WEED CONTROL IN SMALL-SCALE TROPICAL FARMING

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Summary The author describes some practical examples of projects in developing countries in which weed control was one of the problems. The conclusion is that the solution should always suit the circumstances. Many factors may have their influence. The only way to introduce a suggested improvement is to try and convince the farmer of its use. But still no farmer can be expected to take heavy risks. Gradually introduced improvements are in fact a much better way to reach the end in view. The agricultural extension services are responsible for the difficult task of drafting directions for weed control and getting them accepted by the farmers.

INTRODUCTION

In tropical farming weeding demands a great human effort and is often a bottleneck in growing crops. On the other hand, the increasing population necessitates a higher agricultural production which in many countries has to be obtained in an area that can hardly be extended as agriculture already occupies most potentially arable land.

The major part of the population of most less developed countries depends on agriculture and this situation is not likely to change rapidly in the near future. Therefore, it is necessary to consider the consequences before introducing new labour-saving agricultural methods. Such methods would deprive some people of their livelihood. On the other hand it should not be forgotten that higher yields per hectare will imply more harvesting, processing, transport etc., and hence more employment. Only when work has accumulated to such an extent that a crop may be lost, is it advisable to use labour-saving devices and then only provided that they increase the farmer's profit.

In general small-scale tropical farming can be improved in two ways: (a) by improving the growth of local crops (on the whole this will amount to subsistence farming), (b) by introducing new crops.

The current methods are the best basis for the development of new cultivation practices for crops known in the area. The experience which farmers often have unconsciously gained in the course of the years can be very useful. Another advantage is that the farming population sooner accepts changes of current methods if they are not too drastic. Only when these minor changes prove a success, will farmers be inclined to make other changes as well.

If the introduction of a new variety entails a drastic change of cultivation methods, then the problem becomes far more complicated. Sometimes this also applies to cases in which new varieties of existing crops (e.g. new short-straw rice varieties) have to be introduced as they call for an entirely adapted watering and fertilization policy.

Only after extensive trials and preparations made in the areas, can the improvements be expected to be successful. These improvements will mostly include a number of changes such as improved weed control methods, application of fertilizers, improved tillage, introduction of new varieties and so on.

The introduction of improvements is most successful when some progressive farmers are first approached. Once they are convinced of the usefulness of the novel methods their neighbours will be sooner inclined to follow suit. The improvements should be such that farmers will be able to continue them after the introduction phase is over. So in this case a simple home-made hoe is preferable to some complicated apparatus which has to be obtained elsewhere.

The following chapters briefly deal with the weed problems of some ILACO projects. Comparison between the results of the weeding tests of different projects may present a distorted view because the conditions and observation techniques may vary widely. These factors have a much smaller influence in a series of observations in a single project so that in that case comparisons do make sense.

PROJECTS

Project 1. Aménagements rizicoles et bananiers en Casamance, Sénégal.

(a) General description

Soil. In general rather sandy and permeable; the surface is practically flat in the lowlands and slightly sloping in the higher areas.

Rainfall. About 1,700 mm per year, the rainy season lasting 5 months.

Farm size. 1 to 3 ha.

Crops. In general rice on the low area (sometimes alternated with groundnuts); rarely rice on higher soils because of limited rainfall, but mainly groundnuts or other crops, each harvest being followed by a fallow period of up to 5 years to avoid the build up of weeds (especially Imperata cylindrica).

Soil preparation. Rice is grown on 40-70 cm wide ridges on the low land. The intermediate trenches are closed to prevent unused water from running off (so-called tie-ridging). After the first rains have adequately moistened the soil, tillage is started for the next crop. This is done with a long-handled spade removing the ridges' top layers with all the weeds and throwing the whole lot down into the trenches. Subsequently the old ridges are further reduced and the earth is put on the place of the former trenches so that the new trenches are on the place of the old ridges. In so doing the weeds are well dug into the ground. On the higher field plots rice, if any, is usually not grown on ridges. Here soil preparation is limited to the removal of any vegetation without burying it.

(b) Conventional weeding methods

On the low lands the local rice varieties with a growing period of about 160 days are transplanted into the newly tilled ridges when the plants are 6 weeks old. These ridges are usually not weeded, because the weeds are not believed to be able to have an unfavourable effect on the rice which has such a long lead. On the higher lands rice is broadcast and suffers considerable competition because this area is generally not weeded.

(c) Improvements

The first improvement recommended for the low land was a moderate fertilizer application. This almost doubled the yield. At the same time weeds became a more serious problem. When a crop is grown on ridges which are mostly very wet hand weeding is hardly practicable even with improved implements. Consequently tests have shown that the cost of weeding was not compensated by the yield increase. The next improvement on suitable sites was attained by introducing high-grade Taiwan rice varieties with a growing period of 120 days. This requires an entirely different cultivation method:

(i) it must be possible to keep the water level under control; an accurately flat area covered with a shallow water table is necessary, giving weeds a better chance to develop

(ii) the rice should be transplanted as early as 3 weeks after germination. The rice plants have to face weeds at an earlier stage and the farmers complain that they had to bend lower when they transplanted them

(iii) the rice plants also remain smaller with the result that they are again more readily affected by tall growing weeds

(iv) a heavier fertilizer application is necessary so that the investment of the farmer is markedly increased and weed growth is stimulated

(v) efficient mechanical or manual weed control is only possible when the rice is carefully planted in rows.

The introduction of this refined method for rice cultivation has put great demands on the Extension services. It was a risky attempt because it might have turned out to be a failure for the farmers, but on some plots a yield of 4 to 5,000 kg per hectare was attained and this meant double returns as compared with the previous improvement.

The following summaries of the demonstration trials which ILACO have carried out indicate the importance of early and repeated weeding.

Table 1

Influence of number of weeding rounds on yield of rice

Number of weeding rounds	Average yield (kg/ha)
1	1,534
2	1,640
3 and more	1,777

Table 2

Influence of the time of weeding on the yield of rice

First weeding round after	average yield (kg/ha)
0-14 days	1,634
14-21 days	1,225
21-28 days	1,191
more than 28 days	330

On the higher land where otherwise little rice is cultivated, yields could be increased by row-sowing so that light hoe implements could be used for weed control. This is the more important as there is shortage of labour and chemical weed control cannot yet be consiiered owing to the low production capacity of the soil.

Project 2. Rwanda Pyrethrum Project

(a) General description

N.V. ILACO's primary task in this project is to enlarge the pyrethrum area for the processing industry. Only when this is completed, will the improvement of cultivation methods receive more attention.

Soil. Strongly humous; steep slopes in some places and serious danger of erosion.

Elevation. 2,300-2,800 m above sea.

Rainfall. 1,600-3,000 mm per year, rather evenly distributed over 9 months.

Farm sizes. Approximately 2 hectares.

Main crops. Pyrethrum (40%), sorghum, maize, potatoes or peas (50%). Farmers receive land on condition that they devote a certain part to pyrethrum cultivation. Under normal conditions the crop can be left to stand in the field for 4 years. Owing to heavy weed growth the crop often has to be removed as early as 2 years after planting.

Soil tillage. All vegetation is dug under by hand before new plantings are laid out. The pyrethrum plants are split and planted. Mechanization is very difficult on the often rather steep area owing to different obstacles such as rock outcrops in some places, small plot sizes etc.

The most common weeds. Chickweed species, *Pennisetum clandestinum* (Kikuyu grass) thistles (on better soils), *Cyperus* species on moist places, *Oxalis* spp. and moss (on strongly deteriorated soils).

The conditions favour a rapid development of weeds leading to yield losses. The high weed density also reduces air circulation so that the high humidity of the area is raised even more and plant diseases are encouraged.

(b) Conventional methods

Up to now the heavy jembe has fairly commonly been used. In consideration of the late start of weeding the jembe is indeed the proper implement. Weeding is almost invariably done during the dry period for 2 to 3 hours per day. The weeds are dug under. Sufficient labour is available.

(c) Improved methods

Demonstration plots are laid out to convince the farmers of the use of early and repeated weeding. At the same time attention is given to the introduction of new hand tools. Mulching will be considered for weed control and erosion control. A fairly great quantity of the necessary material occurs in the form of *Setaria* plantings bordering the blocks.

In consideration of possible deterioration, soil fertility will receive proper attention. It may be necessary to apply fertilizers which in turn have their effects on weed development. Chemical weed control is not yet considered for the following reasons:

(i) a more serious risk of erosion

(ii) soil deterioration owing to withdrawal of organic matter

(iii) the relatively high costs of chemical weed control

(iv) the availability of sufficient labour.

(d) Extension

Much attention should still be given to the extension to the farmers because they do not yet see the full benefit of the suggested improvements.

Project 3. Pilot Farm Cotton growing at Pujung, Lombok, Indonesia

(a) General description

Soil. Clay, rather flat, circa 100 m above sea-level.

Climate. Monsoon with rains from November-December till April-May; precipitation about 1,500 mm per year.

Farm sizes. Approximately 0.5 ha.

Crops. Cotton and rice alternately.

Soil preparation. After rice has been harvested, a changkul (a heavy digging hoe) is used to make ridges at 1 m-wide intervals for the cultivation of cotton.

Weed species. Cyperus rotundus, Cynodon dactylon, Echinochloa colonum, Euphorbia hirta, Heliotropium indicum, Portulaca oleracea.

(b) Conventional method

A small short-handled iron hoe is rather commonly used to weed. The labourer does this work squatting. Weeding between the newly germinated cotton plants with this implement causes some damage to the crop roots.

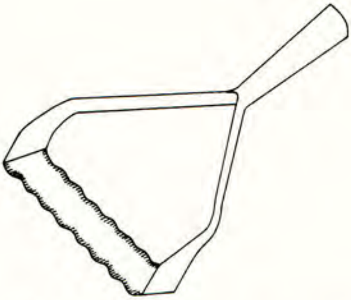
(c) Improvements

Six new hoe types (see Figure 1) were introduced for experiments on some trial fields to compare their effectiveness with that of the common local tool. One series of plots was full of young weed plants and another full of weed that was some weeks old. Weeding times were recorded and after the experiments the participants were asked to give their opinions about the various tools (see Table 3).

Weeding times for young weed must not be compared with those for older weed because the second experiment was made sometime later and the experience gained meanwhile played some part. Mulching proved an unsatisfactory weed control measure because the weeds survived the mulch layer and remained unnoticed for a while. At a later stage some herbicide experiments were carried out. The results showed that the spraying costs were not compensated by yield increase and saving of labour hours. This makes it unattractive for the time being in consideration of the local labour surplus.

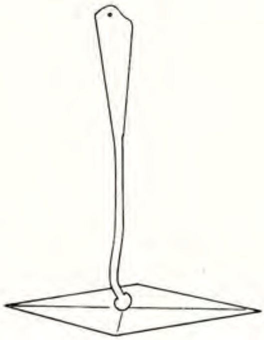
Figure 1

Experimental weeding implements

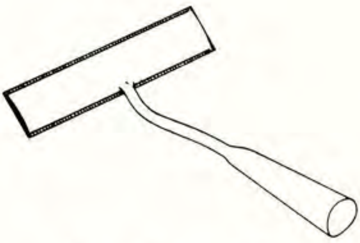


PUSHING/PULLING HOE
WITH UNDULATED EDGES

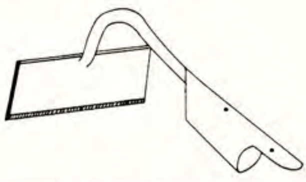
PUSHING/PULLING HOE
WITH DENTATE EDGES



DIAMOND HOE



CONVENTIONAL HOE



LIGHT CHOPPING HOE

Table 3

Comparison of different weeding tools - Indonesia

Tools	Weeding time (h/ha) young weed	Weeding time (h/ha) older weed	Attitude in working	Preference
Push/pull hoe with undulated edges	180	218	slightly bent	2
Push/pull hoe with dentate edges (15 cm)	188	183	bent	4
Push/pull hoe with dentate edges (10 cm)	197	162	slightly bent	5
Long-handled diamond hoe	215	168	bent	7
Short-handled diamond hoe	240	168	squatting	8
Conventional hoe	233	160	bent	9
Light chopping hoe	192	150	slightly bent	1
Long-handled local hoe	203	158	slightly bent	6
Short-handled local hoe	273	158	squatting	3

Project 4. Qatif Experimental Farm, Saudi Arabia

(a) General description

Soil. Sand

Crops. Onion, broad beans, cabbage and cauliflower

Weed species. *Cynodon dactylon*
Juncus maritimus
Schanginia aegyptica
Zygophyllum coccineum
Sonchus maritimus
Launaea nudicaulis
Convolvulus arvensis
Frankenia pulverulenta
Melilotus indicus

(b) Conventional tool

Normally a short-handled sickle is used for weeding which is done in a squatting position. The rate of work is low.

(c) Improved tools

A number of weeding implements was introduced to improve the labour efficiency of the farmers. For this purpose a comparative trial was made with germinating weeds and one with 15 to 20 cm-high weeds. At the same time the farmers were asked to pronounce their preferences. The results are shown in Table 4.

Table 4

Comparison of different weeding tools - Saudi Arabia

Tools	Weeding time (h/ha) young weed	older weed*	Attitude in working	Opinion
Push/pull hoe with undulated edges	37	148	slightly bent	unsatisfactory
Push/pull hoe with dentate edges (15 cm)	38	148	slightly bent	good tool
Push/pull hoe with dentate edges (10 cm)	40	148	slightly bent	good, but 2 is better
Diamond hoe	43	148	slightly bent	tolerably good
Conventional hoe	50	222	slightly bent	bad, impossible to handle
Light chopping hoe	42	222	slightly bent	bad, but slightly better than 5
Local sickle	55	148	squatting	the best tool

* The results of this trial are based on one observation

These data show how prudent one should be in relying on the judgement of people who have worked with a certain tool for years and are suddenly given implements that are entirely new to them. On the other hand the farmer does accept new tools once he is convinced of the benefits. In this case extension should receive proper attention. Introduction of new tools should form part of the work of the Extension services.

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WEED CONTROL IN YOUNG COCOA : MANUAL METHODS COMPARED WITH A PARAQUAT SPRAYING TREATMENT

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Summary Cocoa growth was better with paraquat spraying than with hand weeding. Growth was not significantly different within the compared manual treatments.

Treatments affected the composition of weeds and, in one trial, leaf fall in the dry season. Percentage organic carbon in the surface soil was less in the paraquat treatment but not significantly so.

Herbicide application in small scale cocoa farms in Ghana is unlikely to be economic in the present circumstances.

INTRODUCTION

Manual methods of weed control are usual in small scale cocoa farming. Hammond (1962) described how cocoa is maintained by Ghanaian farmers. Bonaparte (1966) described a more intensive method used on agricultural stations.

Ashby and Pfeiffer (1956) have stressed the importance of the competitive effect of weeds in the tropics. Ruinard (1966), comparing weeding treatments for seedling cocoa grown in boxes, found a 70% increase in dry matter production with good as opposed to poor weeding, and recommended weeding before any other radical modernization by farmers on low incomes. Koenraadt (1962) showed that higher and more frequent slashing of weeds led to better growth of the tree crops.

Trials were laid down to find out which herbicides might be suitable for replacing manual methods. Details of treatments and the preliminary results have been reported (Brown and Boateng in press and preparation). This paper reports the differences between manual methods and a paraquat spraying treatment. Growth of cocoa was best with paraquat spraying and differences between the contrasted manual methods were small. However, the use of paraquat in small scale cocoa growing is debatable.

METHODS AND MATERIALS

Three trials, E12, H12 and Jumapo, were started in successive seasons on sandy and sandy loam soils, marginal for cocoa growing. Hybrid cocoa was used and, at planting, the shade of Manihot glaziovii, Glyricidia maculata or Musa paradisiaca was inadequate, though this improved during the course of the trials. The weed control treatments and other details are shown in Tables 1 and 2. The untreated inter-rows were "brushed" (i.e. slashed with a cutlass) at 9 in. every other month in E12 and H12 and at about 10 in. twice a year at Jumapo.

Table 1

Details of trials

Trial	Spacing of cocoa	Age at last recording	Months of treatment
E12	5' x 5'	3 years	24
H12	7' x 7'	5 years	21
Jumapo	8' x 8'	2 years	12

Table 2

Treatments in trials

Trial		Treatment to 3 ft strip along the cocoa rows
E12	(a)	Paraquat at 0.5 lb per sprayed acre followed 2-4 weeks later at 0.25 lb per sprayed acre, quarterly
	(b)	Low-level brushing 2 in. from the ground monthly, including inter-rows
	(c)	High-level brushing 6 to 9 in. from the ground every other month, and grasses removed monthly from 2 ft diameter circle around cocoa tree
H12	(a)	Paraquat as above (a)
	(b)	As above (c) but 3 ft diameter circle
	(c)	As above (c) but all weeds removed monthly from 3 ft circle around the cocoa
Jumapo	(a)	Paraquat as above (a)
	(b)	The standard method of the Cocoa Division of the Ministry of Agriculture, brushing 3 to 9 in. from ground 3 times a year, with lower brushing in wet weather and higher brushing before the dry season

The cocoa seedlings were marked 6 in. from the ground at the start of the trials, and the diameters measured at that point with Harpenden skin-fold or Vernier calipers. Shortly before each quarterly application of herbicide, the percentage of ground covered by weeds was estimated by eye and then subdivided among the different species.

RESULTS

Growth with paraquat spraying was greater than with manual methods, significantly so in E12 and at Jumapo (Table 3).

Table 3

Effect of treatments on diameter of cocoa, in in.

Trial	Treatment				
	Brushing with a cutlass				Spraying
	Cocoa Division's standard method	Low-level	High-level with selective ring weeding	High-level with clean ring weeding	Paraquat followed by paraquat
E12 (Tafo)	-	0.91	0.96	-	1.19
	S.E. ± 0.044				
H12 (Tafo)	-	-	1.85	1.91	1.96
	S.E. between brushing treatments ± 0.038				
	S.E. between brushing and spraying treatments ± 0.046				
Jumapo	0.61	-	-	-	0.71
	S.E. ± 0.048				

The height and frequency of the brushing and selective weeding had a marked effect on the composition of the flora in E12: low brushing markedly increased *Axonopus compressus* while the other manual treatment increased *Commelina* spp. and other dicotyledons (Table 4).

Paraquat spraying reduced leaf fall, and may have reduced the percentage organic matter in the soil (Table 4). There was a tendency for cocoa growth to be best where weed cover was least. In the paraquat treatments in H12, (the other paraquat treatment in this trial was spraying when required) the correlation between cocoa diameters and percentage weed cover in the strip was highly significant ($r = - 0.66$).

DISCUSSION

The trials were carried out on sandy and sandy loam soils more subject to drought than the better cocoa soils. The leaf fall of the cocoa would appear to indicate that competition from weeds for the soil moisture was likely to be particularly important in these circumstances. The more the treated strip was kept clear of weeds the better was the cocoa growth. The differences seen in these trials are likely to be less on the better cocoa soils with their greater moisture retaining capacity.

There is always the risk that removal of weeds will expose the soil, leading to a reduction in organic carbon content (Cunningham, 1963), and that the good initial growth will not be reflected in cropping (Anon, 1963). In E12 there was a tendency for the spraying treatment with less weed cover to show lower soil organic carbon content. This difference was not significant but suggests the need for more careful study, including measurements before and after treatment.

The marked differences in flora in E12 did not produce significant differences in cocoa growth. Where the cocoa was over one year old, as in these trials, and where the weeds were retained though checked in growth, the treatments appeared to have little effect on the cocoa growth.

Table 4

Details of weed cover, leaf fall and organic carbon

Parameter	Time in relation to treatment	Weed control treatment: Low-level brushing	High-level brushing with selective ring weeding	Paraquat sequential spraying
TRIAL E12				
Percentage of strip covered by weeds				
Axonopus compressus	before	19	27	11
	after	66	10	1
Other *Gramineae* and *Cyperaceae*	before	9	7	21
	after	7	3	3
Xanthosoma and *Commelina* spp.	before	9	8	11
	after	6	14	3
Dissotis rotundifolia	before	38	26	28
	after	16	41	5
Justicia flava	before	6	11	13
	after	0	10	1
Other dicotyledons	before	11	15	13
	after	4	22	3
All weeds	before	92	94	97
	after	99	100	15
Percentage of cocoa trees without leaves in the dry season				
	1st dry season	37	21 S.E. ± 6.3	4
	2nd dry season	41	34 S.E. ± 7.4	1
Percentage organic carbon in 0 to 2 in. depth of soil				
	after	1.30	1.30 S.E. ± 0.065	1.18
TRIAL H12		High-level brushing with clean ring weeding	as above	as above
Percentage strip covered by weeds				
	before	89	84	85
	after	58	83	19

At Jumapo, tall growth of weeds in the irregularly brushed inter-row leaned over the sprayed strip. When this happened, paraquat could not be sprayed without damaging the leaves of some cocoa seedlings, unless the side of the inter-row vegetation had been previously brushed.

A spray pump is a considerable investment for a small acreage. While it could also be used for spraying capsids in immature cocoa, the risk of using the same pump for herbicides and insecticides is always present. Again, the practical difficulties of obtaining spare parts for any spraying equipment remain formidable.

Hammond (1962) reported that, following planting in Ghana, creepers were removed from young cocoa and weeding was done in conjunction with that for any interplanted food crops, with some brushing done once a year. This brushing or slashing was done at ground level, exposing the soil. New methods of cocoa establishment, whereby seedlings are planted in lines, makes better weed control easier. Progressive farmers either brush the cocoa lines or ring weed the young seedlings 2 to 3 times a year. The nurse crops are treated in the same way. This continues until the cocoa is about 3 years old when the whole farm is brushed.

On good cocoa soils this method may be satisfactory, though some improvement in growth might be achieved by adjusting the height of the brushing or its timing to coincide with the onset of competition for moisture.

In a country where the price of cocoa ex farm is about £110 per ton, where there is considerable unemployment, where smallholders' managerial ability is limited and where the cost of small scale purchase of imported herbicides is high (paraquat is about £3.67 per lb ex store at port of entry), the improved growth of cocoa from use of herbicides in small scale cocoa farming is unlikely to be economic.

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WEED CONTROL IN FLOODED RICE IN TROPICAL ASIA

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Summary Experiments at The International Rice Research Institute, at other experiment stations and in farmers' fields in the Philippines, showed that two phenoxy acid herbicides, 2,4-D and MCPA, were equally effective in controlling barnyardgrass [Echinochloa crusgalli (L.) Beauv.] and other annual weeds in transplanted rice grown under irrigated or rainfed conditions without causing sustained toxicity to either indica or japonica rice varieties. These two herbicides are even less expensive than hand weeding in transplanted tropical rice. Other herbicides such as butachlor, S-(4-chlorobenzyl)-N-N-diethylthiolcarbamate ("benthiocarb") with 2,4-D which can control weeds before or after the weeds emerge are more expensive than 2,4-D or MCPA. Butachlor is providing excellent alternative to hand weeding in Taiwan and Korea.

INTRODUCTION

Improved rice varieties have been adopted faster in irrigated areas than in rainfed areas. For example, in 1970-71, two-thirds of the irrigated land in the Philippines is planted to high yielding varieties while in the rainfed areas less than half is (R. Barker, M. Mangahas, and W.H. Meyers, unpublished).

In the irrigated and rainfed areas, the methods of land preparation have not changed much in the past 50 or 100 years. But the rates of fertiliser applied where improved rice varieties are grown has increased substantially compared with rates used on traditional varieties. Poor land preparation combined with a relatively high rate of fertiliser application encourages weed growth. In addition, few farmers in monsoon Asia can keep their paddies flooded throughout the growing season to help control weeds. So, with poor water control and poor land preparation, weed control is a key factor in getting high yields from improved varieties grown with adequate fertiliser application.

From a limited survey, the yield losses due to weed competition were reported to range from 5 to 80 percent in various Asian countries (M.R. Vega, unpublished).

Hand weeding is effective in rice fields in tropical Asia, but it is tedious, time consuming, and at times expensive (De Datta, 1972). Some farmers, however, use rotary weeders to push down the weeds between rows when the rice crop is at the tillering stage. This method controls weeds between rows but not within hills. At The International Rice Research Institute (IRRI) engineers have developed a powered three-row weeder which requires less time and effort than the manual push-type rotary weeder (Navasero and Khan, 1970).

If hand weeding or a rotary weeder (manual or powered) is used, it is not important to know what weeds are removed. But if weeds are to be controlled by chemicals, knowledge of weed species present in the area is essential. In a recent paper, M.R. Vega (unpublished) listed five species as the most common in the paddy fields of Southeast Asia. These are Echinochloa crusgalli (L.) Beauv., Echinochloa colonum (L.) Link, Monochoria vaginalis Presl., Fimbristylis littoralis, Gand., and Cyperus difformis L.

In transplanted rice, some farmers have been applying low cost phenoxy acid herbicides such as 2,4-D and MCPA to control broadleaved weeds and sedges. They spray these herbicides 2 to 3 weeks after these weeds have emerged (Moomaw, Novero, and Tauro, 1966). When the chemicals are applied in this way, farmers still have to remove grassy weeds from the rice fields by hand. We have found, however, that several herbicides, including 2,4-D and MCPA when applied before weeds emerge, can control grasses in addition to broadleaved weeds and sedges (De Datta, Park, and Hawes, 1968; De Datta and Lacsina, 1969; De Datta, 1972).

This paper summarizes our recent data on chemical weed control in transplanted rice.

METHODS AND MATERIALS

Four field experiments were conducted to evaluate promising herbicides for transplanted rice. The first experiment was conducted at IRRI with variety IR24 to compare nine promising herbicide treatments with hand weeding. A randomized complete block design was used with 15 sq m (3x5 m plots) and four replications in each treatment.

A second experiment was conducted to compare results from IRRI with those under different soil and environmental conditions. The varieties used in this experiment were IR20, IR22, and C4-63 at IRRI, IR20 at one BPI station and IR22 at the two other BPI stations. All of these varieties are high yielding semidwarfs.

In the third experiment, phenoxy acid herbicides were evaluated at IRRI using indica and japonica varieties. These varietal groups were suspected to differ in tolerance to early application of phenoxy herbicides. IR20 and C4-63 were used for the indica group, Chianung 242 and PI 215936 (from Taiwan) for the japonica group. A split-plot design was used with herbicide treatments on the main plots and varieties on the subplots. Each plot was 15 sq m. Each treatment was replicated three times.

In these three experiments, barnyardgrass seed [Echinochloa crusgalli (L.) Beauv.] was sown in all plots at 2 to 5 kg/ha immediately after transplanting.

The fourth experiment was conducted in farmers' fields in Laguna and Quezon provinces in the Philippines to evaluate promising herbicides at farm level. The varieties IR20 and C4-63 were grown with 0 and 100 kg/ha N. The design used was a split-split plot with herbicide treatments on the main plots, nitrogen levels on the subplots, and varieties on the sub-subplots. Each treatment was repeated two times. No weed seeds were sown, as there was an adequate weed population in the farmers' fields.

RESULTS AND DISCUSSION

In the test of nine herbicides for transplanted rice at IRRI, S-(2-methyl-1-piperidyl-carbonylmethyl)-O,O-di-n-propyl dithiophosphate (C19490) combined with either 2,4-D or with 2-(1',2'-dimethyl-propylamino)-4-ethylamino-6-methylthio-1,2,5-triazine (C-18898) gave excellent weed control and resulted in high grain yields (Table 1). The new coded herbicide USB 3153* from U.S. Borax, appeared highly

*Chemistry not released.

promising when applied at 2.0 kg/ha a.i., 4 days after transplanting. Granular 2,4-D gave similar grain yield to two times hand weeding. MCPA sprayed on the rice fields 4 days after transplanting, did not control grasses as well as granular 2,4-D and it was toxic to the IR24 rice. The low temperature in early February plus the stress caused by spraying MCPA reduced grain yields significantly compared with yields in hand weeded plots.

Table 1

Weed weight, crop tolerance, and grain yield of transplanted rice variety, IR24, as affected by granular herbicides applied 4 days after transplanting. IRRI, 1972 dry season.

Chemical	Rate (kg/ha)	Grain yield (t/ha) [b/]	Crop toxicity rating [c/]		Weed weight (g/m^2) EC [d/]
			19 DAT	83 DAT	
2,4-D IPE [a/]	0.8	8.6 ab	2	0	46
MCPA-K (spray)	0.8	8.0 b	3	0	194
TCE-styrene [g/]/2,4-D IPE	0.75/0.5	8.6 ab	1	0	0
Butachlor	1.5	8.6 ab	0	0	0
USB 3153 [e/]	2.0	8.4 ab	0	0	0
C-19490 + 2,4-D IPE	0.75+0.5	8.6 ab	1	0	0
"Benthiocarb"	1.5	8.2 b	0	0	0
C-19490/C-18898 (C-288)	0.8/0.2	8.5 ab	1	0	0
NTN 5006 [f/]/2,4-D IPE	2.0/0.45	8.6 ab	1	0	0
Hand weeding	twice	8.9 a	0	0	65
Untreated control	-	- c	0	0	1774

+ = chemicals applied in immediate succession. a/IPE = isopropyl ester. b/Any two means followed by the same letter are not significantly different at the 5% level. c/DAT = days after transplanting. Scale = 0-10; 0 = no toxicity, 10 = complete kill. d/Taken at heading of grasses: EC = Echinochloa crusgalli + similar species (other weeds virtually absent). e/Coded compound, chemistry not released. f/NTN 5006 = O-ethyl-O-(2-nitro-4-methylphenyl)-N-isopropyl phosphorothionoamidate. g/TCE-styrene = α-2,2,2-trichloroethyl styrene. h/"Benthiocarb" = proposed common name for S-(4-chlorobenzyl)-N,N-diethylthiolcarbamate.

In the trial in which herbicides were evaluated for transplanted rice at BPI stations and at IRRI, C-19490, an experimental herbicide from Ciba-Geigy looked highly promising (Table 2).

In tests of the tolerance of transplanted rice varieties to phenoxy acid herbicides neither 2,4-D nor MCPA caused sustained toxicity to the indica varieties, IR20 and C4-63 (Table 3), or to the japonica varieties, Chianung 242 and PI 215936 (Table 4). Weed control was adequate at 0.8 kg/ha a.i. Even at 1.6 kg/ha a.i.,

Table 2

Grain yield of transplanted rice (varieties IR20, IR22, and C4-63) at four locations in the Philippines as affected by granular herbicides applied after weeds emerge (6 days after transplanting). IRRI cooperative weed control experiments, 1972 dry season.

Chemical	Rate (kg/ha)	Grain yield (t/ha)[a] IRRI IR22	IRRI IR20	IRRI C4-63	Maligaya[b] IR20	Bicol[b] IR22	Iloilo[b] IR22
C-19490/C-18898 (C-288)	0.8/0.2	7.0a	6.8abc	6.4a	5.2a	8.0a	6.5a
C-19490 + 2,4-D IPE	1.5+0.5	6.9a	7.5a	6.2a	5.4a	7.6abc	6.2ab
C-19490	1.5	6.8a	7.3ab	6.4a	5.4a	7.0 bcd	6.3a
TCE-Styrene/2,4-D IPE	0.75/0.5	6.8a	7.0abc	6.4a	5.4a	7.8ab	5.5 c
"Benthiocarb"+ 2,4-D IPE	1.0+0.5	6.7ab	7.0abc	6.1a	4.8ab	7.4abcd	6.3a
"Benthiocarb"	1.5	6.4abc	7.2abc	6.3a	5.1a	6.8 cd	6.2ab
NTN 5006/2,4-D IPE	2.0/0.45	5.9 bcd	6.6 bc	6.4a	4.9ab	7.5abcd	6.4a
Butachlor	1.0	5.7 cd	6.5 bc	6.6a	4.8ab	7.4abcd	6.0ab
MCPA-K salt[c]	0.8	5.5 d	6.4 c	6.0a	4.2 bc	6.7 d	5.7 bc
Untreated control	-	2.2 e	2.2 d	3.2 b	1.0 d	0.6 e	1.4 d

+ = chemical applied in immediate succession. a/Any two treatment means followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test. b/Cooperative projects with the Bureau of Plant Industry. c/Herbicide applied before weeds emerge.

Table 3

Effect of early application of granular phenoxy acid herbicides on weed control, crop tolerance and grain yield of indica rice variety. IRRI, 1972 dry season.

Treatment	Rate (kg/ha)	IR20 Toxicity rating[a/] 20 DAT	IR20 Control rating[b/] 76 DAT	IR20 Grain yield[c/] (t/ha)	C4-63 Toxicity rating[a/] 20 DAT	C4-63 Control rating[b/] 86 DAT	C4-63 Grain yield[c/] (t/ha)
2,4-D IPE	0.8	0	10	7.1a	1	10	6.7a
2,4-D IPE	1.6	2	10	7.0ab	2	10	6.6a
MCPA-K salt	0.8	1	8	6.2 b	1	9	6.6a
MCPA-K salt	1.6	3	9	6.5ab	2	9	6.2a
Hand weeding	twice	0	9	7.0a	0	9	6.4a
Untreated control	-	0	4	4.1 c	0	4	3.2 b

Table 4

Effect of early application of granular phenoxy acid herbicides on weed control, crop tolerance and grain yield of japonica rice varieties. IRRI, 1972 dry season.

Treatment	Rate	Chianung 242 Toxicity rating[a/] 20 DAT	Chianung 242 Control rating[b/] 76 DAT	Chianung 242 Grain yield[c/] (t/ha)	PI 215936 Toxicity rating[a/] 20 DAT	PI 215936 Control rating[b/] 76 DAT	PI 215936 Grain yield[c/] (t/ha)
2,4-D IPE	0.8	2	9	4.9ab	1	9	5.0a
2,4-D IPE	1.6	3	9	5.0a	3	9	4.9a
MCPA-K salt	0.8	2	8	4.3 bc	2	8	4.9a
MCPA-K salt	1.6	3	9	4.9ab	4	8	5.1a
Hand weeding	twice	0	9	5.4a	0	8	5.4a
Untreated control	-	0	3	2.2 c	0	2	2.6 b

DAT = days after transplanting. a/Scale: 0-10; 0 = no toxicity; 10 = complete kill. b/Scale: 0-10; 0 = no weed control; 10 = complete control. c/Any two treatment means followed by the same letter are not significantly different at the 5% level.

the toxicity was not severe enough to reduce grain yields of transplanted rice (Tables 3 and 4).

In the experiment with transplanted rice conducted in farmers' fields in the Philippines, the natural infestation of weeds was heavy and use of most herbicides resulted in at least 1.7 t/ha more grain yield than the untreated control (average of two varieties and two nitrogen levels). The grain yields with herbicide treatments were similar to the yield from plots hand weeded twice (Table 5).

Table 5

Effect of applying granular herbicides on the grain yield of transplanted rice in farmers' fields, Laguna, and Quezon Provinces, Philippines. IRRI Agronomy-RPTR Departments cooperative experiment, 1972 dry season.

Chemical	Rate (kg/ha)	Grain yield (t/ha)[a]				
		C4-63		IR20		Total
		0 N	80+20	0 N	80+20	mean
C-19490/C-18898 (C-288)	0.8/0.2	4.4a	6.4a	4.2a	6.1a	5.3
Butachlor	1.0	4.3ab	6.2a	3.9a	5.6ab	5.0
"Benthiocarb"	1.5	3.8 c	6.1a	4.1a	6.2a	5.1
TCE-Styrene/2,4-D IPE	0.6/0.4	4.2abc	6.1a	4.1a	5.5 b	5.0
2,4-D IPE	0.8	4.1 bc	6.4a	4.0a	6.0ab	5.1
MCPA-K salt	0.8	4.1 bc	6.0a	3.9a	5.4 b	4.8
Hand weeding	2 times	4.4a	6.2a	4.2a	5.8ab	5.1
Untreated control	-	3.2 d	4.4 b	2.5 b	3.4 c	3.4

a/Average of two replications and six locations.

These data clearly show that the low cost herbicides 2,4-D or MCPA can control weeds in farmers' fields and substantially increase grain yields when weed population is heavy. In fact, 2,4-D and MCPA are the largest selling rice herbicides in the Philippines. They cost from US$2.50/ha (for liquid formulation) to US$5.50 (for granular formulation). At this price farmers in the Philippines can buy enough 2,4-D or MCPA for season-long weed control at about one-fourth to one-half the cost of hiring labor to weed by hand. One hand weeding of 1 hectare of rice requires about 100 man-hours (De Datta, Park, and Hawes, 1968).

Many Asian rice farmers are reluctant to use chemicals to control weeds until they see the weeds emerge. When the weeds have emerged, it is too late to use 2,4-D to control annual grasses. Chemicals such as butachlor, that give control before and after the weeds have emerged, are more selective than those that give control only before the weeds emerge. However, these selective chemicals are two to four times as expensive (US$10 to $12/ha) as 2,4-D or MCPA (De Datta, 1972). In Taiwan, butachlor at 1.25 kg/ha a.i., costing $16/ha (Chang and De Datta, 1972), is providing excellent alternative to hand weeding which costs about $33/ha. "Benthiocarb" at 1.5 kg/ha a.i., costing $12.50/ha, is also providing excellent weed control in transplanted rice in Taiwan (Chang and De Datta, 1972).

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BAY 6339 H, A NEW HERBICIDE FOR WEED CONTROL IN SUGAR AND FODDER BEETS

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Summary Results of field trials carried out with Bay 6339 H in greatly varying rainfall conditions are presented.

The results show that this new beet herbicide, besides having a broad spectrum of activity and displaying good crop tolerance, is fully effective in both dry and very wet conditions.

INTRODUCTION

The effectiveness of a pre-emergence herbicide often depends upon the moisture content of the soil, in addition to the soil type itself. In dry regions, herbicides often fail to produce their full activity, since the active materials do not reach the zone of weed germination but instead remain on the soil surface where they may undergo chemical-physical degradation.

Where these dry climatic conditions apply, the herbicides must be worked into the soil to improve their effectiveness (Durgeat 1964), which obviously involves much more work.

A new beet herbicide is expected to satisfy the following requirements:-

a) it must be very highly selective
b) it must have a broad spectrum of activity and also be effective against weeds not controlled by other products
c) it must be less dependent upon weather conditions.

For the control of weeds in beet crops, these requirements are very largely met by the new herbicide Bay 6339 H.

METHOD AND MATERIALS

The results were obtained from trials laid down in 25 m^2 plots with four replicates over a period of 3 years. Herbicidal effectiveness was assessed 2 to 3 weeks after beet emergence, by measuring the percentage of weed kill in comparison with the untreated control. Crop tolerance was assessed by visual estimates of the percentage of damage to the beet plants, and counts of emerged beet plants, in comparison with the control. The beet plants were assessed for damage at intervals of 2, 4 and 8 weeks after emergence, and the counts of emerged beet plants were made shortly before singling. Besides the visual assessment, the beet leaf length was measured in some trials, from which the growth height was determined. The counts of emerged beet plants were made in 8 x 10 metre lengths of row per trial, the numbers recorded being converted to percentages in relation to the untreated control (100). The yield results largely originate from small-plot trials (2 x 12.5 m), and represent the means of four replicates.

The yields were calculated as percentages in relation either to the unsprayed and hoed control or to the comparison product, i.e. in relation to 100. Most of the yield results were statistically analysed, (LSD at 5% level).

Bay 6339 H is a wettable powder, containing 65% azolamid and 13% lenacil. The potential uses of azolamid in beet crops were first reported by Eue et al(1970); lenacil has already been described as a beet herbicide by Durgeat (1963); Cussans (1964); Schöll (1965).

Both components differ not only in their spectrum of herbicidal activity (Eue et al 1970) but also, and very largely, in their solubility in water (Fig. 1.).

The two active materials of Bay 6339 H are primarily absorbed through the roots of the germinating and emerging weeds.

By combining lenacil with azolamid, not only are those weeds controlled against which azolamid is less effective (Stellaria media and Polygonum convolvulus), but a synergistic effect is also obtained (Hack et al 1971).

Furthermore, the two components are complementary by virtue of their widely different solubility in water. Azolamid with a high solubility (55,000 ppm at 20°C) is particularly effective under low rainfall conditions, but less effective under high rainfall due to leaching and consequent lack of persistence. Lenacil, on the other hand, is of low water solubility (6 ppm at 25°C) and remains in the surface layer (Koch 1970a) giving prolonged activity even under heavy rainfall conditions.

The following results were obtained with Bay 6339 H over the last three years under very different weather conditions. All rates of Bay 6339 H quoted in this paper are in terms of total active ingredient of the mixture.

RESULTS

Weed control The mono- and di-cotyledonous weeds occurring in the trials, together with their frequency, are listed in Fig. 2. The list corresponds to that published by Koch (1970b). In Fig. 2 the percentage weed control, expressed as the means of all the 108 trials conducted in 1970, 1971 and 1972, are also given. Bay 6339 H was used at 3.1 kg/ha and the comparison product at 2.6 kg/ha (a.i.). Fig. 2 shows clearly the wide spectrum of herbicidal activity exhibited by the combined active ingredients in Bay 6339 H and in particular the improved control of 'difficult' weeds such as Fumaria officinalis, Mercurialis annua, Veronica spp., Viola tricolor and Amaranthus retroflexus. A notable feature of the trials was also the slight degree of variation in the results obtained with Bay 6339 H.

Eue et al (1970) have already reported on the effectiveness of azolamid against certain grass weeds. Bay 6339 H also has a very good effect against Poa annua, Panicum spp. as well as against Alopecurus myosuroides and Avena fatua germinating from close to the surface. In fields where A. myosuroides and particularly A. fatua germinating from greater depth occur as dominant grass weed species, di-allate at 1 kg/ha or TCA at 7.6 kg/ha may be mixed with Bay 6339 H at 2.3 kg/ha to improve control. The results of trials have demonstrated that the mixture of Bay 6339 H at 2.3 kg/ha with TCA at 7.6 kg/ha is best applied as a tank mix pre-emergence. As di-allate or tri-allate must be incorporated when applied pre-drilling, they should be applied as an overall treatment before drilling and followed by Bay 6339 H as a band or an overall treatment pre-emergence.

Crop tolerance The vigour reductions noted at the 1st or 2nd assessment were usually confined to stunting from which, however, the beet plants had fully recovered after four weeks (last assessment). In 1972, veinal chlorosis was observed on odd beet plants at an early stage of growth. The values given in Table 1 all refer to the highest degree of vigour reduction irrespective of whether it was observed at the 1st or 2nd assessment.

Table 1

Percentage vigour reduction of Bay 6339 H treated sugar and fodder beets observed 2 or 4 weeks after emergence, from 108 trials

Treatment	kg/ha	vigour reduction distribution (%)			
		nil	up to 5%	up to 10%	more than 10%
Bay 6339 H	3.1	63	30	6	1
Bay 6339 H	4.7	52	37	8	3
Comparison	2.6	72	21	7	-

The distribution among the different groups shows that Bay 6339 H at 3.1 kg/ha is well tolerated. Even when the dosage rate was raised by 50% to a level of 4.7 kg/ha, the figure remained below 5% in 90% of the trials.

The emergence counts were also classified into groups, and as expected a certain degree of variation is evident in the tabulated figures.

Table 2

Percent emergence of Bay 6339 H treater sugar and fodder beets, in relation to untreated (=100), from 108 trials

Treatment	kg/ha	% emergence (control = 100) distribution					
		80	80-89	90-94	95-99	100-110	110
Bay 6339 H	3.1	1	2	10	36	46	5
Bay 6339 H	4.7	1	4	14	45	33	3
Comparison	2.6	1	1	7	38	49	4

The results presented in Table 2 show that in a high percentage of all the 108 trials, the relative emergence counts for the plots treated with Bay 6339 H at 3.1 kg/ha are within the normal range of variation for the control plots and the comparison product. Slightly reduced emergence is noted when the dosage rate is raised by 50% to a level of 4.7 kg/ha but even then it is only in 5% of all the 108 trials that it falls below 90%.

Results of beet root yield measurements are at present available only for 1970 and 1971. These are presented in Table 3. Figures not reported show that the use of Bay 6339 H does not depress the yield of tops or the sugar content. Statistical significance only occurs in very few instances and these are marked with an asterisk.

Table 3

Yield of sugar and fodder (f) beet treated with Bay 6339 H at 3.1 and 4.7 kg/ha, expressed in %, in relation to unsprayed hoed control or comparison product (= 100)

Year	Unsprayed control	Bay 6339 H		Comparison product at	LSD at 5%	100 kg/ha
		3.1 kg/ha	4.7 kg/ha	2.6 kg/ha	level	
1970	100	104	106	105	11.9	526
	100	106	97	98	13.7	502
	100	106	-	104	-	681
	100	110	-	107	14.6	-
	100	124	-	118	-	556
	100	102	99	103	16.4	-
	100	264	-	248	-	235
f	100	103	-	107	-	1075
f	100	101	-	97	-	950
f	100	122	-	122	-	958
1971	92	107*	109*	100	4.8	618
	97	98	110*	100	7.1	563
	95	110	108	100	17.1	633
	103	108	99	100	13.7	697
	92	94	90	100	11.9	772
	60	106	107	100	25.7	646
	24	106	117	100	18.9	675
	84	104	107	100	18.1	376
	103	108	92	100	16.6	571
	109	109	101	100	12.9	794
	89	94	107	100	11.7	769
	95	87	93	100	14.6	595
	100	102	99	103	12.8	-
	100	104	-	100	-	576
	100	106	-	102	-	434
	100	110	-	110	-	423
	100	284	-	268	-	197
	100	105	-	108	11.7	-
	100	227	-	182	-	352
	100	106	-	105	-	440
	100	139	-	146	-	513
	100	130	-	136	-	552
	100	119	-	119	-	591
f	100	111	-	116	-	1221
f	100	121	-	111	-	920
f	100	111	-	120	-	977

In the last column of table 3 yields are expressed as 100 kg/ha. Neither the 3.1 kg 4.7 kg/ha of Bay 6339 H caused yield depression of sugar beet or fodder beet.

In the studies on crop tolerance, none of the 23 cultivars of sugar beet tested displayed any signs of phytotoxicity and no significant differences were noted between graded and pelleted seed.

DISCUSSION

The comprehensive trials conducted with Bay 6339 H over a period of three years in Europe, the majority of which were laid down in Germany, permit a good assessment to be made of the product's performance, and clearly show that its herbicidal activity is independent of the amounts of rainfall. The three trials years differed very greatly in the amounts of rain that fell in the 8 week period after treatment. On comparing the herbicidal activity of Bay 6339 H with that of the comparison product in the different years (Fig. 3), it is very clearly seen that Bay 6339 H is very much less dependent upon the amount of rainfall than other soil-applied herbicides. The fact that Bay 6339 H continues to be so very effective regardless of the rainfall conditions is most probably attributable to the high solubility of azolamid in water so that early morning dew provides enough moisture for the product to become active. In heavy rainfall conditions, the leancil component with its extremely low solubility in water then ensures that enough herbicidal active material is still present to provide a good level of residual weed control. In view of the complimentary nature of azolamid and lenacil, it is not necessary for Bay 6339 H to be worked into the soil before drilling even in areas of low rainfall. Bay 6339 H will give reliable weed control in sugar beet at 3.1 kg/ha, and on very light soils this rate could be reduced to 2.3 kg/ha.

Acknowledgements

Thanks are due to all colleagues who have contributed to the work reported here.

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Figure 1

Comparison between azolamid and lenacil with regard to herbicidal activity and physical properties

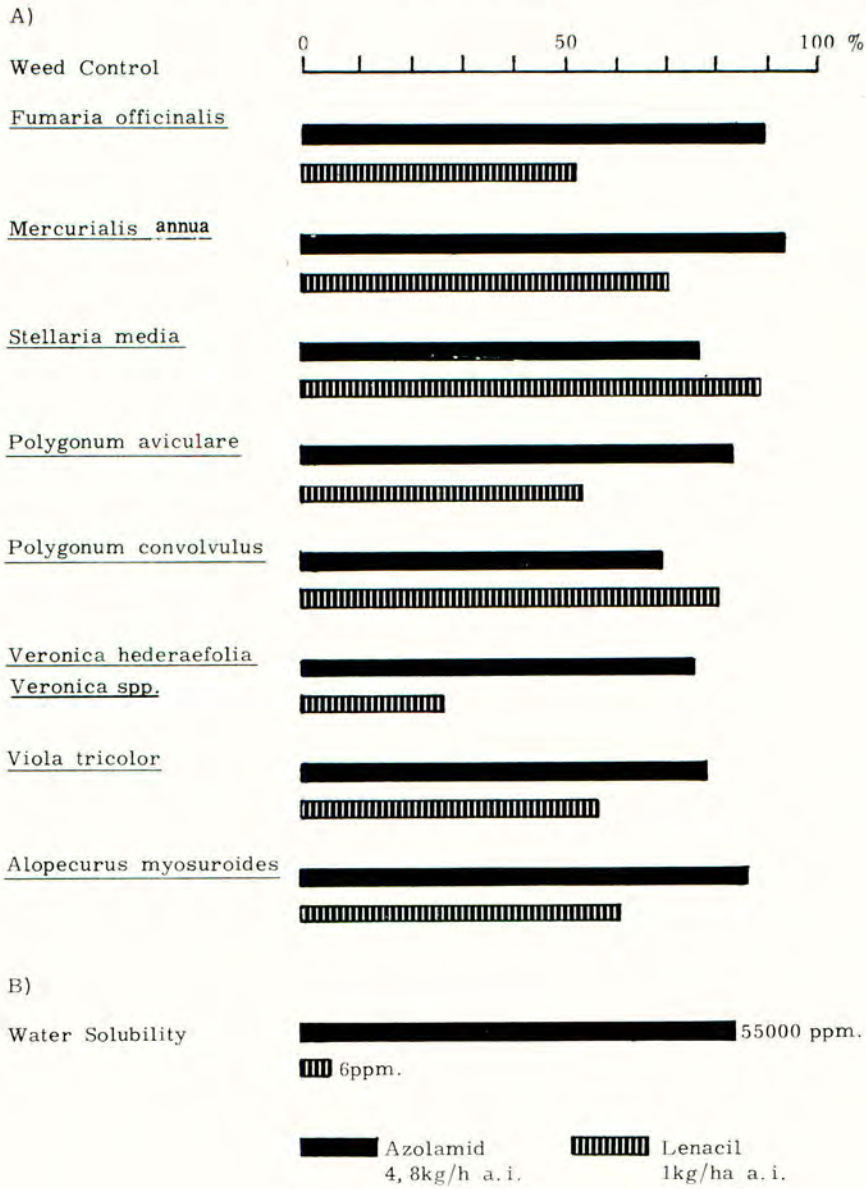
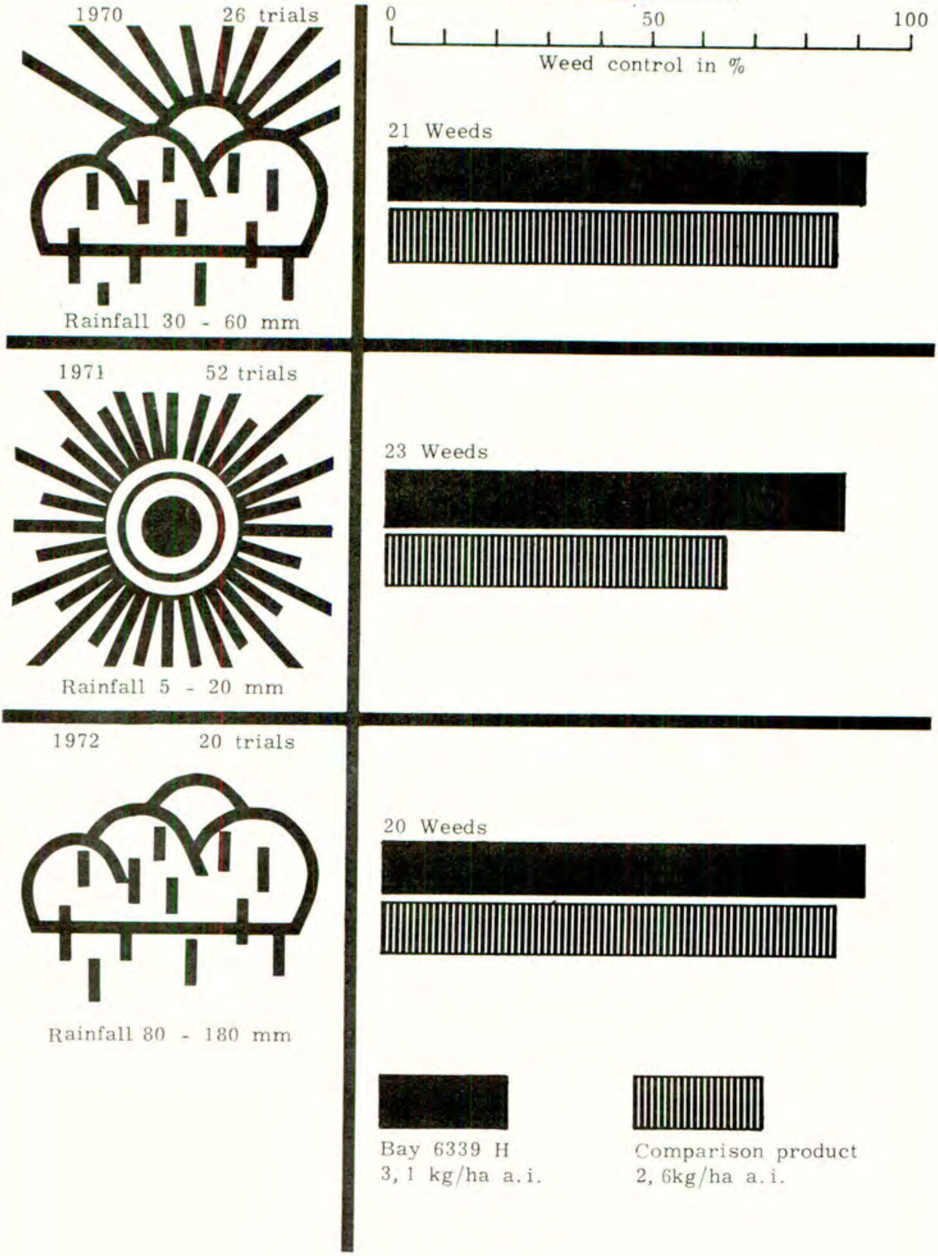


Figure 2

Frequency of different weed species and their control in sugar beet with Bay 6339 H and a comparison product

Figure 3

Weed control under different rainfall conditions till 8 weeks after treatment with Bay 6339 H and a comparison product



Proc. 11th Br. Weed Control Conf. (1972)

CONTROL OF ANNUAL GRASSES AND BROAD-LEAVED WEEDS IN SUGAR BEET WITH NC 8438

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Summary 2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulphonate (NC 8438) investigated as a sugar beet herbicide throughout Europe and the U.S.A. has shown good control of annual grasses and many broad-leaved weeds. Herbicidal activity has persisted long enough to control late-emerging species. Best results were often obtained by pre-emergence application, incorporation proving unnecessary in most situations. NC 8438 followed by phenmedipham was shown to be a good herbicide programme with a broad weed spectrum; mixtures of NC 8438 with other pre-emergence herbicides also gave promising results.

INTRODUCTION

The biological properties of 2-ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranyl methanesulphonate (code number NC 8438) were first described at the 3rd E.W.R.C. Symposium on new herbicides (Pfeiffer, 1969). It was reported at that time that the compound was highly active on grasses, and had some activity on a number of broad-leaved species including *Amaranthus retroflexus*, *Stellaria media* and *Chenopodium album*. Among the crops tested, sugar beet showed marked tolerance.

After initial studies in Britain, NC 8438 was extensively tested on sugar beet in the United States (Ekins and Cronin, 1972) where it was found particularly promising for the control of a wide range of annual grasses and broad-leaved weeds. In 1972 an extensive evaluation of this compound as a sugar beet herbicide was carried out in Europe in co-operation with sugar beet specialists in the countries concerned.

The present paper is intended as a progress report briefly summarising the more important points of the information now available on the field performance of this compound.

METHOD AND MATERIALS

In 1972 NC 8438 was evaluated in sugar beet experiments in 24 European and adjoining countries, including 30 experiments carried out by the authors in U.K., France and Austria. It is impossible to give details of all this work, much of which will be reported elsewhere. An indication of the treatments and methods used by the authors and suggested to other workers is however given below.

NC 8438 formulated as a 20% emulsifiable concentrate was used mainly at doses of 2 to 4 kg/ha a.i. applied either pre-sowing and incorporated to a depth of 2-5 cm or pre-emergence. Phenmedipham was subsequently applied at the recommended dose on part of each plot. In some experiments tank mixtures of NC 8438 with pyrazone, lenacil and propham were included.

Experiment locations were not restricted as to soil, and covered a wide range of types including some organic soils.

RESULTS

Weed control

The susceptibility to NC 8438 of a number of annual grass and broad-leaved weeds is indicated in the following list:-

Susceptible:	Alopecurus myosuroides
	Amaranthus retroflexus
	Anagallis arvensis
	Avena fatua
	Chenopodium album
	Echinochloa crus-galli
	Fumaria officinalis
	Galium aparine
	Papaver spp.
	Polygonum aviculare
	P. convolvulus
	P. persicaria
	Portulaca oleracea
	Setaria viridis
	Stellaria media
	Solanum nigrum
	Urtica urens
	Veronica spp.
Moderately susceptible:	Capsella bursa-pastoris
	Mercurialis annua
	Viola arvensis
Moderately resistant:	Raphanus raphanistrum
	Sinapis arvensis
Resistant:	Lamium purpureum
	Matricaria spp.
	Myosotis arvensis
	Senecio vulgaris
	Thlaspi arvense

Some of the results indicated above are of particular interest.

Alopecurus myosuroides, still relatively uncommon as a weed of sugar beet in Britain, is rapidly gaining in importance in this crop in large areas of Europe. NC 8438 at doses of 1 to 2 kg/ha a.i. has given excellent control of this weed.

Good to excellent control has been obtained of Avena fatua at 2 to 3 kg/ha and of Agropyron repens at 3 to 4 kg/ha. Further work is needed to study the reliability of control of these weeds.

Weeds needing higher temperatures for their germination, such as Amaranthus retroflexus, Setaria viridis, Echinochloa crus-galli, normally emerge relatively late in the season. It has been found that the herbicidal activity of NC 8438 is still high enough at this time to control these late-germinating species.

Compositae spp. have proved markedly resistant to NC 8438, but promising results on weeds of this group have been obtained both by the post-emergence application of phenmedipham after NC 8438, and by the use of mixtures of NC 8438 with pyrazone or lenacil.

Crop response

Throughout the experimentation the high tolerance of NC 8438 shown by sugar beet has been particularly noticeable. This chemical appears to be unique in that it is possible to apply 3 to 4 times the dose needed for weed control without the serious loss of crop which would be expected with other beet herbicides. However, some problems such as temporary growth delays particularly under cold wet conditions and occasional leaf deformities remain to be investigated.

In Britain in 1972 no reduction was found in the number of beet, and there was no observable reduction in the vigour of the plants after application of any of the treatments.

Growing conditions in France were very poor in the spring of 1972, and beet crops generally were poor, uneven and easily affected by herbicides. In these circumstances, most of the treatments tested caused a temporary check to crop growth, at least in some experiments. The crop later recovered completely, and plant stand was not appreciably affected except by a mixture which included propham. Results from Austria were very similar.

Sugar beet treated with NC 8438 sometimes shows abnormalities of growth in the form of adhesion of the expanding leaves, which if persistent, can cause twisting or bunching of the plant tops. On most of the plants showing this effect, the leaves soon free themselves, and later development is normal.

The incidence of abnormality was found to be low, and at a dose of 2 kg/ha only about half the experiments showed any effect at all. Where it did occur, this dose rarely showed more than 2% of the plants with a persistent abnormality.

The cause of this sporadic effect could be associated with genetic factors, but it is not at present fully understood.

DISCUSSION

Over the years, with more and more extensive use of chemical methods of weed control in sugar beet, those weeds which are resistant to the well-established herbicides are increasing in importance. Although there are indications that such weeds can be controlled by the use of recently discovered materials, the application of these herbicides may present difficulties as, for instance, where immediate incorporation is needed after spraying. The work reported here indicates that effective control of these problem weeds can be achieved by pre-emergence surface application of NC 8438.

The problem of weeds resistant to NC 8438 could be overcome either by a sequential treatment with phenmedipham or by using combinations of NC 8438 with other pre-emergence sugar beet herbicides.

The soil persistence of NC 8438 is such that a single pre-emergence application can kill weeds germinating up to at least ten weeks after application, thus effectively controlling late-germinating species such as *Amaranthus retroflexus*, *Echinochloa crus-galli* and *Setaria* spp. The need for late hoeing for weed control could, at least under ideal conditions, thus be eliminated.

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THE EFFECT OF WEEDS ON THE SUGAR BEET CROP

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Summary Field experiments at Sutton Bonington in 1970 and 1971 tested how crop yields were affected by allowing weeds to grow at different stages and how nitrogen and plant arrangement affected the crop's tolerance of weeds. When weeds grew undisturbed throughout the season yields were some 80% lower than when regular weeding was done. However weeds could be allowed to grow during the early or later stages (June, July and August) without incurring yield loss and restricting weeding to a relatively short period during the latter part of May was remarkably effective.

Extra nitrogen stimulated weed (mainly *Chenopodium album*) rather than crop growth and whereas yields of weed-free crops were not improved by more nitrogen, yields of weedy crops were actually depressed. In 1971 a more nearly equidistant arrangement of crop plants restricted weed growth and improved yield but in 1970 effects on weeds and crop were completely reversed.

INTRODUCTION

As growers seek to contain costs of growing sugar beet hand labour is involved to a diminishing extent, even eliminated completely. The combination of herbicides and inter-row hoeing can be remarkably effective in controlling weeds but there are occasions on which they fail to some degree and, unless hand labour is then employed to salvage the situation, weedy crops result. Studies of the effects of weeds have been made in North America (Table 1), but less is known in England of when and how weeds affect growth and yield of sugar beet and succeeding crops.

Whatever weed control measures are used initially, the crop must eventually take over as its own weed control system. It is therefore important to know how cultural practices affect its competitive ability. On sandy soil at Woburn Russell, Keen and Mann (1942) demonstrated that nitrogen alleviated the effects of weeds (Table 2) but this did not hold true at Rothamsted. The success of such an approach depends on knowing for which resources of particular environments important weed species compete.

To some extent the crop's competitive status depends on how quickly it can develop a complete leaf cover. The more uniformly individual plants are distributed over the land surface, ideally equidistant from each other, the more effective is unit leaf area in intercepting light and smothering or preventing the germination of weeds. The system of growing sugar beet with plants arranged in relatively crowded rows allows effective inter-row cultivation but with the advent of suitable herbicides inter-row hoeing could be dispensed with thus allowing greater flexibility in the

Table 1

Experiments testing effects of weeds in sugar beet

	Location	Crop	Predominant weed species
Miller and Meggitt (1962)	Michigan	Sugar beet	*Amaranthus retroflexus* and *Ambrosia elatior*
Brimhall *et al*. (1965)	Wyoming	Irrigated sugar beet	*Amaranthus retroflexus* and *Setaria viridis*
Dawson (1965)	Washington	Irrigated sugar beet	*Echinochloa crusgalli* and *Chenopodium album*
Weatherspoon and Schweizer (1969 & 1971)	Colorado	Irrigated sugar beet	*Kochia scoparia*
Dotzenko and Arp (1971)	Colorado	Sugar beet	*Kochia scoparia*

Table 2 (after Russell 1950)

The effect of weeds and nitrogen on yield of sugar beet at Woburn
Yield of washed roots (t/ha)

Sulphate of ammonia t per ha	Crop Weeded	Crop Weedy	Yield depression due to weeds
0	29.3	23.7	5.6
0.5	38.8	38.7	0.1

choice of plant arrangement. Yields of some vegetable crops are improved by growing the same number of plants per unit area in closer rows than conventional; their ability to smother weeds is greatly enhanced and herbicide activity is required for a shorter period (Bleasdale, 1967). Such a modification might well be effective in the sugar beet crop since it would result in plants being more nearly equidistant from each other.

Experiments at Sutton Bonington, duplicated in 1970 and 1971, tested when the naturally occurring weed flora was most competitive to the crop and explored the possibility that the amount of fertiliser and plant arrangement might affect the crop's tolerance of weeds.

METHOD AND MATERIALS

In both years sugar beet was grown on a fertile gravelly loam overlying Keuper Marl on the Nottingham University Farm. It followed spring barley, which was treated with a mixture of 2,4-D and mecoprop in spring and paraquat on the stubble in autumn.

Experiment 1

This experiment allowed weeds to grow for different periods during the life of the crop (Fig. 1), and made it possible to compare the effects of full season hand weeding with no weed control, and weed infestation early with weed infestation late. Finally it was possible to investigate the existence of a 'critical period' during which effective weed control measures suffice to realise full yield potential, i.e. weeds growing either before or after this period do not affect yield.

Weeding was done by hand on appropriate plots, at weekly intervals until 12 weeks after crop emergence, and plots were check weeded at two weekly intervals thereafter. A standard fertiliser dressing was given and a conventional plant population and distribution used, i.e. 75,000 plants/ha in rows 51 cm apart.

Experiment 2

The aim was to compare the performance of weedy and weed free crops grown with two patterns of plant arrangement and moderate and heavy doses of nitrogen. Three weed control treatments were designed to produce contrasting degrees of weed infestation: a pre-emergence herbicide only, a combination of pre- and post-emergence herbicides and frequent hand weeding (Table 3). Herbicides were applied overall rather than in bands. These were factorially combined with nitrogen (75 and 150 kg/ha N) and plant arrangement treatments (100,000 plants/ha growing 20 cm apart in rows 51 cm apart, and 41 cm apart in beds of five rows 25 cm apart with 51 cm between beds for tractor wheels). In the bed system the ratio of between to within row distances becomes 1.6:1 compared with 2.5:1 in the conventional system; an improvement but still far from equidistant.

Table 3

The overall effect of weed control treatments on sugar yields (t/ha)

	1970	1971
Pyrazone at sowing	7.28	8.33
Pyrazone followed by one application of phenmedipham	-	10.84
Pyrazone followed by two applications of phenmedipham	10.19	11.00
Pyrazone followed by hand weeding	10.52	-
Hand weeding throughout	-	11.41
	($\pm$0.208)	($\pm$0.251)

RESULTS

Experiment 1 The effects of time on weed infestation

In 1970 the period from mid-May until late June was virtually rain free, but rain was heavier and more frequent throughout 1971. This resulted in more prolific weed growth in 1971 (maximum weed dry weights were 704 g/m^2 in 1971 compared with 549 g/m^2 in 1970). Chenopodium album predominated in both years, much less so in 1971 when Tripleurospermum maritimum ssp. inodorum was prolific whereas it has been virtually non-existent in 1970. As weeding was longer continued so Poa annua became progressively more dominant amongst weed species. Contemporary field experiments in which pure stands of different weed species, including C. album, T. maritimum spp. inodorum, Polygonum persicaria and Polygonum aviculare, competed with the crop confirmed that late infestations of Poa annua had little or no effect. Chenopodium album proved to be the most aggressive species when infestation was delayed, i.e. until late May rather than late April.

The penalty for completely failing to control the natural weed flora was the loss of 78% in 1970 and 86% in 1971 of the sugar obtained where weeds were controlled throughout (Fig. 1). In 1970 the sugar concentration (%) within the roots was not affected by weeds, but in 1971 it was depressed in very weedy crops; 18.2% in the continuously weed free crop compared with 17.6% in that weedy throughout.

In both years a broadly similar picture emerges from the series of treatments which allowed weeds to grow at different stages. There was good evidence that the crop was able to tolerate weed growth either early or late in its life; in fact there was a suggestion that the period during which effective weed control was required was relatively short. Crops in which weed control ceased at the end of May produced as much sugar as those in which weeds were controlled throughout and it was quite clear that it was only necessary to control weeds which came into the crop during June, July and August if they created problems at harvest or in succeeding crops via shed seed. Furthermore crops in which weed control measures did not commence until late May also achieved similar yields to those weeded from the outset. The inference that can be drawn when this information is combined is that for full yield potentials to be realised it might only be necessary to kill the weeds which are present in the crop in late May and to prevent fresh infestation for only a short period, perhaps two weeks after this. In 1970 the crop in which weeds were first killed on 31 May and at weekly intervals until 27 June (starting 4 weeks and continued until 8 weeks after crop emergence) but allowed to grow thereafter produced a similar yield to that weeded throughout. In 1971 this was achieved by first weeding on 1 June and then on 7 and 14 June (starting 6 weeks and continued until 8 weeks after emergence); a once and for all weeding on 18 May 1971 did not suffice.

Clearly it is essential to repeat such an experiment for several more years before general conclusions can be drawn. Future experiments will also test the extent to which sowing date affects the picture and attempt to reproduce, using herbicides, particular weed control regimes which have proved to be effective.

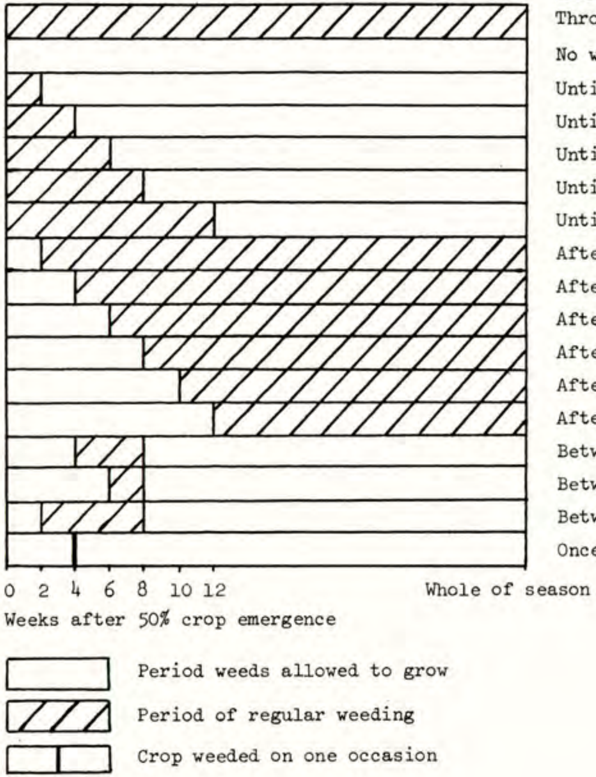
So far it has not been possible to detect carry over effects on the weediness of oat and potato crops subsequently grown on the sites of these experiments but these may become apparent when the rotation goes full circle and sugar beet is grown once again.

Experiment 2

The weed species which evaded control by pyrazone were, in order of importance, C. album, Polygonum convolvulus and P. aviculare in 1970 and C. album and P. aviculare in 1971, when the pyrazone was particularly effective in controlling T. marit-

Fig. 1

The effect of time of weed infestation on sugar yield (t/ha)



Weeds controlled	1970	1971
Throughout the season	9.31	10.66
No weed control	2.04	1.38
Until 2 weeks	6.56	3.83
Until 4 weeks	8.97	9.44
Until 6 weeks	9.59	10.83
Until 8 weeks	9.23	10.89
Until 12 weeks	9.20	11.06
After 2 weeks	8.29	-
After 4 weeks	9.24	10.88
After 6 weeks	6.98	10.25
After 8 weeks	6.68	8.34
After 10 weeks	4.78	6.52
After 12 weeks	3.68	4.47
Between 4 and 8 weeks	8.83	11.03
Between 6 and 8 weeks	-	10.08
Between 2 and 8 weeks	8.46	-
Once at 4 weeks	-	8.43
	S.E. ±0.484	S.E. ±0.303

imum ssp. inodorum. They developed to reach a maximum weight of 352 and 340 g/m^2 in 1970 and 1971 respectively; in nearby crops in which weeds were never controlled equivalent values were 549 and 704 g/m^2.

At the end of the season the penalty for restricting weed control measures to this initial application of pyrazone was the loss of 31% and 27% of the potential sugar yield (Table 3). In 1970 it seemed necessary to apply phenmedipham on two occasions to give effective control; on 18 May to kill P. convolvulus, P. aviculare and early germinating C. album and again on 9 June to kill later germinating C. album which by then had reached the four leaf stage. In 1971 a single application, on 6 May was sufficient. Though non-significant, there was a tendency in both years for yields to be slightly smaller where phenmedipham rather than hand weeding was used for post-emergence weed control. So few weeds evaded control by the herbicide that it seems more likely that the difference was a reflection of the setback to growth occasioned by the herbicide, rather than competition from weeds. Four weeks after the application of phenmedipham in 1971, crop dry weight was depressed by 27% and recovery may never have been complete.

Table 4

The effect of nitrogen level and plant arrangement on sugar yield (t/ha) of weed-free (pyrazone and hand weeding in 1970 and hand weeding throughout in 1971) and weedy crops (pyrazone at sowing)

1970

	Weed-free			Weedy		
Nitrogen (kg/ha)	75	150	Mean	75	150	Mean
Spacing (cm)						
20 x 51	9.74	9.68	9.71	8.06	7.01	7.54
41 x 25*	11.54	11.11	11.33	7.44	6.63	7.04
Mean	10.64	10.40		7.75	6.82	

S.E. body of tables ±0.416
S.E. means ±0.294

1971

	Weed-free			Weedy		
Nitrogen (kg/ha)	75	150	Mean	75	150	Mean
Spacing (cm)						
20 x 51	11.19	11.56	11.34	7.67	7.28	7.48
41 x 25*	11.19	11.70	11.45	9.73	8.63	9.18
Mean	11.19	11.63		8.70	7.96	

S.E. body of tables ±0.502
S.E. means ±0.355

*Yields calculated ignoring the bed system, i.e. assuming 25 cm rows overall.

Table 4 compares the effects of nitrogen and plant arrangement in weed-free and weedy crops. Considering first the effect of agronomic treatments on the weed-free crop, extra nitrogen stimulated top growth but failed to improve sugar yield. Growing the crop in narrow rows was remarkably effective in 1970 but not in 1971. There was no evidence in either year that modifying plant arrangement affected the response to extra nitrogen.

Extra nitrogen had pronounced effects on the vigour of weed growth, increasing maximum weed dry weight/m^2 by 40% and 47% in 1970 and 1971 respectively. In these experiments weeds responded more than the crop to extra nitrogen and in marked contrast to the situation in the Woburn experiment (Table 2), the yield of weedy crops was actually depressed by additional nitrogen. These experiments are not strictly comparable, for at Woburn the comparison was between applying and not applying nitrogen, but different patterns of response of the crop:weed balance to added nitrogen might arise because the weed flora differed. At Woburn, ".... the experimental area carried a considerable weed population, particularly twitch, some docks and thistles. Annual weeds did not begin to look serious until the very end of July, when the commonest were shepherd's purse (Capsella bursa-pastoris), groundsel (Senecio vulgaris) and fat hen (Chenopodium album) and during August mayweed (Matricaria inodora) and cudweed (Gnaphalium uliginosum) also became noticeable" (Russell, Keen and Mann, 1942). The predominant species at Sutton Bonington, C. album, seems particularly prolific in highly fertile conditions; the picture may be altered radically in situations where this species is not so prevalent. The response of different weed species, which are common in sugar beet fields to light, water and nutrients will be studied in controlled experiments.

The more nearly equidistant arrangement of crop plants had the desired effect on weed growth in 1971. Although small, this effect seems to have been important, for growing in narrow rows improved the yield of the weedy crop, whereas it had little effect on the weed-free crop. However in 1970 the reverse effect occurred with more plants of C. album growing more vigorously within the bed system, particularly where extra nitrogen was applied. This is difficult to explain. More of the land surface, 20% rather than 10%, was affected by the action of the press wheels when drilling the narrow rows, but it seems hardly likely that any modification this might introduce to the germination and early growth of weeds, or the efficacy of the herbicide, could account for such a marked difference.

Thus, on our evidence, it seems that while effects of fertilisers and plant arrangement on the balance between crop and weeds are real enough, and can be large enough to be important, they are complex and still unpredictable.

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THE USE OF SUGAR BEET HERBICIDES ON SANDY SOILS

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Summary Three pre-emergence herbicides, propham, chlorpropham and fenuron mixture, pyrazone and lenacil, each at three rates, 0.75, 1.0 and 1.25 times the recommended rate, were tested in a replicated trial on loamy sand and sandy loam soils of the Newport series over Bunter sandstone at Gleadthorpe E.H.F. An unsprayed control was included and all plots were split, half being treated with a post-emergence spray of phenmedipham at full rate.

The propham, chlorpropham and fenuron mixture caused reductions in beet seedling vigour and numbers sufficient to reduce yields. It also gave poorer weed control than the other materials and was considered unsuitable for this soil type.

Pyrazone and lenacil reduced seedling vigour temporarily, but did not reduce plant number or affect yield. Lenacil gave consistently good weed control, even in a dry season when pyrazone was less active. The combination of lenacil at three-quarter rate followed by phenmedipham gave good weed control with little risk to the crop.

INTRODUCTION

A history of poor beet seedling emergence and a continuing supply of hand labour from a local mining village has so far made drilling to a stand unattractive at Gleadthorpe Experimental Husbandry Farm. In these circumstances band spraying with residual herbicides has been used mainly to speed the hand singling operation. The soils are loamy coarse sands or sandy loams of the Newport Series over Bunter sandstone, requiring low rates of herbicide to avoid damage to the crop. Herbicide toxicity had been suspected as one factor contributing to poor crop emergence.

Work at the Norfolk Agricultural Station (1970) and reports by Bray (1968, 1969) and Eddowes and Caldwell (1968) suggested that the combination of a reduced rate of pre-emergence herbicide with a post-emergence material might give good weed control and reduce the risk of crop damage on sandy soils.

The trial was designed to test the efficacy of reduced rates of pre-emergence herbicides in controlling weeds until singling time and also to assess the latitude in application rate possible before crop damage occurred. Each plot was split to allow the application of post-emergence herbicide. The effects on beet emergence and vigour were measured and weeds were assessed before hand singling. Thereafter the crop was kept clean mechanically until harvest to allow the effect of herbicides on yield to be measured in the absence of variable weed competition.

METHODS AND MATERIALS

Soils

The mechanical analysis of trial site soils was as follows:-

	Trial year:	1970, 1972	1971
Soil type : Newport Series		Sandy phase	Loamy phase
	Stones	7	9
	Coarse sand	60	42
International Classification	Fine sand	20	31
(Percentage by weight)	Silt	7	11
	Clay	6	7

Treatments

Pre-emergence spraying, which followed drilling at the first opportunity, was done with a calibrated experimental machine. All herbicides were applied overall in 20 gallons of water per acre. In each case the normal rate was the manufacturer's recommendation for the soil type and the high and low rates were obtained by multiplying this by a factor of 1.25 or 0.75 respectively.

Post-emergence spraying was timed according to the maker's recommendation, based on the size of the weeds present. In 1971 the previously untreated sub-plots were sprayed four days earlier than plots which had been treated with pre-emergence material, where surviving weeds were stunted.

Main plots: Pre-emergence herbicides

Material and level of application		Rate per acre of formulated product 1970, 1972	1971	a.i. (lb/ac) 1970, 1972	1971
1. Pyrazone	low	1.87 lb	1.87 lb	1.50	1.50
2. "	normal	2.50 lb	2.50 lb	2.00	2.00
3. "	high	3.12 lb	3.12 lb	2.50	2.50
4. Lenacil	low	0.75 lb	1.12 lb	0.60	0.90
5. "	normal	1.00 lb	1.50 lb	0.80	1.20
6. "	high	1.25 lb	1.87 lb	1.00	1.50
7. Chlorpropham +)	low	3.75 pints	3.75 pints	1.00	1.00
8. propham +)	normal	5.00 pints	5.00 pints	1.33	1.33
9. fenuron)	high	6.25 pints	6.25 pints	1.66	1.66
10. Control - no spray		-	-	-	-
Sub-plots: Post-emergence herbicide					
1. Phenmedipham		5 pints	5 pints	1.0	1.0
2. Control - no spray		-	-	-	-

Statistical layout. Randomised blocks with split plots; four replicates.

Sub-plot size. Treatment 1/87 ac, harvest 1/194 ac.

Records

(i) Beet numbers were counted at intervals from the time of emergence to detect any delay caused by treatment and the beet were also scored for visual damage.
Before singling final counts of beet numbers were made.
Weeds were assessed by counts made in 5 or 10 random quadrats (12 in. x 12 in.) per sub-plot. Dominant species were recorded individually.

(ii) Beet in the three harvest rows were counted before harvest to establish final plant populations.

(iii) Each plot was harvested by hand, the roots washed and weighed and samples taken for sugar analysis.

RESULTS

Table 1

Principal dates				Rainfall (in.) in 10 day periods after pre-emergence spraying		
Year	Drilling	Pre-emergence spraying	Post-emergence spraying	1-10	11-20	21-30
1970	25 March	27 March	25 May	1.14	0.51	0.74
1971	29 March	2 April	10* & 14 May	0.02	0.00	2.33
1972	23 March	24 March	17 May	1.38	0.97	0.05

* plots not treated with pre-emergence materials

In both 1970 and 1972 rain followed spraying within two days, but in 1971 three weeks elapsed before sufficient rain fell to wash the materials into the soil. Sprays were applied in all three seasons to soil with a dry surface, but moisture was always present at a depth of 0.25 in.

Table 2

Visual vigour scores and pre-singling counts of beet as % of control

Material	Rate	1970 Vigour	1970 No.	1971 Vigour	1971 No.	1972 Vigour	1972 No.
Pyrazone	Low	98	90	100	103	99	101
	Normal	95	107	98	99	94	93
	High	92	101	99	103	90	108
Lenacil	Low	99	99	101	101	97	93
	Normal	97	96	99	99	97	94
	High	93	105	100	100	89	113
Propham +	Low	95	94	99	101	97	99
chlorpropham +	Normal	89	60	97	99	90	93
fenuron	High	78	55	95	96	72	78
Unsprayed control		100	100	100	100	100	100
(plants/ac, thousands)			44		136		54

In 1970 and 1972 both pyrazone and lenacil caused a small reduction in beet seedling vigour. The effect was slightly worse at higher application rates, when some leaf distortion also occurred. The beet recovered in about fourteen days. Neither material affected seedling number. Propham, chlorpropham plus fenuron caused a much greater reduction in seedling vigour, but little distortion, and the beet took a month to recover. The high rate reduced seedling number by 45% in 1970 and by 28% in 1972 and the normal rate by 40% in 1970.

In 1971 neither pyrazone nor lenacil caused any damage to the beet and very little occurred when the propham, chlorpropham and fenuron mixture was used.

Table 3

Weed numbers as percentage of control

Material	Rate	1970 Nil	1970 Phenmedipham	1971 Nil	1971 Phenmedipham	1972 Nil	1972 Phenmedipham
Pyrazone	Low	17.9	5.1	33.8	10.2	2.7	2.7
	Normal	11.1	1.7	22.1	5.3	3.4	1.3
	High	8.6	0.9	21.0	4.1	4.7	0.7
Lenacil	Low	17.1	1.7	11.9	2.5	3.4	0.0
	Normal	8.6	3.4	4.8	1.7	4.7	0.7
	High	9.4	2.6	2.5	0.8	3.4	1.3
Propham +	Low	28.2	20.5	53.7	29.6	45.0	14.8
chlorpropham +	Normal	19.7	12.0	59.6	18.1	40.9	7.4
fenuron	High	14.5	6.0	49.1	21.6	29.5	7.4
Control - no spray		100	83.8	100	32.1	100	64.4
(Weeds/ac, thousands)		255		1573		325	

The main weed species were *Matricaria* spp., *Chenopodium album*, *Poa* spp., *Polygonum aviculare*, *Stellaria media*, *Polygonum convolvulus*, *Senecio vulgaris* and *Sinapis arvensis*. In 1970 the principal weeds were *P. aviculare* and *P. convolvulus*, in 1971 C. album and Matricaria spp. and in 1972 Matricaria spp.

Pyrazone and lenacil both reduced weed numbers in all three seasons. Weed kill improved when the rate was increased from low to normal but there was no further improvement at the high rate of application. In the dry conditions of 1971 lenacil performed well but the effect of pyrazone was reduced.

At Gleadthorpe E.H.F. the propham, chlorpropham and fenuron mixture was considerably less effective as a herbicide than the other two materials.

Phenmedipham alone gave a variable kill of weeds in the three seasons studied. In combination with pre-emergence materials it consistently improved weed kill, frequently reducing weed populations to a very low level.

Table 4

Final plant population and yield

Material	Rate	Final plant population thousands/ac	Yield of washed roots ton/ac	Sugar percentage	Sugar yield cwt/ac
1970					
Pyrazone	Low	24.3	14.2	17.2	48.9
	Normal	24.7	15.0	17.3	51.9
	High	24.1	14.3	17.3	49.2
Lenacil	Low	25.0	14.3	17.5	50.2
	Normal	24.3	13.6	17.4	47.3
	High	25.6	14.7	17.2	50.7
Propham +	Low	24.2	14.3	17.1	48.9
chlorpropham +	Normal	19.4	14.1	17.3	48.8
fenuron	High	17.6	12.9	17.0	43.8
Control - No spray		25.5	13.9	17.3	47.9
		SE ± 0.79	± 0.36	± 0.13	± 1.30
1971					
Pyrazone	Low	37.3	21.3	16.4	69.9
	Normal	36.6	21.5	16.4	70.6
	High	35.6	21.6	16.4	71.0
Lenacil	Low	36.9	21.7	16.5	71.9
	Normal	37.3	21.5	16.5	70.9
	High	37.0	22.0	16.6	72.9
Propham +	Low	36.7	21.1	16.6	69.8
chlorpropham +	Normal	37.2	21.7	16.4	71.5
fenuron	High	37.1	21.4	16.5	70.5
Control - No spray		35.8	20.8	16.6	68.9
		SE ± 0.65	± 0.31	± 0.07	± 1.15

The post-emergence herbicide did not affect population or yield so only the mean figures for each rate of pre-emergence herbicide have been presented.

In 1970 propham, chlorpropham and fenuron reduced plant populations when applied at the normal and high rates. In the latter case the loss of plant was sufficient to depress the yields of both roots and sugar. Pyrazone and lenacil did not affect yield at the rates tested.

In 1971 all herbicides at all rates gave similar beet yields. The yield from the unsprayed control was slightly depressed, probably because of pre-singling competition from the very high weed population.

Results from the 1972 trial are not yet available, but will be subject to high errors because of wind erosion which followed the final weed assessment.

DISCUSSION

The propham, chlorpropham and fenuron mixture gave disappointing results, especially as it was the cheapest material tested. In two seasons it caused considerable reductions in beet seedling vigour and numbers, sufficient to depress crop yields. In no season did it kill as many weeds as the other two materials and it must therefore be considered unsuitable for use on coarse sandy soils.

Pyrazone and lenacil caused temporary loss of vigour in the beet seedlings, but did not reduce seedling number or affect final yield. Whilst the margin of safety with these materials was not large, dosage rates 25 percent in excess of the recommended rate were tolerated by the crop even in two seasons when very wet weather followed herbicide application. Both materials gave good weed control in wet springs and were less active in a dry spring. In dry conditions lenacil appeared to retain more activity than pyrazone.

Phenmedipham applied at the full rate improved on the kill of weeds already achieved by the pre-emergence herbicide. Lenacil applied at the reduced rate, followed by phenmedipham, gave consistently good results in all three seasons and was a little more reliable than the combination of pyrazone at reduced rate with phenmedipham.

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RESIDUAL CHEMICAL WEEDING SYSTEMS ON SUGARBEET

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Summary Chemical weeding systems using short-lived herbicides like cycloate and phenmedipham only appear technically obsolete. The candidate 2, ethoxy-2,3-dihydro-3,3-dimethyl-5-benzofuranol methanesulphonate (NC-8438) applied preplanting and in split application with phenmedipham herbicides improves early weed control by greater efficacy and persistence.

Early chemical persistence without tillage plus crop competition forms the new base for weed control technology in sugarbeet. These results and field observations suggest that selective residual systems can be designed with the capability of complete weed control until harvest.

INTRODUCTION

Several chemical-physical weeding systems on sugarbeet have been proposed by North American researchers, namely, Dawson(1965), Schweizer and Weatherspoon (1968), Sullivan et al. (1970, 1972), Wicks and Anderson (1970), Hendrick et al. (1971) and Norris and Orr (1971), among others. These systems (preplant followed by postplant application) permit machine thinning the crop and planting to stand in practical weed absence. In most instances, tillage and hand weeding after thinning are required to provide relatively weed-free fields at harvest.

In particular, field experience shows that the common soil-acting herbicides break down too rapidly to sustain early weed control and certain weeds escape. Timely application and overlap activity of supplemental weed control measures is difficult to achieve under farm conditions. Dawson (1971) showed that when 10 to 20 days elapsed between phenmedipham and trifluralin applications weeds emerged and escaped control. The evidence clearly indicates that the current chemical weeding systems are too complicated for general use and that the systems lack the required residual reliability to insure total machine farming.

Therefore, the goals of this continuing research when compared to standard practices are:

1) To evaluate preplant and postplant chemicals and mixtures for superior efficacy and adequate persistence.

2) To design residual chemical systems capable of economic weed control until harvest.

METHOD AND MATERIALS

All candidates and weeding systems were evaluated at Longmont, Colorado. The soil was a clay loam containing 28% clay, 31% silt, and 41% sand with 1.4% organic matter. Irrigation supplemented natural precipitation each year.

Preplant herbicides were incorporated at the 1.5 in. depth with a power tiller at planting time which occurred in early April. Postplant herbicides were foliar-applied at early species maturity stages in early to mid-May. A four week span occurred between preplant and postplant applications when herbicides were applied in sequence.

Applications were made logarithmically. The rates reached half-dosage at 23.5 ft in a 2-row, 100 ft plot. The tractor-mounted sprayer delivered 14.1 gal/ac in a 7 in. band when the equipment operated at 2.25 mile/h at 32/in^2 with ES-4 nozzle tips. Candidates were formulated as e.c. or w.p.

Artificial weed seedings were made simultaneously with crop planting each year. Main species in dense mixture in the untreated plots were Amaranthus retroflexus, Kochia scoparia, Setaria viridis, S. italica, and Echinochloa crus-galli. Monogerm sugarbeet seed was sown at nine seeds per ft of row at the 1 in. soil depth.

All treatments were fully randomized and replicated each year. Plant count observations were taken approximately five weeks after soil application and two weeks after foliar-application alone or in sequence. These observations were made at a place in each row estimated to have the highest percentage weed control with the least crop injury (optimal response). Visual estimates of beet retardation and treatment persistence were made. Data were analyzed statistically by computer, and results are reported as percentages of the untreated controls.

RESULTS

The results from these progressive studies are shown in Tables 1-3.

Preplant screens: Long-term screens (1966-72) reveal that the standard preplant herbicides (cycloate and cycloate + di-allate) are capable of 80 percentage points weed control on weed infestations common in Colorado (Table 1). Notably, Kochia scoparia was tolerant unless NC-8438 and 3-hydroxy-propionanilide isopropyl carbamate (R-11913) were applied in mixture with cycloate and pyrazone. Crop selectivity remained at a commercial level.

Postemergence screens: Long-term postemergence screens showed that the standard herbicides (phenmedipham and pyrazone + dalapon) were somewhat less effective on weed control than the preplant treatments (Table 2). Phenmedipham controlled Kochia scoparia and Setaria spp. more effectively than pyrazone + dalapon. Amaranthus retroflexus escaped phenmedipham but not EP-475. The addition of NC-8438 and ethyl m-hydroxy carbanilate carbanilate (EP-475) in mixture with phenmedipham improved Kochia control. SN-503 is a 1:1 mixture of phenmedipham and EP-475.

Sequence screens: Preplant and postplant herbicide sequences gave superior efficacy when compared to each placement alone (Table 3 vs. Tables 1 and 2).

The standard sequence, cycloate applied preplanting followed by pyra-

Table 1

Summary of preplant screens on sugarbeet, 1966-1972
(Scores and seedling counts as % of controls)

Treatment lb a.i./ac	Sugarbeet Vigor	Stand	Weeds[(x)] Amar.	Kochia	Other	Brdlv.	Set.	Mean
Cycloate+di-allate 3.0+1.0	83	105	89	19	68	71	96	83
Cycloate+pyrazone 3.5+3.5	85	108	89	22	85	75	90	82
Cycloate 3.5	84	102	84	29	78	78	85	81
Pyrazone 6.25	86	99	84	48	74	75	50	62
Cycloate+R-11913[(v)] 3+1	86	97	91	69	97	89	93	91
Cycloate+di-allate[(v)] 4.5+1.25	87	101	92	32	73	83	95	89
Cycloate+pyrazone[(v)] 3.5+3.5	93	102	93	18	93	81	90	85
Cycloate+NC-8438[(z)] 2.25+0.5	92	103	98	75	94	91	100	95
Pyrazone+NC-8438[(z)] 3.75+1.5	92	118	99	68	90	91	97	94

(x) Amar. = Amaranthus; Set. = Setaria. Other refers to other broadleaf weeds including Chenopodium album, Solanum nigrum, and Capsella bursa-pastoris, while Setaria includes E. crus-galli counts herein and in Tables 2 and 3.
(v) Mean 1970-1972.
(z) Mean 1971-1972.

Table 2

Summary of postemergence screens on sugarbeet, 1968-1972
(Scores and seedling counts as % of controls)

Treatment lb a.i./ac	Sugarbeet Vigor	Stand	Weeds Amar.	Kochia	Other	Brdlv.	Set.	Mean
Phenmedipham 2.0	84	95	56	83	81	72	84	78
Pyrazone+dalapon[(x)] 4.0+2.25	73	102	84	70	77	79	68	73
Pyrazone+dalapon[(v,x)] 4.0+2.25	78	105	88	58	76	80	72	76
Phenmedipham[(v)] 2.25	89	95	53	78	80	69	81	75
NC-8438+phenmedipham[(z)] 2.25+0.75	87	108	75	87	97	84	93	88
SN-503[(z)] 1.75	90	99	99	89	75	92	73	82

(x) Wetting agent was applied with pyrazone+dalapon.
(v) Mean 1970-1972.
(z) Mean 1971-1972.

Table 3

Summary of preplant - postemergence sequence screens, 1971-1972
(Scores and seedling counts as % of controls)

Treatment lb a.i./ac	Sugarbeet Vigor	Sugarbeet Stand	Weeds Amar.	Weeds Kochia	Weeds Other	Weeds Brdlv.	Weeds Set.	Weeds Mean
1971-1972								
Cycloate+NC8438 1.5+1.0 -SN503 0.5	90	110	100	93	92	97	100	98
NC8438 2.5 -pyrazone+dalapon 3.0+2.0	94	112	100	89	92	94	100	97
Cycloate 3.0 -phenmedipham 1.0	89	119	95	91	92	94	98	96
Cycloate 2.5 -pyrazone+dalapon 3.0+2.0	91	106	75	86	78	77	98	87
1972 only								
Cycloate+NC8438 1.5+1 -NC8438+SN503 1+0.5	75	110	100	100	100	100	100	100
Pyrazone+NC8438 1.5+1.0 -NC8438+SN503 1+0.5	78	116	100	95	100	99	100	99
NC8438 1.5 -NC8438+SN503 1.0+0.5	80	118	100	95	94	99	99	99
NC8438+U27267 1.5+0.75 -SN503 0.5	78	128	100	86	100	98	100	99
U27267 (x) 2.5 -SN503 0.75	78	120	92	82	82	89	100	94
NC8438 2.25 -SN503 0.75	73	114	100	72	100	96	89	92
Pyrazone+NC8438 1.5+1.0 -SN503 0.5	80	120	100	86	100	98	81	89

(x) 3,4,5-tribromo-N,N,α-trimethylpyrazole-1-acetamide (U-27267).

zone + dalapon foliar-applied, had less efficacy particularly on certain broadleaf weeds than cycloate followed by phenmedipham (Table 3). NC-8438 applied preplanting improved final broad-spectrum weed kill when compared to cycloate followed by pyrazone + dalapon.

In 1972, complete weed control was obtained at thinning and afterwards from several new herbicide sequences containing NC-8438 applied in split application with preplant and postplant mixtures. Kochia scoparia was controlled to a high degree with these split treatments. Sugarbeet seedlings had a high tolerance towards these promising sequences, and the effective chemical dosages were comparatively low (Table 3).

Field observations indicated that chemical weeding persistence from the most effective sequences containing NC-8438 remained active until the crop covered the rows (mid-July).

DISCUSSION

These results suggest in part the advance design for chemical weeding on sugarbeet.

New candidates like NC-8438 offer the investigator the opportunity to perfect complete chemical weeding systems effective until harvest. Early broad-spectrum chemical persistence plus crop competition forms the new plan for weed control technology. Elimination of in-the-row cultivation and the replacement of short-lived herbicides especially those applied late or at layby, with true residual herbicides applied early in sequence or in split application appear to be applicable practices.

The research objective continues to be technical simplicity in practice thereby eventual reduction in production costs.

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THE USE OF A MIXTURE OF TRIETAZINE AND LINURON FOR WEED CONTROL IN POTATOES

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Summary Trietazine, at rates up to 4 lb a.i. per acre, is shown to be exceptionally well tolerated by potatoes. At high rates, excellent weed control was achieved. Lower rates in combination with linuron proved to give weed control and crop safety equal to, or even marginally better than, six commercial standard herbicide treatments. This combination covered a wider weed spectrum than trietazine or linuron alone.

INTRODUCTION

The use of trietazine in potatoes was first reported in 1958 when a dose of 3 lb a.i. per acre gave good weed control with adequate crop safety under Canadian conditions. Further reports from Britain of the use of trietazine in potatoes in the years 1959-64 have been published by Cox and Elliott (1965), Neild and Proctor (1962), Milford and Pfeiffer (1962) and Pfeiffer and Phillips (1964). Chesterford Park Research Station made investigations of trietazine as a potato herbicide each year during the period 1962-68. In 1967 and 1968 it was also investigated in mixture with other herbicides for the same use. In 1970 a further intensive research and development programme was carried out, leading to the introduction of a trietazine/linuron product for use in British potato production. This paper gives detail of research and development work on this particular product.

METHOD AND MATERIALS

Description of experimental methods used in 1970

In 1970 a large number of trials were planned in most potato growing areas of England and Wales. A total of 20 small plot replicated research trials (13 treatments x 4 replications) were eventually laid down. The sites were widely spaced throughout the U.K. Details of these sites are given in Table 1.

Table 1

Details of Sites

Location		Crop type	Soil type	Dose used (Table 2)
Pembs.	1	Early	FSL	Early
"	2	"	"	"
"	3	"	"	"
"	4	"	"	"
"	5	"	"	"
Essex	1	2nd early	Loam	Med.
"	2	Main	"	"
Cambs.	1	"	FSL	"
"	2	2nd early	"	"
"	3	Main	CL	Heavy
Beds.	1	"	FSL	Med.
"	2	"	"	"
"	3	"	SCL	Heavy
"	4	"	CL	"
Lincs.	1	2nd early	Loam	Med.
"	2	Early	LFS	Early
Norfolk		Main	CSL	Med.
Carmarthen.		"	SCL	Heavy
Berks.		"	SL	Med.
Hunts.		"	Loam	"

FSL = Fine sandy loam
CSL = Coarse sandy loam
CL = Clay loam
SL = Sandy loam
SCL = Sandy clay loam
LFS = Loamy fine sand

A large number of these sites were on early potatoes. This proved to be extremely useful in the circumstances, for many of the maincrop sites did not show a reasonable germination of weeds due to the exceptional drought conditions in May and June.

Plot size was 6-7 feet (2 full rows) x 8 yards. Application of treatments was at varying times from immediately post-planting to 50% emergence of the crop. On several sites weeds were emerged and on some even beyond the cotyledon stage at spraying. Weed control assessments were made some 3-4 weeks after spraying, and again pre-harvest. Crop damage assessments were made at the same time.

A total of eleven research trials were harvested. Potato plant counts were made prior to harvest, and corrections made to permit comparison between plots. In the trials, six of the treatments were commercial standards. Thus all assessments could be judged against the performance of these standards. In expressing the yields for the various treatments, these have been shown as a percentage of the mean of the six commercial standards used. Dosage rates for all treatments were generally varied according to soil type: increased by 30% for heavy soils (silt loam or heavier); reduced by 30% for very light soils (loamy fine sand or lighter) and by 25% for earlies, irrespective of soil type. Table 2 gives full details.

Table 2

Treatments and dose variation for soil types

Treatments	Main crop Medium soil oz/ac a.i.	Main crop Heavy soil oz/ac a.i.	Earlies All soil types oz/ac a.i.
1. Linuron + trietazine	16 + 16	21 + 21	12 + 12
2. " "	12 + 12	16 + 16	9 + 9
3. Trietazine + simazine	32 + 3	42 + 3.9	24 + 2.25
4. Trietazine	16	21	12
5. "	32	42	24
6. "	64	84	48
7. Linuron + simazine	16 + 3	21 + 3.9	12 + 2.25
8. Linuron	20	26	15
9. Buturon + tricuron	56 (product)	73 (product)	42 (product)
10. Chlorbromuron	24	31	18
11. Linuron + paraquat	16 + 12	21 + 16	12 + 9
12. Ametryne	22	31	16
13. Prometryne + simazine	32	41	24

RESULTS AND DISCUSSION

(a) Weed control

Assessments of weed control obtained in eleven research trials are summarised in Table 3. A statistical comparison between pairs of treatments (using the Wilcoxon signed rank test) was made, and this is presented in Table 4 (for ten treatments only). The conclusions that can be drawn from this comparison of treatments are that trietazine alone and trietazine + linuron at 2 lb total a.i. per acre gave the best standard of weed control more often than linuron at the recommended dose. At the lower dose of trietazine + linuron (1.5 lb total a.i. per acre) weed control was marginally inferior to the higher dose, but still equal to linuron.

Though 1970 was not a good season for assessments of weed control, except on early planted experiments, it was possible to obtain reliable weed control results from 11 of the 20 trials. For the same climatic reason, it is difficult to draw final conclusions on the relative resistance/susceptibility of individual weed species to a mixture of trietazine and linuron. But it is reasonable to conclude that the use of a mixture of two different chemicals (a urea and a triazine) should give certain definite advantages in terms of total weed spectrum over one chemical alone. For instance, linuron will normally not fully control Fumaria officinalis and Avena fatua, nor Galium aparine, Tripleurospermum maritimum ssp. inodorum, Veronica spp. or Polygonum aviculare if emerged before spraying. A further group of experiments, which space does not permit to be reported here, showed quite clearly that trietazine plus linuron gave excellent weed control at all times of application except on one experiment where the heavy weed population was well beyond the cotyledon stage at time of spraying. The contact and residual action of both ingredients was otherwise quite adequate in controlling all species encountered in these experiments, even after emergence, provided the weeds were in or near the cotyledon stage. The relative merits of the three treatments in controlling a few of the more difficult weed species is shown in Table 5. This information is drawn not only from this series of trials but from wide scale field use of the different materials.

Table 3

% Weed Control

Treatments (dose oz/acre a.i.) Medium soil - main crop		Pembs. 1	Pembs. 2	Pembs. 3	Pembs. 4	Pembs. 5	Carms. (S. Wales)	Cambs. 2	Essex 2	Lincs. 1	Lincs. 2	Berks.	MEAN
1. Linuron + trietazine	16 + 16	89	89	85	97	95	65	97	97	98	94	79	90
2. " "	12 + 12	85	78	76	94	88	52	93	94	98	89	81	84
3. Trietazine + simazine	32 + 3	91	85	90	97	94	78	93	91	95	94	90	91
4. Trietazine	16	75	73	37	82	79	41	76	91	91	96	70	74
5. "	32	84	78	80	97	90	71	89	93	91	93	82	86
6. "	64	91	90	98	100	97	91	91	96	97	96	93	95
7. Linuron + simazine	16 + 3	89	76	82	97	94	61	96	96	93	91	82	87
8. Linuron	20	83	91	86	93	92	33	96	97	98	91	79	85
9. Buturon + tricuron	56 (product)	71	76	81	93	92	64	85	91	88	89	49	80
10. Chlorbromuron	24	86	70	85	91	93	42	93	93	90	87	54	80
11. Linuron + paraquat	16 + 12	78	78	79	93	85	52	99	96	96	87	76	84
12. Ametryne	24	84	56	38	87	91	48	97	97	98	90	37	75
13. Prometryne + simazine	32 (total)	81	69	70	89	80	72	94	93	98	93	66	82

Table 4

Comparison of weed control between pairs of treatments (Wilcoxon) (P = 0.05) from 11 research trials 1970

Treatment → compared with treatment ↓		Trietazine + linuron 16 + 16	Trietazine + linuron 12 + 12	Trietazine + simazine	Trietazine 32	Trietazine 64	Linuron + simazine	Linuron	Linuron + paraquat	Ametryne	Prometryne + simazine
1. Trietazine + linuron	16 + 16		-	=	-	=	-	=	-	-	-
2. "	12 + 12	+		=	=	+	+	=	=	=	=
3. Trietazine + simazine		=	=		-	+	=	=	-	-	-
5. Trietazine	32	+	=	+		+	=	=	-	=	=
6. "	64	=	-	-	-		-	=	-	-	-
7. Linuron + simazine		+	-	=	=	+		=	-	-	=
8. Linuron	20	=	=	=	=	+	=		=	=	-
11. Linuron + paraquat		+	=	+	+	+	+	=		=	=
12. Ametryne		+	=	+	=	+	+	=	=		=
13. Prometryne + simazine		+	=	+	=	+	=	+	=	=	
		6+	0+	4+	1+	8+	3+	1+	0+	0+	0+
		3=	6=	4=	5=	1=	4=	8=	4=	5=	5=

* for full details of dosage rates see Table 3.

Table 5

Weed resistance

	Linuron	Trietazine	Linuron + trietazine
Avena fatua	R	IR	IR
Brassica campestris	S	IR	S
Fumaria officinalis	R	S	S
Galium aparine	IR	I	I
Matricaria spp.	IR	S	S
Polygonum aviculare	IR	S	S
Veronica spp.	IR	SI	SI

R = resistant
S = susceptible
I = intermediate

(b) Crop safety

In these trials, the contact effect on the emerging potato plants was not serious in any instance. From the evidence available, it can be said that trietazine plus linuron is likely to give less chlorosis on a partly emerged crop than linuron alone at commercial doses. On one trial, where the crop was 20% emerged at time of spraying, linuron gave very marked crop chlorosis whereas the trietazine plus linuron treated plots showed negligible effect. It should be added that there was no evidence of this early chlorosis causing yield loss, even from the linuron plots where chlorosis was marked.

The results of harvesting the 11 research trials are given in Table 6. From this it is clear that trietazine plus linuron had no adverse effect on the crop.

Table 6

Yields from 11 trials expressed as % of 6 commercial standards

Treatments (dose oz/acre a.i.) Medium soil - main crop		Pembs. 1	Pembs. 2	Pembs. 3	Pembs. 4	Pembs. 5	Lincs. 1	Hunts.	Cambs. 2	Beds. 2	Essex 2	Berks.	MEAN
1. Linuron + trietazine	16 + 16	103	125+	104	93	104	102	103	113	104	98	115	106
2. " "	12 + 12	85	113	101	108	97	108	99	111	102	117	115	105
3. Trietazine + simazine	32 + 3	96	107	85	93	100	103	85	90	100	97	115	97
4. Trietazine	16	100	98	79	105	93	102	102	70-	93	122	105	97
5. "	32	83	88	98	102	99	103	114	96	94	108	106	99
6. "	64	79	134+	104	102	102	101	94	94	90	96	112	101
7. Linuron + simazine	16 + 3	90	111	95	105	102	105	89	107	103	100	110	102
8.)		105	121	107	102	106	98	107	105	102	111	109	107
9.) Mean of 6		98	103	104	90	95	103	93	78-	105	83	105	96
10.) commercial		92	115	107	105	97	103	91	102	97	84	93	99
11.) standards = 100%		92	113	92	102	100	99	105	101	100	121	105	103
12.)		103	67-	98	99	100	95	96	103	92	100	85	94
13.)		109	82-	92	102	102	101	107	111	104	101	102	101

+ or - indicates significance at P = 0.05.
The results from Cambs. 2 and Pembs. 2 can be attributed to weed competition for - and excellent weed control for +.

(c) Soil residues

Soil samples were taken from a number of early sites at time of harvest, and were bio-assayed in the greenhouse using oats and mustard as test plants. This was a very sensitive test indeed, and cannot be directly related to field performance without further work. However, such tests did indicate that trietazine plus linuron might cause some problems with succeeding brassica crops if the interval between spraying and drilling was short. In this respect, trietazine plus linuron is estimated to give similar results to linuron, greater safety than prometryne/simazine, but slightly less safety than ametryne. The product recommendations have been drawn up to exclude this possibility.

Field results were carefully checked following all experiments with trietazine plus linuron, and it was found that in all except two cases (in Kent, collards sown within 12 weeks of herbicide application), no damage to succeeding crops resulted. These succeeding crops included winter wheat, ryegrass, transplanted cauliflower and direct drilled collards. In one further trial in Lincolnshire, where collards were direct drilled after early potatoes, no damage was recorded even at double dose. From observations on all other trials, we would expect there to be no danger of soil residues, even to direct sown collards, when drilling occurs at least 14 weeks after spraying, and where adequate cultivations occur after harvesting the potato crop.

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THE DEVELOPMENT OF METRIBUZIN* IN THE U.K. FOR WEED CONTROL IN POTATOES

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Summary Metribuzin was evaluated as a herbicide in potatoes between 1969 and 1972, using both pre- and post-crop emergence applications covering a wide range of cultivars and soil types. Thirty replicated small plot trials have been conducted, supported by 20 non-replicated grower trials. The material has demonstrated both contact and residual action via the weed leaf and root. Rates of up to 1.05 kg a.i./ha pre-crop emergence and 0.7 kg a.i./ha post-crop emergence have controlled a wide range of weeds combined with a high level of crop safety. Increases in yield over untreated plots have been achieved, comparable with those obtained from the use of existing herbicides. Post-emergence applications of metribuzin gave equivalent yield increases to the pre-emergence applications on main-crop potatoes. The ability to use metribuzin as a contact and residual herbicide with post-crop emergence applications demonstrates a step forward in the development of potato herbicides.

INTRODUCTION

A report on the chemistry and various potential uses of a group of organic compounds discovered by Farbenfabriken Bayer A.G. and known as the substituted triazinons was published by Eue et al (1969).

One of this group, 4 - amino - 6 - t - butyl - 3 - methyl-thio - 1, 2, 4 - triazin - 5 - one was selected as being of particular use for weed control in potato crops. This active ingredient has been given the common name of metribuzin and the code number BAY 94337. A 70% wettable powder which readily suspends in water was formulated for field trials and given the code number 6159.

Metribuzin has a low mammalian toxicity and a solubility in water of 1200 ppm. Further details of chemical physical and toxicological properties are given in the Product Information Sheet (Anon 1971).

Trials carried out by Bayer in Germany suggested that metribuzin gives a fast kill of a wide range of weed species when applied both pre- and post-weed emergence. The material could be applied pre-crop emergence and also post-emergence up to a crop height of 10 centimetres (Eue et al 1970).

Trials were initiated in the U.K. by Bayer Agrochem Ltd in 1969 and have been continued until 1972. The trials programme was designed to obtain sufficient information for commercial recommendations and to satisfy the Agricultural Chemicals Approval Scheme.

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*Metribuzin is the proposed common name for 4 - amino - 6 - t - butyl - 3 - methyl-thio - 1, 2, 4 - triazin - 5 - one.

METHOD AND MATERIALS

Metribuzin was used throughout the trials programme as the 70% w.p. formulated as 6159. All rates are expressed in terms of active ingredient. The formulation was found to mix readily with water, and during the whole of the development programme no problems of sedimentation and blocking of sprayer nozzles and filters were encountered.

A total of 30 replicated small plot trials were carried out on mineral soils in the main potato growing areas of England and Scotland, covering a wide range of soil types, to assess the effect of metribuzin on weeds and to check its effect on the potato crop. Several trials have also been conducted specifically to study the tolerance of a full range of potato cultivars and the effect of the material when applied to organic soils.

Plot sizes were 1/500 ha and treatments were applied by pressurised knapsack sprayers in 200-300 l/ha of water at approximately 2.8 kg/cm^2 using overall soil and foliar applications.

Assessments

(1) Weed Control: Numbers of weeds of each species were counted using flexible quadrats 1 m x 0.3 m in size, placed over the ridge, doing five counts per plot at weed seedling emergence and again five days later. The number of weeds of each species were then recorded as a percentage of those found on the untreated plots, this figure being used to express the degree of control.

(2) Effect on Crop: Observations were made on any phytotoxic symptoms observed, and plant damage was graded on a 1 (no damage) to 9 (complete crop death) scale throughout the period of the trials, according to the scale (table 1) produced by the Federal German Biological Institute (Bolle 1964).

Table 1

Scale of plant tolerance

Damage grade		Actual damage
1	No symptoms	No damage
2	Very slight symptoms	Up to 2.5% of plants damaged
3	Slight symptoms	Up to 5.0% of plants damaged
4	Marked symptoms	Up to 10.0% of plants damaged
5	Heavy damage	Up to 15.0% of plants damaged
6	Intolerable damage	Up to 25.0% of plants damaged
7	Completely negative	Up to 35.0% of plants damaged
8	Completely negative	Up to 67.5% of plants damaged
9	Completely negative	Completely destroyed

(3) Yield: Yield assessments were made at harvest by taking 5 x 1 m lengths of row from each plot, ensuring a constant number of plants. Results were expressed as a percentage of the yield from untreated plots.

(4) Soil Analysis and Classification: Representative samples from the top two inches of soil were taken from each site. The soil was initially finger assessed for texture, subsequently a mechanical analysis was carried out using the Bouyoucos hydrometer method, (the latter analysis is required on some of the 1972 trials). The soil was then classified on the basis of sand, silt and clay content (Pizer et al 1957). Organic matter contents were determined using the dichromate titration technique.

Trials were carried out on the following soil types: loamy coarse sand (LCS), loamy sand (LS), coarse sandy loam (CSL), sandy loam (SL), fine sandy loam (FSL), very fine sandy loam (VFSL), loam (L), silty loam (ZyL), silt loam (ZL), clay loam (CL). In addition trials were also carried out on soils containing more than 10% organic matter (prefixed by Org) and those having more than 40% organic matter (peat).

RESULTS

1. Root and leaf uptake of metribuzin by weed seedlings.

The mode of action of metribuzin was examined at Rowhill Experimental Farm during 1971, by treating Radish (Raphanus sativus L.) seedlings growing in sterilised loam, as follows:-

(a) To test for root uptake. The foliage of seedlings at the cotyledon to 1 true leaf stage was protected by tin foil. The chemical was then applied to the soil only, at 450 l/ha, and at 2.8 kg/cm^2, using a converted Van der Weij small plot applicator.

(b) To test for leaf uptake. Radish seedlings at 1-2 leaf were treated with the small plot applicator as in (a) above, but the soil was protected by a thick layer of vermiculite. After spraying, the vermiculite was removed so that only the radish leaves were treated.

In both tests, complete kill of the seedlings resulted within ten days. Metribuzin is therefore active when absorbed through the roots or when applied to the foliage.

Further tests were carried out when the chemical was applied to several weed species before germination and also at emergence. It was observed that Veronica spp, Chenopodium album and Urtica urens were completely controlled when treated before germination, but that Polygonum convolvulus, Polygonum aviculare, Tripleurospermum maritimum ssp. inodorum, Alopecurus myosuroides and Avena fatua were better controlled when treatment was delayed until between emergence and the cotyledon stage.

2. Persistence of metribuzin in the soil.

Bio-assay tests were carried out during 1970 and 1971 to determine the speed of breakdown of metribuzin in the soil.

In 1970, treatments were applied in early February, at 2.4 kg/ha and at 4.8 kg/ha. Rates were much higher than the highest rate likely to be recommended (1.05 kg/ha) and also very little rain fell during the test. It is therefore not surprising that sensitive crops sown at monthly intervals after spraying, should still be affected up to twenty-two weeks after spraying.

In 1971, treatments were applied in early March, and again, sensitive crops were drilled across the treatments at monthly intervals.

All treatments at rates from 2.1 kg/ha down to 0.35 kg/ha were strongly active for two months, but rates of 1.05 kg/ha and below did not affect the indicator crops sown twelve weeks after spraying.

The rate of 2.1 kg/ha slightly depressed the braird of the crops drilled sixteen weeks after spraying, however the trial was non-replicated, and crops were drilled without previous cultivation. It would be presumed that the usual cultivation carried out before planting a following crop would disperse the herbicide residue and hence eliminate this effect.

Only limited experience of residual activity has been obtained in field trials so far.

In one trial in 1972, metribuzin was applied to an early potato crop in early April on a coarse sandy loam. The crop was lifted ten weeks later and cauliflowers, savoy and cabbage (Brassica oleracea L.) were planted one day later. At 0.7 kg/ha, the chemical only affected the plants very slightly although at 1.05 kg/ha, symptoms were quite marked. With present information sixteen weeks appears to be the minimum interval between application and safe planting of a susceptible crop such as cauliflowers.

3. Weed control.

Metribuzin is an extremely potent herbicide, completely controlling many weeds even when applied at a late stage of growth.

Results from all our trials specifically studying control of weeds are summarised in table 2. From the table it can be seen that the control of certain weeds require further comment.

No trial was specifically designed to study the effect on Avena fatua in potatoes, but the weed appeared in three trials in sufficient numbers to conclude that if sprayed before the 2 leaf stage, a moderate level of control can be expected.

Fumaria officinalis which has become a problem weed in some areas, is well controlled both pre- and post-emergence.

Polygonum convolvulus is better controlled when treated shortly after it has emerged.

Polygonum aviculare is very well controlled if application is carried out either before weed emergence or before the weed has grown more than two inches. After this stage aviculare will be scorched and stunted, but it has been observed that it can recover to some extent. However, in some cases total control of aviculare was given by metribuzin when the weed was in flower, indicating that other factors are involved.

Tripleurospermum maritimum is well controlled when applications are made pre-emergence, but when treated after the three leaf stage, control has been erratic, very good control being achieved on some occasions while poor control has been found on one trial. Where poor control was noted, the crop was also advanced, and may have protected the weed from the chemical.

In one trial carried out at Blidworth near Mansfield in 1972, a heavy population of Agropyron repens was sprayed in early June when at the 2 leaf stage. Good control was achieved by metribuzin at 1.05 kg/ha when the trial was assessed in early August. Even better control of repens was noted in 1971 and 1972 when metribuzin at 1.40 kg/ha and at 2.1 kg/ha was incorporated just before planting. Further work must be carried out in 1973 before any firm recommendation on the control of repens can be made.

Work carried out in 1972 on organic soils was partly unsuccessful because of the lack of a normal second flush of weeds following quite closely behind the first flush. Only single applications of metribuzin were made, and very good control was observed with the 2.1 kg/ha rate. It was thought that a split application of metribuzin at 1.05 kg/ha carried out just before emergence and again three weeks later would be optimal in a 'normal' season, but more experimental work must be carried out to confirm this.

4. Crop tolerance

Early potatoes. Metribuzin at rates up to 1.05 kg/ha was applied pre-emergence, on a wide range of soil types, to the following potato cultivars: Arran Comet, Arran Banner, Arran Pilot, Craig's Alliance, Craig's Royal, Epicure, Home Guard, Maris Page, Maris Peer, Red Craig's Royal, Red Ulster Premier, Ulster Chieftan, Ulster Dale, Ulster Premier, Ulster Prince, Ulster Sceptre. In most cases, even at the highest rate, there was no sign of damage, however, in a very few cases there was some evidence of very slight yellowing or stunting. Because of the length of persistence of metribuzin, and the short growing season for early potatoes, post-emergence applications are not necessary.

Table 2

Weed control with metribuzin. Summary of 30 trials 1969-1972
(Median% control)

Weed species	Rate kg/ha	Pre-em. of crop			Post-em. of crop			Starred rating	
		0.52	0.70	1.05	0.52	0.70	1.05	Pre-em.	Post-em.
Avena fatua		-	81	69	-	-	-	**	
Chenopodium album		100	100	100	100	100	-	***	***
Fumaria officinalis		91	91	100	-	100	100	***	***
Galium aparine		-	100	100	-	-	-	***	
Lolium perrenne		74	98	100	44	74	-	***	*
Papaver spp.		-	100	100	-	100	100	***	***
Poa annua		99	100	100	79	100	100	***	***
Polygonum aviculare		94	97	99	97	100	98	***	***
Polygonum convolvulus		67	74	67	94	96	95	*	***
Polygonum persicaria		98	100	100	100	100	-	***	***
Raphanus raphanistrum		100	100	100	100	100	-	***	***
Senecio vulgaris		100	100	100	-	95	-	***	***
Sinapis arvensis		-	99	100	-	-	-	***	
Stellaria media		100	100	100	99	100	99	***	***
Thlaspi arvense		-	97	100	-	100	99	***	***
Tripleurospermum maritimum		100	99	100	81	79	-	***	**
Urtica urens		90	97	98	100	95	-	***	***
Veronica agrestis		100	100	100	100	100	100	***	***
Veronica hederifolia		100	100	100	100	100	-	***	***
Viola tricolor		100	99	100	99	96	-	***	***

* The starred rating is a guide only and is based on % control, as follows:
*** very good effect 90-100% control ** satisfactory effect 75-89% control
* inadequate effect, less than 75% control

Main crop potatoes. Pre-emergence applications are defined as those put on at up to 50% crop emergence. Post-emergence applications are those put on after 50% emergence and up to a crop height of 15 cm.

In general, maincrop cultivars seem to be tolerant of pre crop-emergence applications of metribuzin, although under certain circumstances Maris Piper may be more sensitive. Post-crop emergence applications appear to be relatively safe, although slight chlorosis or stunting sometimes occurs.

Crop symptoms. Where phytotoxicity occured, it took the form of interveinal chlorosis, followed in some cases by death of the plant leaflets. These symptoms were usually transient, the crop quickly recovering and returning to full vigour.

Table 3

Tolerance of early potato varieties to metribuzin applied pre-crop emergence at 1.05 kg/ha

Cultivar	Soil type	Score	Cultivar	Soil type	Score
Arran Comet	L	1	Ulster Sceptre	LS	1
	CL	1		CSL	1
Arran Pilot	SL	1		FSL	1
	L	1		L	1
Epicure	L	1	Arran Banner	L	1
Home Guard	L	1	Craig's Alliance	L	1
	CL	1	Craig's Royal	L	1
	CL	1	Maris Page	L	1
Red Ulster Premier	L	1	Maris Peer	LS	1
Ulster Chieftan	L	1		VFSL	2
	CL	1		L	1
Ulster Premier	L	1		CL	1
	CL	2	Red Craig's Royal	L	2
Ulster Prince	LCS	2		L	1
	LS	3	Ulster Dale	L	1
	CSL	1			
	L	1			
	ZL	1			
	CL	1			

In all cases the untreated crop tolerance value was 1.

Table 4

Tolerance of main crop potato varities to metribuzin applied pre-crop emergence at 1.05 kg/ha and post-crop emergence at 0.7 kg/ha

Cultivar	Soil	Damaged score		Cultivar	Soil	Damaged score	
		Pre-em.	Post em.			Pre-em.	Post-em.
Desiree	CL	1	1	Pentland Crown	LCS	2	2
Dr. McIntosh	L	1	2.5		LS	1	2
King Edward	LCS	1.5	1.5		CSL		1
	FSL	1	1.5		SL		3
	SL		3		L	1	2
	ZL		4.5		ZL	1.5	1
	CL	1	1		CL	1	1
Majestic	VFSL	1	1		Org	1	
	FSL		1	Pentland Dell	CL	1	1.5
	L	1	2	Record	Sl	1	2
	CL	1	1	Redskin	SL	1	1
Maris Piper	CL	1	2.5	Ulster Glade	L	1	
	Peat	1	1				
	LCS	2.5	1.5				

5. Yield results.

Yield results have been obtained chiefly from the 1971 trials, though data from the 1972 trials on early potatoes are included.

Early potatoes. For early potatoes the yield data refer to pre-crop emergence applications.

It can be seen that generally the metribuzin treated plots gave higher yields than the untreated plots, and those treated with a standard herbicide.

Table 5

Yield results for early potatoes expressed as % of untreated crop

Cultivar	Soil Type	Rate of metribuzin (kg/ha) 0.7	1.05	Standard treatment	Untreated (t/ha)
Arran Pilot	SL	130	119	138	17.1
Home Guard	CL	196	194	212	9.0
Maris Peer	LS	115	98	120	5.3
	VFSL	121	121	152	17.6
Ulster Prince	LCS	114	100	95	9.6
	CSL	102	116	104	37.4
	ZL	277	220	222	8.0
Ulster Sceptre	LS	96	93	92	13.8
	CSL	112	126	110	17.1
	FSL	118	141	131	11.5

Main crop potatoes. Results are given for both pre- and post-crop emergence applications. Generally there is little difference in yield between pre- and post-crop emergence applications, and both increased yields considerably in the majority of trials.

Table 6

Yield of main crop potatoes expressed as % of untreated crop

Cultivar	Soil type	Rate of metribuzin (kg/ha) Pre-em. 0.7	1.05	2.1	Post-em. 0.3	0.7	Standard treatment	Untreated (t/ha)
King Edward	LCS	101	99	99	98	91	136	43.1
	LCS	98	102	97	87	105	106	63.9
	FSL	142	131	131	146	127	134	42.6
Majestic	VFSL	177	193	190	143	179	169	48.8
	L	258	317	340	251	382	265	7.0
Maris Piper	Peat	78	90	94	103	90	80	72.8
	LCS	154	136	124	134	141	181	32.4
Pentland Crown	ZyL	220	212	199	217	186	191	19.3
	ZL	109	109	105	106	111	106	18.1
	ZL	104	94	92	104	97	86	55.9
	LCS	77	88	80	94	90	70	62.4
Redskin	SL	138	132	128	134	120	131	45.1

6. Grower trials.

In addition to the small plot replicated trials described above, a total of twenty non-replicated grower trials were also carried out during 1972, applying metribuzin pre- and post-crop emergence, in comparison to the farmers' standard herbicide treatment. Materials were applied through the farmers' own field spraying machines. Rates of up to 1.05 kg/ha pre-emergence and 0.7 kg/ha post-emergence were used on plots of 0.2 - 0.4 ha size.

Resultant weed control and crop safety confirmed the good results achieved in the small plot work. Yield data are not yet available.

7. Crop residue and taint tests

Crop residue determinations to date are entirely satisfactory and a programme of taint tests on varieties used for canning and for the frozen chip market is in hand.

DISCUSSION

Trials carried out between 1969 and 1972 demonstrated that metribuzin kills weeds by both contact and residual action, uptake being via roots and leaves. Work to date suggests that following crops should not be planted until sixteen weeks after application of metribuzin. Metribuzin controlled a wide range of weeds both pre- and post-weed emergence. It gave good control of "problem" weeds such as *Polygonum convolvulus*, *Polygonum aviculare*, *Tripleurospermum maritimum* and *Fumaria officinalis*. Some effect against *Agropyron repens* and *Avena fatua* was also observed.

Metribuzin was shown to be safe on a wide range of early and main crop potato cultivars when applied pre-crop emergence. It was also safe on main crop varieties when applied post-crop emergence though slight crop damage was recorded on some cultivars. This damage was transient and soon disappeared. The yields achieved following the use of metribuzin were generally higher than on untreated plots, and comparable with those from the plots treated with a standard material. On main crop potatoes, post-crop emergence applications gave yield responses equivalent to the pre-crop emergence applications, showing that the occasional transient phytotoxicity symptoms had no effect on the final crop yields.

A programme of grower applied trials carried out in 1972 confirmed the results outlined above.

The post-crop emergence safety of metribuzin allows the practice of chemical weed control in potatoes to take another step forward, as a grower can now wait until the bulk of weeds in his crop have germinated irrespective of the degree of crop emergence, before applying his herbicide. This allows a good contact kill of emerged weeds and extends the period of residual weed control further into the growing season until the fully expanded canopy of crop foliage will suppress further weed growth.

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THE USE OF TRIETAZINE AND A TRIETAZINE/ SIMAZINE MIXTURE FOR WEED CONTROL IN PEAS

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Summary This paper presents evidence from a final year's field testing of a trietazine based herbicide combination for weed control in peas, and discusses earlier growth chamber research, leading to this new development.

A mixture containing trietazine + simazine (0.98 + 0.14 kg a.i./ha) has been shown to give very good and reliable selective weed control in peas under a wide range of U.K. conditions.

The mixture should ideally be used pre-emergence. It is safe on all soil types, except light sandy or very stony soils (LS or lighter, New Jersey scale).

The spectrum of weeds controlled covers the majority of broad-leaved weeds and grasses, excluding cleavers (*Galium aparine*) and wild oats (*Avena fatua*) with intermediate results on black bindweed (*Polygonum convolvulus*).

The combination shows persistent weed control for up to ten weeks, and is in this respect superior to most other herbicides used in peas.

INTRODUCTION

This paper describes a number of research trials carried out in 1971. Earlier work both in the field and in the greenhouse had shown trietazine and a mixture of trietazine + simazine to be extremely well tolerated by peas.

Prior to the field experimentation reported in this paper, detailed growth chamber work on the single and combined effects of stress factors on the safety of trietazine and other treatments were carried out. The stress factors included: susceptible varieties, very light soils, shallow planting, low temperatures, excessive moisture and placement of the chemical in close proximity to the germinating pea seed.

Peas showed an exceptionally high degree of tolerance to trietazine under a wide range of adverse conditions. Only under conditions of (a) incorporation of the chemical in the top 3.8 cm of soil, and (b) a light soil saturated by heavy watering, followed by warmer dryer conditions (i.e. a sharp increase in transpiration rate) was the safety of trietazine lower than that of prometryne. Details of this work will be published later.

METHOD AND MATERIALS

Sites - 24 sites widely scattered in eastern England, as detailed in Table 1.

Table 1

Location	Soil type (ADAS scale)	Variety	Dose	Drilled	Sprayed	Pre/Post-emergent application
1. Bourne	FSL	Sprite	M	16/2	22/2	Pre
2. Spalding 1	ZyL	Scout	M	25/2	26/2	Pre
3. Royston	Calc VFSL	Maro	M	25/2	12/3	Pre
4. Holbeach 1	VFSL	Sprite	M	11/3	19/3	Pre
5. Holbeach 2	Zyl	Sprite	M	12/3	19/3	Pre
6. Halesworth 1	LS	Kelvedon W.	L	17/3	29/3	Post
7. Bungay	LS	Tessa D	L	3/3	29/3	P of E
8. Wisbech 1	ZyCL	Scout	H	10/3	30/3	P of E
9. Holbeach 3	VFSL	Myzar	M	12/3	30/3	Pre
10. Wisbech 2	ZyCL	Scout	H	12/3	30/3	Pre
11. Yeldham	FSL	Maro	M	26/3	1/4	Pre
12. Grimsby 1	FSL	Sprite	M	24/3	2/4	Pre
13. Ipswich 1	FSL	Maro	M	27/3	5/4	Pre
14. Ipswich 2	FSL	Vedette	M	23/3	5/4	P of E
15. Wroxham 1	LFS	Jade	M	25/3	6/4	Pre
16. Martham	LFS	Scout	M	5/4	13/4	Pre
17. Wroxham 2	LS	Jade	M	13/3	13/4	Post
18. Henham	CL	Maro	H	16/3	14/4	Post
19. Grimsby 2	L	Jade	M	10/4	15/4	Pre
20. Loddon	LCS	Freezer '69	L	26/3	19/4	Post
21. Spalding 2	VFSL	Jade	M	8/4	20/4	Pre
22. Kings Lynn	LS	Superfection	L	5/4	20/4	Post
23. Woodbridge	FSL	Jade	M	23/3	22/4	Post
24. Halesworth 2	FSL/SCL	Jade	M	20/4	22/4	Pre

Soils - lightest - loamy coarse sand; heaviest - clay loam.

Variety and sowing dates 10 different varieties.

Earliest sowing: Sprite on 16th February, 1971
Latest sowing: Jade on 20th April, 1971

Time of herbicide application - ranged from within 24 hours of sowing to 31 days post-sowing.

15 sites fully pre-emergent
3 sites at point of emergence
6 sites post-emergence of crop

Treatments:

As in Table 2. For light soils (sandy loam, loamy sand and lighter) the standard dose was reduced by 25%; for heavy soils (clay loam and heavier), increased by 25%.

Table 2

No.	Treatment	Medium soils (wolds, silts, loams) kg/ha	Light soils (loamy sand & sandy loam) kg/ha	Heavy soils (clay loam & heavier) kg/ha
1.	Trietazine + simazine	0.85 + 0.14	0.64 + 0.105	1.06 + 0.175
2.	"	0.98 + 0.14	0.74 + 0.105	1.22 + 0.175
2a.	"	1.96 + 0.28	1.48 + 0.21	2.44 + 0.35
3.	"	1.12 + 0.14	0.84 + 0.105	1.40 + 0.175
4.	"	1.40 + 0.14	1.05 + 0.105	1.75 + 0.175
5.	Trietazine	1.12	0.84	1.40
6.	"	1.40	1.05	1.75
7.	"	1.70	1.28	2.12
8.	"	2.24	1.68	2.80
9.	"	3.40	2.55	4.25
10.	Prometryne	1.40	1.05	1.75
11.	"	1.40	1.05	1.75
12.	Untreated	-	-	-
13.	"	-	-	-

Plot size: 8 metres x 2 metres, 4 replications.

Application: All treatments applied by knapsack sprayer at a pressure of 1.4 kg/cm^2 and in 200 l./ha of water.

Harvesting: For selected treatments whole plots were cut by sickle and total vine weight recorded. A sub-sample of 20 kg/plot was vined, thus allowing calculation of comparative yields of vined peas to be made from up to 4 treatments and control.

RESULTS

The mean figures from a series of assessments of weed control obtained with each treatment are given in Table 3. Due to an extremely dry season in 1971, and the resulting lack of weed growth in some areas, it was found that no meaningful weed assessment could be made on 9 of the 24 experiments, the table thus includes results from 15 experiments.

Table 3

% Weed Control

No.	Treatment	Dose (medium soils) kg/ha	Bourne	Spalding 1	Royston	Holbeach 1	Halesworth 1	Bungay	Wisbech 1	Holbeach 2	Yeldham	Ipswich 1	Ipswich 2	Wroxham 2	Henham	Spalding 2	Woodbridge	MEAN	Class
1.	Trietazine + simazine	0.85 + 0.14	88	84	99	84	85	85	78	83	95	96	97	84	91	77	86	87	B+
2.	"	0.98 + 0.14	92	85	99	89	86	87	78	89	82	98	98	87	94	84	86	90	A-
2a.	"	1.96 + 0.28	92	95	100	97	95	98	94	91	97	98	100	93	95	93	89	95	A
3.	"	1.12 + 0.14	89	87	99	89	91	88	80	89	94	99	95	88	94	87	87	90	A-
4.	"	1.40 + 0.14	92	87	99	89	89	92	82	84	93	97	99	91	94	91	89	91	A-
5.	Trietazine	1.12	87	85	97	82	80	86	78	79	92	92	96	81	88	83	87	86	B
6.	"	1.40	91	85	96	86	86	91	86	87	90	97	100	89	86	86	87	90	A-
7.	"	1.70	92	85	98	89	89	93	82	92	97	98	99	93	97	86	93	92	A-
8.	"	2.24	95	88	99	94	96	96	85	93	99	98	100	95	99	90	94	95	A
9.	"	3.40	96	91	100	95	97	97	95	96	98	100	100	97	97	96	96	97	A+
10.	Standard (prometryne)	1.40	80	88	96	82	82	77	86	84	93	91	86	93	99	92	87	88	B+
11.	"	1.40	81	82	97	84	82	78	89	-	92	-	89	88	97	92	87	88	B+
12.	Untreated	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-
13.	"	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	-

<u>Classes:</u>

A (excellent) = 90-100%
B (good) = 80-90%
C (rather poor) = 70-80%
D (inadequate) = less than 70%

It was not expected that all 24 experiments would be harvested for yield, due to limitation of time and labour. The results from harvesting 11 experiments (9 vined and 2 dry harvested) are given in Table 4. Exceptionally weedy or uneven experiments were excluded.

Table 4

Yields as percentage of untreated

Location	Trietazine + simazine 0.98 + 0.14 kg/ha	Standard (prometryne) 1.40 kg/ha	Trietazine + simazine 1.96 + 0.28 kg/ha	Trietazine 3.40 kg/ha
Spalding 1	104.5	-	90.2	118.7+
Royston	101.0	86.6	93.7	-
Holbeach 1	104.7	-	106.4	125.6+
Long Sutton	91.9	99.2	93.5	94.4
Halesworth 1	119.7+	-	116.8+	127.0+
Ipswich 2	84.4	80.5	75.0-	67.4-
Martham	101.2	-	103.3	88.0-
Grimsby 2	168.4+	151.3+	136.2+	157.3+
Loddon	91.6	88.2	65.1-	52.5-
Woodbridge	114.7	-	103.2	97.8
Bungay	108.4	113.2	121.1+	-
MEAN	108.2	103.1	100.4	103.1

+ = significant yield increase at)
- = significant yield decrease at) P = 0.05

DISCUSSION

It is evident from Table 3 that all treatments gave acceptable weed control. Detailed observations throughout the season demonstrated the prolonged herbicidal activity of trietazine and of the mixture.

In one experiment, Raphanus raphanistrum germinating 5-7 weeks after herbicide application was well controlled by treatments containing trietazine, but not by the commercial standard used. This, together with evidence from trials reported by Edwards and Lake (1972), emphasises one particular property of trietazine. Trietazine is only very slowly leached from the soil surface. Although trietazine is more soluble (20 ppm) than simazine (5 ppm), it is less readily leached than simazine and thus very much more persistent in the top layer of soil than either simazine or prometryne. It is this factor, of exceptionally long activity at the soil surface, that makes trietazine of value in the pea crop, where a full crop canopy is often slow to form.

This advantage is not outweighed by any problems of persistence of herbicidal activity in following crops. Careful studies and bio-assays have been made and, even at the highest rate of 3.4 kg/ha of trietazine (well over twice the recommended dose), no effect on a wide range of following crops has been observed.

However, this extremely slow leaching characteristic of trietazine does present some limitation. On several sites, it was observed that Polygonum convolvulus was less susceptible to trietazine than most other weeds. This was concluded to be a partial resistance, but was further highlighted by the inability of trietazine to be leached very far below the soil surface. The P. convolvulus seedlings were found to be germinating from a depth of 4-5 cm, and were unaffected by the herbicide. Thus it would appear that the property contributing to the high value of trietazine also gives rise to a minor weakness in giving only partial control of weeds germinating from well below the soil surface, unless these weeds are exceptionally susceptible. In large scale commercial use of the mixture in 1972, no major problems of weed susceptibility or crop safety were encountered.

As shown in Table 4, no significant yield reductions occurred in any of the experiments with the normal rate (0.98 + 0.14 kg a.i./ha) of the trietazine/simazine mixture. Also, the yields obtained were similar to those obtained with the commercial standard, prometryne. Yield reductions at the double dose occurred only in two experiments, due to light soil type and very shallow planting.

The relative safety of trietazine itself is illustrated by the yield data at a dose of 3.4 kg/ha, i.e. four times the rate of trietazine recommended in the mixture. Even at this very high dose, yield reduction only occurred at the two experiments with very light soil and shallow planting.

In complete confirmation of growth chamber studies, very high crop toxicity occurred in one experiment on coarse sand with shallow planting and very heavy rain immediately after application. The use of trietazine under such conditions is, of course, excluded from recommendations.

In general, trietazine, and more specifically a mixture of trietazine + simazine, is shown to be an extremely effective and safe herbicide for use on peas. The mixture is thus a valuable addition to the range of herbicides for use in the pea crop, the factors of particular value being the ideal long period of residual activity at the soil surface and the extreme safety to peas under a very wide range of conditions.

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Proc. 11th Brit. Weed Control Conf. (1972)

GROWER TRIALS WITH A MIXTURE OF TRIETAZINE AND SIMAZINE IN PEAS

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Summary Grower trials were carried out on 58 sites in 1971 with a mixture of trietazine and simazine for the control of annual broad-leaved weeds in peas. The vast majority of the sites were on pea crops contracted for processing.

A wide range of annual weeds was controlled including many of those which can be very damaging to the pea crop, such as *Aethusa cynapium*, *Polygonum aviculare*, *Tripleurospermum maritimum* ssp. *inodorum*, *Papaver rhoeas* and *Veronica* spp. Particularly noticeable was the control of late germinating weeds such as *Sinapis arvensis*.

INTRODUCTION

Weed control in pea crops, particularly processed peas, is of the upmost importance. Competition for space, nutrients, moisture and air from the earliest stages of growth can have a very serious effect on crop quality and yield. Weed growth later can interfere with mechanical harvesting and the presence of certain species can lead to contamination of the final product.

A mixture of trietazine at 14 oz a.i./ac and simazine at 2 oz a.i./ac had been shown to be effective and selective as a herbicide in peas (Ball *et al* 1972). This series of grower trials was designed to test the reliability of this mixture under practical farm conditions. To this end, the sites were spread to cover as wide a range of soil type, climatic conditions and pea variety as practically possible. Where applicable they were also chosen in conjunction with the processing company concerned.

METHOD AND MATERIALS

Fifty-eight non-replicated sites were laid down comparing the trial material with the grower's standard commercial treatment. The trial material was formulated as a 50% w.p. Application was made at three doses according to soil type as set out in Table 1.

Table 1

Distribution of Soil Type and Dose

No. of sites	Soil type (New Jersey Scale)	Dose in oz/ac Trietazine + Simazine
7	LS - LFS	10.5 + 1.5
43	LVFS - ZyL	14.0 + 2.0
8	L - ZyCL	17.5 + 2.5

A wide range of vined peas, and a number of dry harvest pea varieties was sprayed. Also included was one site on a fresh green pick crop.

The distribution of sites was widespread, but as would be expected, the highest proportion was in East Anglia (18), Lincolnshire (18) and South Yorkshire (6). However, other areas were covered including Somerset, Hampshire, Worcestershire, Leicestershire, Nottinghamshire, and Scotland.

In all cases the trial material was applied by the grower or his operator through the normal farm sprayer under the direct supervision of a Fison's Regional Technical Officer. Volumes of water varied from 20 - 50 gal/ac, the majority being in the 20 - 30 gal/ac range.

In practice, most were sprayed prior to emergence. At most sites spraying occurred in the 10 days before crop emergence and before any weeds had emerged. Where weeds were present, they were no bigger than the cotyledon stage.

All sites were regularly assessed throughout the season.

RESULTS

a) Crop effects

On two sites some crop effects were noted. In both cases slight over-dosing had occurred, one on loamy fine sand and one on fine sandy loam. This was seen as a yellowing of the plant at emergence and a slight check to crop growth. Yields were not taken as they were considered to be unaffected on these sites. Otherwise there was no visible crop check, even on sites where the peas were already emerging at the time of spraying.

b) Weed control

The main weeds present on the untreated areas and the number of sites at which they occurred are given in Table 2. Also shown is the level of control obtained from the trietazine/simazine mixture expressed as the number of sites falling in the good, intermediate and poor categories.

Table 2

Control of main weed species with trietazine/simazine mixture

Weed spp.	Total number of sites occurring	Number of sites in each category		
		Good*	Intermediate*	Poor*
Aethusa cynapium	7	7	0	0
Alopecurus myosuroides	1	1	0	0
Anagallis arvensis	2	2	0	0
Atriplex patula	3	2	0	1
Brassica nigra	2	1	1	0
Capsella bursa-pastoris	5	5	0	0
Chenopodium album	12	12	0	0
Fumaria officinalis	8	7	0	1
Galeopsis tetrahit	2	0	1	1
Galium aparine	5	1	0	4
Lamium purpureum	6	6	0	0
Papaver rhoeas	3	3	0	0
Poa annua	6	3	3	0
Polygonum aviculare	33	27	5	1
Polygonum convolvulus	31	9	22	0
Polygonum persicaria	5	1	4	0
Raphanus raphanistrum	3	3	0	0
Senecio vulgaris	3	3	0	0
Silene alba	2	2	0	0
Sinapis arvensis	24	19	5	0
Sonchus oleraceus	3	2	1	0
Spergula arvensis	2	2	0	0
Stellaria media	27	26	1	0
Thlaspi arvense	1	1	0	0
Tripleurospermum maritimum ssp. *inodorum*	20	18	2	0
Urtica urens	5	5	0	0
Veronica hederifolia	5	4	1	0
Veronica persica	18	17	1	0
Viola arvensis	10	0	8	2

*Good = 80% control and above *Intermediate = 60% to 80% control

*Poor = under 60% control

On 51 of the 58 sites, the standard treatment was prometryne. At the other sites dinoseb amine or dinoseb acetate was applied post-emergence. Comparisons of the overall broad-leaved weed control were made between the trietazine/simazine mixture and prometryne and are shown in Table 3.

Table 3

Comparison of trietazine/simazine mixture and prometryne in overall weed control

	Trietazine/simazine Better	Prometryne Better	Treatments Equal
No. of sites	37	4	10

DISCUSSION

The general level of overall annual broad-leaved weed control was very good, and as can be seen in Table 2 was fairly consistent, from site to site. Weeds that were well controlled at all the sites on which they occurred were Aethusa cynapium, Anagallis arvensis, Papaver rhoeas, Raphanus raphanistrum, Senecio vulgaris, Silene alba, Spergula arvensis, Thlaspi arvense, Urtica urens.

Excellent control was also seen at all but a few sites of Fumaria officinalis, Polygonum aviculare, Sinapis arvensis, Sonchus oleraceus, Stellaria media, Tripleurospermum maritimum ssp. inodorum and Veronica spp. Weeds where the control was generally acceptable were classed as intermediate and included Atriplex patula, Galeopsis tetrahit, Polygonum convolvulus and Poa annua. The weeds Galium aparine and Viola arvensis were only poorly controlled.

The trietazine/simazine mixture was shown to be an effective and reliable herbicide in peas. It compared favourably with the standard prometryne treatment in 37 of the 51 sites where the two were sprayed alongside each other, and was worse on only 4 sites. This better control from the trietazine/simazine mixture was often only apparent later in the season, towards harvest. The trial material appeared to persist longer and be more active on late germinating weeds. This was particularly noticeable on Sinapis arvensis and Papaver rhoeas.

On a number of sites control was not acceptable and over-spraying with dinoseb amine was necessary. In nearly all cases this was due to lack of sufficient available moisture to activate the chemical in a long period of dry weather. For instance, on one site it was 42 days before there was any appreciable rainfall after spraying. However, on other sites where rain came after 2 - 3 weeks, the small weeds which had already germinated were well controlled. Small weeds, up to the cotyledon stage, were controlled if present at the time of spraying. It would appear, therefore, that the trietazine/simazine mixture remained on or very near the surface of the soil. This would account for the persistency of the treatment and also for the lack of crop damage.

Overall weed control was not satisfactory on 6 of the 58 sites, and these were oversprayed. A further 4 sites were also treated with a post-emergent spray of dinoseb amine, because the rest of the field was being oversprayed. This compared favourably with the grower's standard prometryne, where 13 sites needed a second treatment.

Polygonum convolvulus was not completely controlled on all sites and was noticeable as one of the first weeds to appear where overall weed control was not acceptable. Closer examination often showed that this weed had germinated from deeper than most of the other annual broad-leaved weeds. By the time that there was adequate rainfall, this weed was often too well established, with too deep a rooting system, to be controlled.

Looking at the different doses, varied according to soil type, it was seen that the control on the very light loamy sand - loamy fine sand and medium soil categories loamy very fine sand - silty loam was generally excellent. On the heavier soil loam - silty clay loam, the level of weed control was generally very good, provided sufficient moisture was present. Where this was not the case, weed control suffered more than on the lighter soils.

Where some of the crop had emerged at the time of spraying, no damaging effects were seen.

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