33.3	0.9	5.4	4.1	3.0	4.5	2.3	1.0	105.8	99.0
E	-	-	-	3.6	2.0	1.0	1.0	1.0	95.5	97.0
F	-	-	0.1	0.2	1.0	1.0	3.8	6.0	71.3	88.5
G	-	-	0.1	1.8	1.3	1.0	1.0	1.0	100.0	100.0
H	-	-	1.9	2.6	1.5	1.0	2.0	1.0	98.1	98.8
Control	71.4	53.2	97.4	57.2	9.0	9.0	1.0	1.0	89.0	99.0
I	7.0	0.5	1.9	0.9	-	3.5	1.5	1.0	105.4	98.6
J	5.5	0.3	1.3	0.7	-	2.0	1.0	1.0	92.1	98.0
K	4.2	-	0.7	0.6	-	1.5	1.8	1.0	89.1	93.7
L	1.4	0.1	0.9	0.4	-	1.5	3.3	1.3	98.5	100.4
M	-	-	0.4	0.8	-	1.5	1.0	1.0	98.7	96.9
N	-	-	0.3	0.2	-	1.0	1.0	1.3	93.4	97.0
O	0.1	-	-	0.1	-	1.0	2.5	2.0	100.0	100.0
P	0.4	0.1	0.1	-	-	1.0	2.5	1.5	107.2	101.0
Control	81.0	40.7	113.8	42.0	-	9.0	1.0	1.0	89.3	99.0

Poa annua, *Echinochloa crus-galli*, and *Setaria* spp. are all susceptible to H-22234 and were effectively controlled (Tables 2, 3, 4). *P. annua* control was much better with pre-emergence treatments than with pre-sowing incorporated treatments.

Matricaria chamomilla control with H-22234 was also very good (Tables 2 and 4). Rates 1.5 - 2.0 kg/ha gave 95% control, or better, in trials where H-22234 was applied as a pre-emergence treatment. When H-22234 was applied pre-sowing incorporated, there was a striking reduction in control (Tables 3 and 4).

Table 7

Alopecurus myosuroides control with combinations of H-22234 and pyrazone in a trial near Abbenes, Holland

Herbicide	kg/ha	Alopecurus % Control
pyrazone	2.4	81
	3.2	96
	4.0	80
H-22234+pyrazone	1.92 + 2.4	93
	2.40 + 2.4	97
	2.88 + 2.4	99
	1.92 + 3.2	98
	2.40 + 3.2	100
	1.92 + 4.0	99
	2.40 + 4.0	98
	2.88 + 4.0	94

Table 8

Weed control in sugar beets with pre-emergence application of H-22234 alone and in combination with pyrazone. Test conducted during 1972, near Wilmington, Delaware

Herbicide	Rate kg/ha a.i.	Percent Control Ar 1/	Ca	B	Ec	S	Percent Sugar Beet Injury
H-22234	2.24	82	8	0	93	77	0
	3.36	76	20	0	99	90	0
	4.48	90	30	0	100	100	0
cycloate 2/	4.48	98	60	0	90	93	0
pyrazone	2.24	40	73	74	70	0	0
	3.36	71	97	86	77	80	0
H-22234 + pyrazone	2.24 + 2.24	95	93	87	100	98	0
	3.36 + 2.24	99	93	99	99	94	0
	2.24 + 3.36	98	99	99	100	98	0
	3.36 + 3.36	99	100	99	100	99	0

1/ Ar = *Amaranthus retroflexus*; Ca = *Chenopodium album*; B = *Brassica* spp.; Ec = *Echinochloa crus-galli*; S = *Setaria* spp.

2/ cycloate applied pre-sowing and incorporated 5-6 cm.

Polygonum aviculare, Capsella bursa-pastoris, Viola tricolor were effectively controlled if H-22234 was applied pre-emergence at 3.0 - 4.0 kg/ha (Tables 2 and 4). Incorporation resulted in poor control.

A. fatua is only moderately susceptible to H-22234. Rates that control grasses and susceptible broadleaf weeds are generally too low for consistent A. fatua control. Results from a series of trials in France illustrate A. fatua control (Table 9). Data in Table 9 show individual ratings for three trials, an average of the three, and an average for six trials which includes data from the three shown individually. A. fatua control increased with increasing rates of H-22234, and at 3.84 kg/ha, control was equal to that with di-allate in three trials; however, in the other three trials where A. fatua populations were greater, and/or moisture conditions were less favorable, di-allate clearly outperformed H-22234. Incorporation of H-22234 pre-sowing did not improve control, and it failed completely in one trial. The results of these trials suggest that under favorable conditions a 4.0 kg/ha rate of H-22234 alone, or in combination with pyrazone, would give adequate control. The data also show that incorporation would not be necessary.

Combining H-22234 with another pre-emergence herbicide or applying it sequentially with other herbicides have given very good, broad-spectrum weed control in sugar beets. H-22234 + pyrazone mixtures were complementary in their action and controlled most weeds (Tables 4, 6, 7, and 8). Broadleaf weeds not satisfactorily controlled by H-22234, or grasses and Amaranthus spp. not satisfactorily controlled by pyrazone, were all controlled by the mixtures. The results show that the rates required when either compound is used alone, can be reduced when the two are applied together.

Sugar beet tolerance to H-22234 was excellent in all trials. Rates of 4.0 kg/ha and above sometimes caused a temporary stunting, but beets recovered and appeared normal later in the season. This temporary nature of the stunting at higher rates was confirmed by yield data showing no significant yield reduction at harvest.

Table 9

Percent control of Avena fatua with H-22234 during 1973 in France

Treatment	kg/ha	Trial I	Trial II	Trial III	Mean	Mean 6 trials
H-22234 pre-em.	1.92	64	33	82	69	64
" "	2.88	74	67	52	63	56
" "	3.84	94	58	86	86	80
H-22234 pre-sowing inc.	2.88	81	63	0	36	50
di-allate pre-sowing inc.	1.4	89	67	89	87	94
pyrazone pre-em.	2.4	72	26	87	74	54
" "	3.2	43	19	23	31	40
H-22234 + pyrazone pre-em.	2.88 + 2.4	63	63	24	45	62
" " "	2.40 + 3.2	63	70	95	79	70
H-22234 + pyrazone pre-inc.	2.4 + 2.88	70	47	78	71	76
pyrazone + di-allate pre-inc.	3.2 + 1.4	82	81	90	86	90

DISCUSSION

Numerous trials with H-22234 in sugar beets have defined the spectrum of weeds controlled, the most desirable method of application, and the rates required. Data presented here are examples of H-22234 behavior.

Many annual grasses are controlled by H-22234 at 1.5 - 2.5 kg/ha, but controlling susceptible broadleaf weeds often requires 2.0 - 3.5 kg/ha. Studies have shown that the shoot, or coleoptile, is the main site of absorption by grasses and that root uptake is secondary. Therefore, maximum activity is expected when H-22234 remains in a shallow zone area near the soil surface. Pre-emergence treatment is favored over pre-sowing incorporated treatment where some moisture may be expected after treatment but before weeds emerge. In arid regions a shallow incorporation is beneficial.

H-22234 is not a broad-spectrum herbicide, but controls many annual grasses and a more limited number of broadleaf weeds. Commercial sugar beet herbicides, as is the case with most herbicides, are selective to certain weeds and do not do a complete job. There is a need for better herbicides, or herbicides that can fill in the missing gaps. H-22234 is complementary to commonly used pre-emergence herbicides and assists in broadening the spectrum of weeds controlled. Depending on the specific weed problems, H-22234 can be applied either pre-emergence and beets subsequently sprayed post-emergence with phenmedipham, or as an alternative, H-22234 can be applied in mixture with other pre-emergence herbicides such as pyrazone, lenacil or ethofumesate. It is unlikely that H-22234 would be used as the sole chemical treatment in sugar beets.

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THE INGESTION OF WEED SEED BY EARTHWORMS

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Summary. Experiments in petri-dishes showed that Lumbricus terrestris L. ingested weed seed and subsequently a proportion of the ingested seed was found viable in the wormcast. Large numbers of seeds were found in wormcasts collected from grasslands. When the distributions of seedling and wormcast populations were mapped and the maps examined it was observed that seedlings were most often established at a site where a wormcast was found, or had previously been recorded.

It is suggested that wormcasts may be more important sites for the establishment of seedlings in a sward than has been generally realised.

Résumé. Des expériences faites dans des boites de Petri ont démontré que L. terrestris L. a ingéré des graines de mauvaise herbe et il en a résulté qu'on a découvert quelques graines viables dan chaque déjection. On a trouvé de nombreuses graines dans des déjections de vers de terre ramassées des prés. Quand on a dressé un plan de la répartition de jeunes plants et de la population des déjections et on a examiné les plans, on a observé que maintes et maintes fois les jeunes plants ont été établis à l'emplacement où on a trouvé une déjection de ver de terre ou qu'on a préalablement enrégistré.

On propose que les déjections de vers de terre soient les emplacements plus importants pour l'établissement de jeunes plants dans un gazon qu'on n'a généralement rendu compte.

INTRODUCTION

Turf which contains numerous wormcasts soon becomes infested with weeds. Weed seeds are brought up through the soil by the earthworms and quickly establish in the loose, friable soil of the casts on the surface (Fryer and Evans, 1968). There does not appear to be any substantial published evidence to support this statement, although Milton (1939) reported the presence of viable seeds in wormcasts. Studying the behaviour of seeds on the soil, Harper et al (1965) observed two wormcasts formed on the soil surface during the course of one experiment where seed of Plantago spp. had been evenly distributed over the surface. Later a large number of seedlings of Plantago lanceolata and P. major appeared in association with the casts. One possible explanation of these events is that the seeds were ingested by the earthworm and subsequently cast.

Some evidence is available to allow the suggestion that earthworms ingest seeds.

Darwin (1881) quotes Carnegie and Henson who both found viable seed in earthworm burrows. van der Pijl (1969) has quoted Dr. Doeksen who claims to have found seed inside earthworms.

This paper describes experiments designed to find whether L. terrestris ingests seeds, and whether ingested seeds are subsequently cast in a viable state. Field observations were also made to discover if viable seeds occur in wormcasts, and whether seedling emergence is correlated with wormcast production.

METHODS, MATERIALS AND RESULTS

Experiment 1. The ingestion of weed seeds by Lumbricus terrestris L.

Seeds and fruits (dispersal propagules) of 18 species of weeds were selected. Plastic petri-dishes were prepared with Whatman No. 3 filter paper to which was added 6 ml of deionised water. There were 20 replicates each of 10 seeds for each species (McRill and Sagar, 1973, for details). Where appropriate the grains had their awns removed but the lemmas and paleas were left intact. From the fruits of the compositae any pappus present was removed.

Table 1

The percentage of offered seed ingested by Lumbricus terrestris and the percentage ingested seed recovered from cast

Weed Species	Seed component tested	Percentage of offered seed ingested	Percentage of ingested seed recovered
Veronica persica Poir.	Seed	66	67
Poa annua L.	Caryopsis + palea and lemma	60	28
Silene dioica (L.) Clairv.	Seed	54	83
Agrostis tenuis Sibth.	Caryopsis + palea and lemma	50	0
Anagallis arvensis L.	Seed	49	57
Poa trivialis L.	Caryopsis + palea and lemma	40	41
Sonchus arvensis L.	Achene	31	87
Cerastium holosteoides Fr.	Seed	30	77
Sonchus asper (L.) Hill.	Achene	25	80
Capsella bursa-pastoris (L.) Medic.	Seed	24	50
Urtica dioica L.	Nut	23	52
Holcus lanatus L.	Caryopsis + palea and lemma	18	33
Trifolium repens L.	Seed	16	63
Plantago major L.	Seed	15	48
Matricaria recutita L.	Seed	8	63
Cirsium palustre (L.) Scop.	Achene	6	83
Rumex crispus L.	Nutlet	2	50
Ranunculus repens L.	Achene	1	100

The results presented in Table 1 indicate the percentage of seeds of each weed species tested that was ingested by *L. terrestris.*

L. terrestris ingested seeds, but there was a wide variation between the species, from 1% for *Ranunculus repens* to 66% for *Veronica persica.* The percentage of ingested seed cast by *L. terrestris* also varied, less than 50% of those of *Poa annua* and *P. trivialis* were recovered, while over 80% of those of *Sonchus arvensis* and *S. asper* were recovered.

Experiment 2. The seed content of earthworm casts.

Earthworm casts were collected from five grassland sites during late February 1973. The sites were at (a) the Pen-y-ffridd Experiment Station (P-Y-F), U.C.N.W., Bangor, (b) the Treborth Botanical Gardens, U.C.N.W., Bangor (c) a field close to Menai Bridge, Anglesey (O.S. Sheet 107, G.R. 546718), (d) a field close to Beaumaris, Anglesey (O.S. Sheet 107, G.R. 601772) and (e) a field at Penmon, Anglesey (O.S. Sheet 107, G.R. 624805). Five samples of wormcasts, each of 100 g fresh weight were collected from each site. Care was taken when collecting the casts not to collect soil on which the casts might be resting. The casts were placed in seed trays and regularly watered for one year. At weekly intervals any seedlings present were identified and removed. The seed trays were in a greenhouse (min. temp. 15°C) and subject to a minimum 18 h of light per day.

From Table 2 it is clear that large numbers of viable seeds can occur in wormcasts. At both Penmon and P-Y-F large numbers of viable seed were recovered, while at the other three sites the numbers were much lower.

Table 2

The mean number of seedlings per 100 g of cast soil

Weed Species	Penmon	P-Y-F	Treborth	Menai Bridge	Beaumaris
Agrostis spp.	128.2	214.8	1.6	15.8	52.0
Arenaria serpyllifolia L.	30.4	12.2	14.4	4.6	1.0
Sonchus spp.	7.1	12.0	1.4	1.4	1.8
Chenopodium album L.	0.8	0.4	1.6	0.4	0.6
Holcus lanatus L.	6.8	158.2	0.0	2.4	0.4
Stellaria media (L.) Vill.	9.4	8.0	2.0	0.0	0.6
Ranunculus spp.	3.8	70.0	0.4	0.2	0.0
Trifolium spp.	1.4	3.6	0.4	0.4	0.0
Anagallis arvensis L.	0.6	30.8	7.6	0.0	0.2
Poa spp.	36.8	161.2	0.0	0.2	0.0
Carex spp.	87.6	46.2	0.2	0.0	0.0
Urtica dioica L.	6.8	1.6	0.0	0.0	2.2
Plantago spp.	2.2	0.0	0.2	0.0	0.2
Rumex spp.	0.6	1.0	0.0	0.0	1.2
Matricaria spp.	17.4	0.0	0.0	0.8	0.0
Lamium spp.	1.8	10.0	0.0	0.0	0.0
Convolvulus arvensis L.	0.0	0.2	0.6	0.0	0.0
TOTAL	340.7	730.2	30.4	26.2	60.2

Experiment 3. The distribution of seedlings and wormcasts in the field.

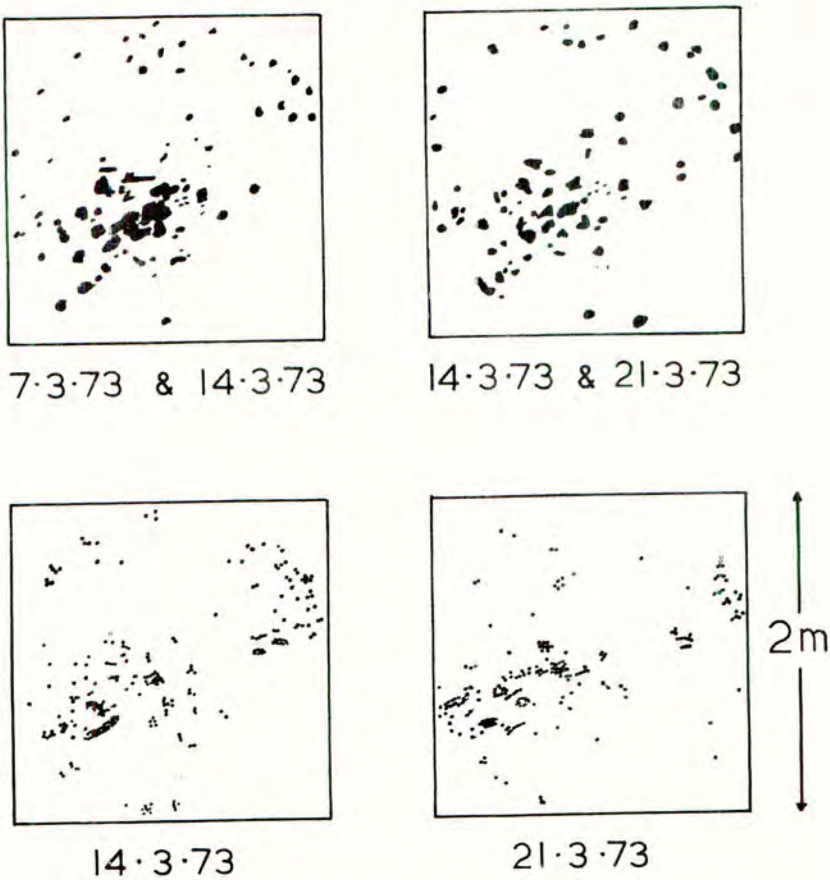
A permanent quadrat, $4m^2$, was laid out in grassland at the Treborth Botanical Gardens, U.C.N.W., Bangor in February 1973. From 23rd February until 10th May 1973, at weekly or fortnightly intervals, maps of the distribution of dicotyledon seedlings and wormcasts were made.

The maps of the distribution of wormcasts and seedlings in March (Fig. 1) show a close correlation between the two populations. It will be observed that seedlings often occured either where wormcasts were present or where they were previously recorded.

Fig. 1.

The relationship between the occurrence of wormcasts and seedlings in grassland at Treborth

Upper Row - wormcast distribution Lower Row - seedling distribution



DISCUSSION

When a lawn or a grassland is sown, it is usual for many unsown seeds to produce emerged seedlings (Fryer and Evans, 1968) and only capable management can ensure that the sown species come finally to dominate the new sward. Later in the life of such a sward, deterioration or 'run-down' frequently occurs due to the invasion of the sown community by weeds, both grasses and dicotyledons. If plants are to successfully invade a sward and become established, germination of their seed must occur at the right place at the right time. If the right place for a seed to germinate and become an established seedling is a break in a closed community, the earthworm cast may be of importance.

The data presented in Table 1 shows Lumbricus terrestris to be capable of ingesting weed seed and subsequently casting a proportion of the ingested seed. Table 2 shows that seeds are also present in wormcasts taken from the field. There are three major ways that seeds could have entered the casts that were examined; they may have been cast by the earthworm; they may have been blown onto the cast or they might have been contaminants from the surrounding soil in the sample collected. By carefully collecting only fresh wormcasts it is reasonably certain that the last two possibilities were reduced to such an extent as to be too improbable for serious consideration. Certainly the degree of possible contamination could hardly have accounted for the large numbers of seeds found. It is argued therefore that the seeds found in the casts had passed through the gut of earthworms. Viable seeds in wormcast have been reported by Chippindale and Milton (1932) and Milton (1939).

If the wormcast is a right place for seed germination, the seed must also be present at the right time. Evans and Guild (1947), showed that wormcast production was seasonal being greatest during the spring and the autumn. A similar periodicity is found in the germination of many weed seeds. Of the species reported in this paper Arenaria serpyllifolia for example germinates mainly in the winter and spring (Brenchley and Warington, 1933), Chenopodium album and Anagallis arvensis in the spring, early summer and autumn, and Stellaria media in the spring and autumn (Fryer and Evans, 1968). Whether this is a direct relationship between the spring and autumn activity of earthworms and the germination time of all these species is not clear. However, when Fig. 1 is examined it is apparent by eye that a seedling is more likely to occur if a wormcast was earlier occupying a site than if no wormcast had recently been present. These observations allow the suggestion that the earthworm places the seed in the right place at the right time for germination.

The results in Table 1 show not only that L. terrestris ingests seeds, but that it does so selectively. This selectivity may be of evolutionary importance and could affect the species composition of a habitat.

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