C 6313, A NEW CIBA BROMO-SUBSTITUTED UREA HERBICIDE

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Summary A new bromo-substituted phenyl urea herbicide was synthesised by the Chemistry Division of CIBA Ltd. in 1961. Since then, a large number of trials in the greenhouse and the field have been carried out all over the world.

Several important crops have shown tolerance to C 6313 in situations where the weeds were well or adequately controlled. These crops are : carrots, cereals and groundnuts, pre- and post-emergence ; dwarf beans, soybeans, peas, maize and potatoes, pre-emergence only ; and leeks, celery and tobacco, post-transplant.

Results of some of the field experiments, both small-plot and yield trials, are presented in this paper. The herbicide has fairly typical properties for a substituted urea of low to moderate water solubility, being fairly resistant to leaching, and strongly adsorbed onto organic matter and clay in the soil. A wide range of weeds is controlled, pre-emergence and in the seedling stage. A list of these is presented in the Appendix to this paper.

However, C 6313 has exhibited an exceptional degree of foliar contact activity against overwintering broad-leaved weeds, and appears to be somewhat more active post-emergence than most other substituted ureas.

The herbicide possesses a low order of mammalian toxicity.

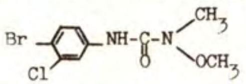
Further field trials, experiments to evaluate the time for which residues persist in the soil, and extended toxicity trials are in progress or are planned for the near future.

INTRODUCTION

Since 1951, when the first substituted urea herbicide (monuron) was described, a great number of these compounds have been synthesised and tested. In 1960, CIBA Ltd. began a programme of research on bromo-substituted ureas, which led in 1960 to the discovery of metobromuron (Patoran) and in 1961 to the synthesis of C 6313.

PHYSICAL AND CHEMICAL PROPERTIES

C 6313 has the formula N-(4-bromo-3-chlorophenyl)-N'-methoxy-N'-methyl urea :



which has the empirical formula $C_9H_{10}BrClN_2O_2$, giving a molecular weight of 293.6.

The compound in its pure state consists of pale tan-coloured crystals with a melting point of 94-96°C. The solubility is 50 ppm in water, comparable with that of diuron, and less than that of most other substituted ureas. As would be expected, it exhibits a relatively low degree of mobility in the soil and is moderately resistant to leaching.

The compound is formulated as a 50 % wettable powder.

BIOLOGICAL PROPERTIES

C 6313 is absorbed by both the roots and leaves of plants, and can therefore act on weeds both pre- and post-emergence. It is a strong inhibitor of the Hill reaction, the photolysis of water carried out by plant chloroplasts during photosynthesis : the I_{50} dose was 2.2×10^{-7}M, compared with that of diuron and linuron, 2.0×10^{-7}M, monuron 1.7×10^{-6} and fluometuron $4.5 \times 10^{-}$, on isolated chloroplasts extracted from peas, var. "Alaska".

TOXICOLOGY

The Acute Oral LD_{50} for female rats is 4287 mg/kg of body weight. Symptoms of distress occurred at rates of 1000 mg/kg and above, but all the animals recovered completely within 14 days. No effects attributable to C 6313 were seen in the organs investigated during a necropsy carried out 14 days after treatment.

Dermal applications were made to the abdominal skin of albino rabbits after close clipping of the hair, and abrasion of the skin of half the test animals. The rates of application were 1.0, 2.15, 4.64 and 10 g/kg of body weight applied for 24 hours and then removed. Temporary inflamation was seen on one of the animals with abraded skin. Otherwise no symptoms of irritation or toxicity were noted for 14 days after application, and the animals gained weight normally. No gross changes in body organs were seen at necropsy. The acute dermal LD_{50} for C 6313 on rabbits is thus greater than 10 g/kg of body weight.

The application of 100 mg of dry C 6313 to the eyes of albino rabbits produced moderate temporary conjunctival irritation, and inducted corneal lesions with or without corneal opacity in 3 of the 4 animals tested. The symptoms subsided within 3 days in 2 of these animals.

A sub-acute feeding test over one month on young albino male rats was carried out with rates of 316, 1000 and 3160 ppm supplied in all the food eaten. At the 2 higher rates, growth rate and food consumption were reduced, and at the highest rate, white blood cell counts were significantly increased while red blood cell counts, blood cell volume and haemoglobin values were depressed. No animals died, and necropsy after 1 month of feeding on C 6313 revealed no gross pathological symptoms attributable to C 6313.

The "no-effect" level of C 6313 in the food of male albino rats lies between 316 and 1000 ppm.

Two-year extended feeding tests are now in progress.

EXPERIMENTAL RESULTS

a) General Results and Observations

Primary evaluation and further greenhouse testing showed that a wide range of important seed-propagated weeds was controlled, both by pre-emergence and by post-emergence treatments at any stage between emergence and the 6-leaf stage, at rates which were tolerated by several important crops, in particular carrots, peas and small-grain cereals.

The results have been amply confirmed by more than 100 field trials, varying from unreplicated small-plot observation trials to yield trials, carried out in many countries all over the world.

Tolerance to pre-emergence applications has been reported in maize, potatoes, peas, dwarf beans, soybeans and sorghum. Post-transplant applications to leeks.

celery and tobacco have shown selectivity, while both pre- and post-emergence applications have been successful in carrots, cereals and groundnuts.

The rates of application necessary for selective weed control vary greatly on different soil types. As little as 0.75 kg a.i./ha gave excellent weed control on a very sandy soil, while twice this rate has several times given only adequate weed control on silt-loam and clay soils, and 2 or even 3 kg a.i./ha has been necessary to achieve optimum results in some trials on heavy soils. Humus content also affects the performance of C 6313 since in a dune-sand soil of high (6-7%) humus content, 3 kg a.i./ha was insufficient to control normally susceptible weeds while 0.75 kg a.i./ha gave excellent results on a similar marine-derived sand soil with a low humus content. Crop selectivity does not appear to be much altered by these large variations in the application rates ; that is, the crops which tolerated the rates of C 6313 necessary to achieve weed control in light soils or soils with a low humus content have generally tolerated the higher rates necessary in soils with a high clay or humus content.

The effects on weeds of C 6313 applied pre-emergence are like those of other substituted urea herbicides. Weed seedlings often emerge, but turn yellow and wilt while still in the cotyledon stage. The post-emergence effects, however, have in some cases been extraordinary. A scorching effect described as being like that of DNOC has been reported on overwintering broad-leaved weeds in winter-sown cereals, and generally the necrotic symptoms seen on treated weeds have been more severe and rapid in their development than is usual with substituted ureas. Moreover, quite large broad leaved weeds, with up to 6 leaves, have rapidly been killed.

The time for which residues can persist in soil is not accurately known at the moment, because of the short time that the product has been field tested ; trials to evaluate soil persistence are planned for the near future.

b) Detailed Results of Small-Scale Experiments

(i) Time of application trial in carrots

Seed of carrots, var. "Nantaiser" was shallowly sown by machine in a humus-rich sandy loam soil, and sprayed on 3 succeeding dates, as follows :

A. 2 days after sowing, pre-emergence to the crop, when a few weeds had emerged and were in the cotyledon stage. The soil was moist, and the day cool and cloudy.

B. 6 days after sowing, when the carrots were emerging, and the weeds were between the cotyledon and 2-leaf stages. The soil was dry, and the weather hot and sunny.

C. 23 days after sowing, by which time the carrots had 2 true leaves, and the weeds were 8 cm high and had between 4 and 6 leaves. Again, the soil was dry and the weather warm.

The application rates of C 6313 were 1, 1.5 and 2 kg a.i./ha : at dates A and B, 500 l. of spray/ha were used, while at date C, a volume of 800 l./ha was applied. The treatments were replicated 4 times.

Table 1 shows the weed control and crop health scores awarded to the treatments 4 and 7 weeks after the date A treatment, 3 1/2 and 6 1/2 weeks after the date B treatments and 1 week and 4 weeks after the date C treatments were sprayed.

Table 1. Time of Application Trial with C 6313 in Carrots : Weed Control and Crop Health Scores (Averages for 4 Replicates)

Time of Application	Rate of C 6313 kg a.i./ ha	Time Sowing Spraying (Days)	Weed Control Scores after following times (weeks)		Crop Health Scores after following times (weeks)	
			A.) 4 B.) 3 1/2 C.) 1	A.) 7 B.) 6 1/2 C.) 4	A.) 4 B.) 3 1/2 C.) 1	A.) 7 B.) 6 1/2 C.) 4
A.)	1.0	2	4	3	2	1
	1.5	2	3	2	1	1
	2.0	2	2	1	1	1
	0		60% cover	100% cover	1	1
B.)	1.0	6	2	2	3	2
	1.5	6	1	2	2	2
	2.0	6	1	2	3	4
	0		85% cover	100% cover	1	1
C.)	1.0	23	3	2	3	3
	1.5	23	3	2	3	4
	2.0	23	3	2	4	5
	0		100% cover	100% cover	1	1

The scores are awarded on the scales of from 1-9 recommended by the European Weed Research Council ; 1 indicates complete weed control or a healthy crop, while 9 indicates either complete kill of the crop or no effect on weeds. The scales differentiate between smaller increments in weed density and crop damage over the range 1-4 than over the range 5-9, since it is desirable to have a more accurate idea of the amount of weed growth over the range 0-10% cover than at greater weed densities.

It will be seen that crop tolerance of all rates applied pre-emergence was excellent, but barely adequate when 2 kg a.i./ha was applied at emergence, and not adequate when the same rate was applied to carrots at the 2-leaf stage. Initially, weed control was better when C 6313 was applied to young emerged weeds (stage B), but at the second assessment, only minor differences were noted.

No crop damage was caused by pre-emergence applications, and the only treatment causing unacceptable damage to the crop was the 2 kg a.i./ha rate applied at the 2-leaf stage.

The only weed not adequately controlled, by pre-emergence, and by late post-emergence applications in particular was Portulaca oleracea, which comprised 15-20% of the total weed population in this trial. Occasional plants of Amaranthus retroflexus, Galinsoga parviflora and Solanum nigrum occurred in plots treated with the lowest rate of C 6313 : Chenopodium album was completely killed by all treatments.

(ii) Post-emergence trial in carrots

Plots were marked out in beds of broadcast-sown carrots growing in a sandy soil of low humus content, and sprayed with C 6313 at 0.75 and 1.5 kg a.i./ha when the crop had reached the 2-3-leaf stage.

Table 2 shows the weed control and crop health scores awarded 3 and 8 weeks after spraying. Each score is the average for 3 replications.

Table 2. Post-emergence Trial of C 6313 in Carrots : Weed Control Scores and Crop Health Scores (Averages for 3 Replicates)

Rate of C 6313 kg a.i./ ha	Weed Control Scores after the following times (weeks)		Crop Health Scores after the following times (weeks)	
	4	9	4	9
0.75	2	1.5	1	1
1.5	1	1	1	1
0	60-70% cover	80 % cover	1	2.5

A dense stand of weeds, comprising <u>Chenopodium album</u>, <u>Polygonum persicaria</u>, <u>Solanum nigrum</u>, <u>Lamium amplexicaule</u>, <u>Veronica</u>, <u>Senecio vulgaris</u>, <u>Stellaria media</u>, <u>Sonchus oleracea</u> and <u>Medicago lupulina</u>, was completely controlled by both rates of C 6313 until near harvest, by which time the carrots in the unsprayed plots were stunted by the effect of weed competition. The underground portions of the treated carrots were up to 50% longer and thicker than those pulled from control plots.

(iii) Pre-emergence trial in peas

In a humus-rich sandy loam soil, peas var. "Kleine Rheinländerin", were sown by machine, and sprayed 3 days later with C 6313 at 1, 1.5 and 2 kg a.i./ha. There were 4 replicates of each treatment. At spraying, the soil surface was dry, but the pea seeds had swelled prior to germination, and some weeds had just emerged.

Assessments of weed control and crop health were carried out 4 and 8 weeks after treatment, and the results of these assessments are shown in table 3 below.

Table 3. Pre-emergence Trial of C 6313 in Peas : Weed Control and Crop Health Scores (Averages for 4 Replicates)

Rate of C 6313 kg a.i./ ha	Weed Control Scores after the following times (weeks)		Crop Health Scores after the following times (weeks)	
	4	8	4	8
1.0	5	7	1	1
1.5	3	5	1	1
2.0	2	4	1	1
0	90% cover	90% cover	1	1

8 weeks after treatment, the following weeds were growing in control plots : <u>Galinsoga parviflora</u>, <u>Stellaria media</u>, <u>Urtica urens</u>, <u>Chenopodium album</u>, <u>Sonchus oleracea</u> and small numbers of <u>Polygonum</u>, <u>Amaranthus retroflexus</u>, <u>Senecio vulgaris</u>, <u>Lamium</u> and <u>Echinochloa crusgalli</u>. Of these, only the first was controlled by the 1 kg a.i./ha rate of C 6313, while the 1.5 kg rate in addition controlled <u>U. urens</u>. The highest rate of C 6313 failed to control only <u>Polygonum sp</u>., <u>S. vulgaris</u> and <u>E. crus-galli</u> at this time. A minimum of 2 kg a.i. of C 6313/ha was necessary on this soil to control adequately this dense and varied weed flora. No damage to the peas resulted from any rate of application.

(iv) Post-emergence trial in spring-sown wheat

Small plots (15 m^2) were marked out in a field of spring-sown wheat, and sprayed in mid-April, when the wheat was at the 2-3-leaf stage, prior to tillering. The weeds were between the cotyledon and the 3-leaf stage of development. C 6313 was applied at 0.5, 0.75, 1.0 or 1.25 kg a.i. in 600 l./ha.

Assessments of weed control and crop health, on the 1-9 scales described in section (i), were carried out 2 and 6 1/2 weeks after treatment. Results are shown in table 4 below.

Table 4. Post-emergence Trial of C 6313 in spring-sown Wheat : Weed Control and Crop Health Scores (Average Scores for 4 Replicates)

Rate of C 6313 kg a.i./ha	Weed Control Scores after the following times (weeks)		Crop Health Scores after the following times (weeks)	
	2	6 1/2	2	6 1/2
0.5	4	4	2	1
0.75	3	4	2	1
1.0	2	3	2	2
1.25	2	2	3	2
0	33% cover	66%cover	1	1

Sinapis, the commonest weed, and Polygonum, were controlled by all the rates of C 6313 for 6 1/2 weeks. Vicia was partially controlled by all rates, but well controlled only by 1.0 and 1.25 kg a.i./ha. Matricaria and Alopecurus myosuroides were controlled only by the highest rate, while 0.5 and 0.75 kg a.i./ha had very little effect on these weeds. Initially, slight damage to the crop was caused by C 6313 at 1.25 kg a.i./ha, and the lower rates appeared to lessen the growth rate slightly ; after 6 1/2 weeks, damage by the 2 higher rates (score, 2) was confined to this slight and unimportant stunting effect.

(v) Post-emergence time of spraying trial in winter wheat

In a crop of wheat sown in late autumn, 3 replications of 4 rates of C 6313 were sprayed at each of 3 growth stages, as follows :

A : during tillering
B : late tillering-shooting, 2 weeks after A
C : one-node stage, 2 weeks later than B.

The main weeds present were Matricaria, Alopecurus myosuroides and Apera spica-venti. Assessments of crop health and weed control were carried out when the wheat had almost finished flowering, some 7 weeks after the latest spraying, and 9 and 11 weeks respectively after the stage B and A sprayings. The results are shown in table 5 below.

Table 5. Post-emergence time of spraying Trial in winter-sown Wheat : Weed Control and Crop Health Scores (Average Scores for 3 Replicates)

Application stage	Rate of C 6313 kg a.i./ha	Time of spraying	Weed Control Scores after the following times (weeks) A.11 B.9 C.7	Crop Health Scores after the following times (weeks) A.11 B.9 C.7
A.	0.25		6	1
	0.5	Mid-April	5	1
	1.0	1966	4	2
	2.0		2.5	1.5
	0		50% cover	1
B.	0.25		6	1
	0.5	29.4.1966	5	1
	1.0		4	2.5
	2.0		3	3
	0		60% cover	1
C.	0.25		7	1
	0.5	14.5.1966	5	1.5
	1.0		6	3
	2.0		4.5	4
	0		60% cover	1

In general, crop damage with C 6313 at 0.5, 1.0 and 2.0 kg a.i./ha tended to increase with increasing age of the wheat, while the weed control at stage C (one node stage) was less than that obtained with earlier treatments. Consequently no rate applied at stage C gave adequate selective weed control, while at stage B, the crop damage with 2 kg a.i./ha was approaching the tolerable limit, while 1 kg a.i./ha was giving only just adequate control of weeds. At stage A, early tillering, rates between 1 and 2 kg a.i./ha appear capable of supressing this weed population without causing more than a trace of damage to the crop.

On the fine silt-loam soil of Central Belgium, provided that spraying is carried out before the end of tillering, C 6313 is capable of killing Apera spica-venti, and supressing Alopecurus myosuroides and Matricaria to a level where their competitive effect on winter wheat is slight.

c) Yield Trial Results

(i) Post-emergence trial in winter barley

Spring applications of C 6313 and three comparison compounds were made to 4-times replicated plots of winter-sown barley at the 3-5-leaf stage of the crop and 1-3-leaf or small rosette stage of the weeds. A randomised complete-block design was used in the trial, the yield results presented below being the averages from 4 replicates. Yields were taken from a 20 m^2 portion of each plot during August.

Table 6. Post-emergence Trial in winter-sown Barley : Yield Results

Rate of C 6313 kg a.i./ha	Yield, kg/ha (mean of 4 replicates)	Range Test		
1.0	3,338	A		
1.25	3,213	A	B	
0.75	3,100	A	B	
0.5	2,737		B	C
0	2,469			C

Treatments having a category letter in common are not significantly different at the 5 % level of probability ; treatments awarded a letter or combination of letters without one or more in common are significantly different at this level.

In this trial, the yields from plots treated with 0.75, 1.0 and 1.25 kg a.i./ha rates of C 6313 were not significantly different, and all were significantly better than the untreated control. All the rates of C 6313 above 0.5 kg a.i./ha tested in this trial were capable of significantly increasing yield. The weeds occurring in the plots were Alopecurus myosuroides, Galium aparine, Sinapis arvensis and Vicia. The first, though not well controlled by C 6313, was sufficiently well suppressed by rates above 0.5 kg a.i./ha to encourage the yielding of barley to a statistically significant extent.

(ii) Time of Application trial in spring-sown wheat : post-emergence

Spring wheat was sown in March, and 3 identical trials were sprayed at 3 different times during April and May. Each treatment was replicated 4 times at each spraying date.

The main weeds growing in the area were Sinapis arvensis, Matricaria, Polygonum and Stellaria media. The wheat was sprayed at the 2-3-leaf stage at mid- and late-tillering, when the weeds were at the 2-3-leaf or small rosette, 5-leaf or large rosette and 6 or more leaf stages respectively.

A portion of each plot 15 m^2 in extent was harvested, and the grain threshed out and weighed. The results are shown in table 7 below.

Table 7. Time of Application Trial in spring-sown Wheat : Yield Results (grain yields, kg/ha, means of 4 replicates)

Rate of C 6313 kg a.i./ha	Sprayed at 2-3-leaf stage of crop	Range Test		Sprayed at mid-tillering	Range Test		Sprayed at late-tillering	Range Test	
0.75	3,616	A*		3,333	A*		2,750	A	
1.25	3,566	A*		3,024	A		2,675	A	
0.5	3,542	A*		3,324	A*		2.900	A	
1.0	3,541	A*		3,158	A		2.825	A	
0	2,333		B	2,107		B	2,000		B

A* (A) : significantly better than control at the 1% (5%) level of probability

In general, the later the time of application, the lower were the grain yields of the wheat Though the differences in crop damage and weed control were not large. it could be seen that the later the applications of C 6313 were made, the greater was the risk of crop damage and the poorer became the control of the weeds. This effect, as reflected in yield, was noticeable with all rates of C 6313, emphasising the necessity of applying C 6313 just before, or early during, tillering of cereals.

(iii) Pre-emergence trial in Peas

Peas, var. "Kleine Rheinländerin", sown in a light, sandy humus-rich soil, were treated with 3 rates of C 6313, and comparison products. Spraying was carried out 3 days after sowing. The weeds were similar to those listed as occurring in the small-plot trial in peas, Sect. 4 b iii. Yields were taken from an area 16 m^2 in each plot, and are shown in table 8 below.

Table 8. Pre-emergence Trial in Peas : Yield Results

Rate of C 6313 kg a.i./ha	Yield of peas, kg/ha (Averages of 4 Replications)	Yield as % of control yield
1.0	7,770	118
1.5	9,390	143
2.0	9,110	139
0	6,580	100

On this soil type, rates of C 6313 between 1.5 and 2 kg a.i./ha are capable of controlling a mixed population of broad-leaved weeds without damage to the crop, and of considerably increasing the resulting yield of peas.

Appendix

Efficacy of C 6313 : Weed Susceptibilities

Weed Species adequately controlled by C 6313 at 1 - 2 kg a.i./ha

Ambrosia artemesifolia
Amaranthus retroflexus
Anagallis arvensis
Apera spica-venti
Atriplex patula
Brassica kaber
Capsella bursa-pastoris
Cerastium holosteoides
Chenopodium album
Convolvulus arvensis
Digitaria sanguinalis
*Echinochloa crusgalli
Eleusine indica
Euphorbia sp.
Fumaria sp.
Galinsoga parviflora
Lamium amplexicaule
Lamium purpureum
Medicago lupulina
Mollugo verticillata
Papaver rhoeas
*Plantago lanceolata
Poa annua
Poa pratensis
Polygonum aviculare
Polygonum convolvulus
*Polygonum persicaria
*Portulaca oleracea
Raphanus raphanistrum
*Senecio vulgaris
Setaria glauca
Sinapis arvensis
Solanum nigrum
Sonchus oleraceus
Spergula arvensis
Stellaria media
Thlaspi arvense
Urtica urens
Veronica hederifolia
Vicia sp.
Viola sp.

Species marked * tend to be more susceptible to post-emergence applications and have shown resistance to pre-emergence applications on a few occasions.

Weed Species suppressed or controlled by C 6313 at 2 kg a.i./ha, but rarely by 1 kg a.i./ha

Centaurea cyanus
Galium aparine
Lolium perenne
Polygonum spp. (sometimes)
Setaria verticillata
Veronica persica

Weed Species resistant to C 6313 at rates selective in crops

Alopecurus myosuroides
Cirsium arvense
Cirsium vulgare (may be susceptible to pre-emergence applications)
Datura stramonium (probably)
Matricaria spp. (often reduced in size, but rarely killed)
Sorghum halepense

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A NEW HERBICIDE

2-AZIDO-4-ETHYLAMINO-6-t-BUTYLAMINO-1,3,5-TRIAZINE

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Summary Chemical, toxicological and biological information is given concerning a new s-triazine herbicide, 2-azido-4-ethylamino-6-t-butylamino-1,3,5-triazine, coded WL 9385. The compound has a broad herbicidal spectrum, pre- and post-emergence and a wide range of potential uses which include the selective control of annual grasses and MCPA/2,4-D - resistant dicotyledons in cereals. The compound has a short predictable half-life in the soil and is virtually non-leaching. Its rapid inactivation in soil is a chemical rather than a microbiological degradation.

INTRODUCTION

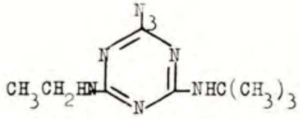
WL 9385, 2-azido-4-ethylamino-6-t-butylamino-1,3,5,-triazine is the most active compound of a new series of herbicidal symmetrical triazines, a chemical class which has been widely investigated since the discovery of the active chloro-(bis)alkylamino-s-triazines in 1955.[1] Despite this early discovery and the potentially large number of possible compounds within the class, relatively few novel s-triazine herbicides of comparable potency have since been reported. Those which have been developed show considerable persistence in soil.

In structure/activity relationships and in mode of action, the azido-(bis)alkylamino-s-triazines broadly resemble their chloro-analogues,[2,3] but data summarized in this paper indicate that WL 9385 differs appreciably from earlier s-triazines in physicochemical, physiological and herbicidal properties, and is notably less persistent in soil.

Chemical and Physical Properties

Structure:

Code no: WL 9385



Chemical name: 2-azido-4-ethylamino-6-t-butylamino-1,3,5- triazine.

Empirical formula: $N_8 C_9 H_{16}$ Molecular weight: 236.

Solubility: Water, 72 ppm (20°C) 129 ppm (40°C) Highly soluble in common non-polar organic solvents.

Physical form: (absence of light) white crystals

Melting point: 101-104 °C

Vapour pressure:

°C	Pressure (mm Hg)
20	7.4×10^{-7}
30	3.8×10^{-6}
40	1.8×10^{-5}

Thermal stability: Sublimes unchanged at temperatures just above melting point. Decomposition starts at approximately 130-140 °C

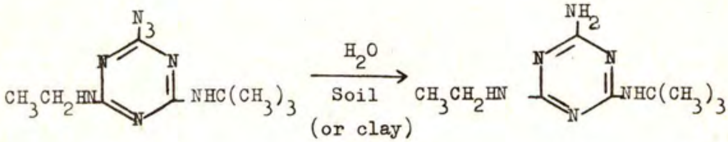
Hydrolytic Stability: Aqueous solutions moderately to highly stable, depending on pH.

0.1%w Solutions at 100 °C:

pH	half-life (hours)
4.0	96
6.0	538
8.0	107

Photochemical stability: In the solid state, thin films change from white to yellow-brown on exposure to daylight or ultra-violet light. This decomposition follows first order reaction kinetics and has a half-life of approximately 240 hours. The decomposition products are non herbicidal.

Stability in soil: WL 9385 is chemically decomposed in the presence of moisture in all soils so far investigated. Herbicidally inactive compounds are formed, the predominant compound being (II).



WL 9385 (II)

The kinetics of the decomposition, though complicated, are most satisfactorily described by a zero-order rate equation. The rate constant is of the order 1.5 - 2.0 mg/g soil per day. Some dependence on soil pH is indicated, but no large variation has been observed between a number of different soils.

The reaction is not bio-dependent, and proceeds at similar rates on sterilised soils and moist clay minerals. Water is necessary for the conversion and very little decomposition occurs on air-dry soils.

Sorption in Soil: WL 9385 is adsorbed about twice as strongly as atrazine and simazine; the maximum concentration under average temperate rainfall is likely to be limited to the top 1 cm of the soil.

Toxicology

1. Acute Toxicity

Oral LD_{50}	Mouse	200-400 mg/kg
	Rat	460 mg/kg
	Fowl	>2,000 mg/kg
Percutaneous LD_{50}	Rats	>1,000 mg/kg
LC_{50} (2 hour exposure)	Fish	Range 10-100 ppm
Cumulative Toxicity	Rats	Survived repeated oral administration of one half LD_{50}

2. Oral exposure in Mice — Fed daily for 30 days at levels of up to 1,000 ppm without any effects being observed.

Toxicity Rating: WL 9385 is of low to moderate toxicity and its use as a herbicide should not be limited on grounds of toxicity.

Longer term matabolism and residue studies in animals, plants and soils are in progress.

Biological data

Typically, WL 9385 exhibits broad-spectrum pre- and post-emergence herbicidal activity and is particularly effective in controlling seedling annual grasses post-emergence at rates down to 0.5 kg/ha, but not established annual and perennial species. Pre-emergence, a wide range of shallow-seeded annual weeds can be controlled by WL 9385, and this includes several dicotyledonous species moderately tolerant of MCPA and 2,4-D.

Weed species susceptible to WL 9385

Grasses/Sedges	Dicotyledons
Setaria viridis (Green setaria)	Portulaca oleracea (Purslane)
Eleusine indica (Goose grass)	Stellaria media (Chickweed)
Brachiaria platyphyllum (Para grass)	Spergula arvensis (Spurry)
Digitaria sanguinalis (Crab grass)	Sinapis arvensis (Charlock)
Digitaria adscendens (Crab grass)	Chenopodium album (Fat hen)
Echinochloa colonum (Jungle rice)	Senecio vulgaris (Groundsel)
Echinochloa crus-galli (Barnyard grass)	Polygonum persicaria (Persicaria)
Panicum fasciculatum (Witch grass)	Ipomoea spp. (Morning glory)
Rottboellia exaltata (Corn grass)	Amaranthus spp. (Pigweeds)
Fimbristylis spp. (Rice grass)	Matricaria inodora (Scentless mayweed)
Eragrostis spp. (Love grasses)	Urtica urens (Annual nettle)
Poa annua (Annual meadowgrass)	Anthemis cotula (Stinking mayweed)
Alopecurus spp. (Foxtails)	Capsella bursa-pastoris (Shepherd's purse)
Cynodon dactylon (Bermuda grass)	Lepidium draba (Thanet weed)

WL 9385 shows considerable promise for pre- and post-emergence weed control in cereals, notably in maize, rice, wheat and barley. Pre-emergence application has been most successful in situations not requiring lengthy residual activity, and when application can be timed to coincide with the main weed flush e.g. in irrigated crops. Crops tolerating up to 4 kg/ha pre-emergence include the above cereals, potato and cotton. In Western Europe excellent weed control, combining pre- and post-emergence activity has been achieved in maize, wheat, barley and potato by application of $1\frac{1}{2}$-3 kg/ha within a few days of crop emergence. There have also been indications of acceptable tolerance in wheat at later stages of growth, and of the practicability of under-sowing grass seed mixtures in cereals after application of WL 9385.

Encouraging results have been obtained by pre- and early post-emergence application of WL 9385 as a directed spray in established herbaceous transplant, tree and bush crops, even shallow-rooting species.

In its mode of action WL 9385 resembles other s-triazines herbicides in being a potent inhibitor of photosynthesis <u>in vitro</u>, but differs appreciably in herbicidal properties, notably in its much shorter persistence and mode of decomposition in soil. Thus, chemical studies in a range of soils indicate a half-life range of 1-8 days at 20°C, in the dosage range 2-20 kg/ha. In moist soil inactivation of WL 9385 is not, like that of most herbicides, dependent on microbiological activity, and it is less dependent on herbicide concentration and soil type.

In the combination of its unusual soil reaction properties, wide spectrum weed control pre- and post-emergence, and range of selective uses WL 9385 presents some intriguing new opportunities for crop management in agriculture and horticulture, particularly in intensive mixed cropping systems which require herbicides of limited and predictable duration.

Acknowledgement

The authors thank numerous colleagues for their contributions to the above studies.

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SD 11831 - A NEW HERBICIDE FROM SHELL

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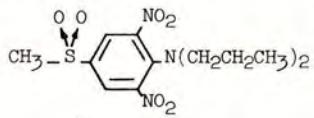
Summary SD 11831 (4-(methylsulfonyl)-2,6-dinitro-N,N-dipropyl aniline) is a selective herbicide sold in the U.S. as PLANAVIN* Herbicide. The compound acts to arrest growth of the radicle of germinating seedlings, preventing weed establishment. This herbicide appears safe to man and animals and disappears in a predictable manner from the soil. Shell have received federal registration for its use in cotton and soybean fields in cotton-growing areas of the U.S. Registration for several additional crops is being pursued.

INTRODUCTION

SD 11831 is a new herbicide developed by Shell and sold in the U.S. as PLANAVIN* Herbicide. Chemically it is 4-(methylsulfonyl)-2,6-dinitro-N,N-dipropyl aniline, having the following structure:

MW = 345



SD 11831 forms rectangular prism-type crystals and in the pure state is light golden-orange in color with a melting point of 151-152°C. The vapor pressure is very low, being less than 1.5×10^{-6} mm of mercury at 25°C. At this temperature the water solubility is 0.6 ppm. Solubility in acetone is 36%, dimethyl sulfoxide 33%, and 2-nitropropane 25%. SD 11831 is poorly soluble in common hydrocarbons, alcohol, and aromatic solvents. When formulated, it is a bright yellow wettable powder of good suspendability.

Available data suggest that SD 11831 will not present any hazard to man or animals. The acute oral LD_{50} for both mice and rats is greater than 5000 mg/kg. Percutaneous acute toxicity to albino rabbits is greater than 2000 mg/kg. Five fish species, bluegill, gambusia, goldfish, trout, and silver salmon, tolerated suspensions of 20 ppm for 48 hours. This is much higher than its solubility in water. No adverse effects are apparent in long term toxicology studies with rats and dogs currently under way.

The mode of action of SD 11831 appears to be the inhibition of plant cell division. Species vary considerably in the concentrations required to inhibit root growth. Wheat root growth, which is inherently quite sensitive, is completely inhibited by 6×10^{-8}M SD 11831 in solution culture. This is approximately 0.02 ppm. More tolerant species require higher concentrations for inhibition and, as with cotton, may show a time lag for the onset of inhibition.

Cell elongation does not appear to be inhibited by SD 11831. On the contrary, a swelling appears at the tips of affected roots in most species. Although

* Shell trademark

histological examination shows large cells in what is normally the meristematic region, further work remains to elucidate the mode of action.

As the previous attention given to root growth would imply, SD 11831 is primarily a pre-emergence herbicide. Since it is active on cell division, it must be placed in the zone where the weed seeds germinate and growth starts in order to be effective. Most weedy grasses are highly sensitive. Some of the species most easily controlled are watergrass, Echinochloa crusgalli; crabgrass, Digitaria sp.; foxtails, Setaria sp.; witchgrass, Panicum capillare; annual bluegrass, Poa annua; and annual ryegrass, Lolium multiflorum. Under ideal conditions in sandy soils these species are controlled at rates of 0.25 lb/ac and less. For practical purposes, however, 0.5 to 1 lb/ac will be required. Many broadleaf species are also controlled as seedlings at these rates. These include fiddleneck, Amsinckia douglasiana; curly dock, Rumex crispus; plantains, Plantago sp.; dead nettle, Lamium amplexicaule; bull mallow, Malva nicaeensis; and purslane, Portulaca oleracea. Species having a little tolerance and requiring 0.75 to 2 lb/ac for control are downy brome, Bromus tectorum; wild oats, Avena fatua; pigweed, Amaranthus sp.; lambs-quarters, Chenopodium album; prickly lettuce, Lactuca scariola; shepherds purse, Capsella bursa-pastoris; groundsel, Senecio vulgaris; knotweed, Polygonum aviculare; cress, Lepidium sp.; and others.

Weeds not adequately controlled at dosages of 1-2 lb/ac include certain nightshades, Solanum sp.; mustards, Brassica sp.; smartweeds, Polygonum sp.; ragweed, Ambrosia artemisifolia; and velvetleaf, Abutilon theophrasti. Established perennial weeds and deep germinating species such as cocklebur, Xanthium pennsylvanicum, are also resistant.

When sprayed post-emergence on the foliage of plants, SD 11831 causes temporary stunting. The recovery of shoot bud growth would indicate that the initial dose taken up by the meristem is detoxified and not replenished by translocation from the rest of the plant. Post-emergence applications appear to be effective only on crabgrass seedlings. If the application is made to young seedlings in the two-leaf stage with undeveloped secondary roots, development is completely arrested and the seedlings eventually die.

CROP TOLERANCE

The selective tolerance of SD 11831 by various crops and certain weeds can result from a degree of inherent physiological or biochemical tolerance or simply from escape due to immobility of this compound in the soil. Beans (pinto variety) grow normally in 12 ppm of SD 11831 mixed throughout a sandy loam soil. This appears to be an example of biochemical selectivity.

Seeds having well-developed embryos with large numbers of unexpanded cells in the radicle can, upon germination, make considerable root growth without further cell division. This can put the root tip out of the zone of the chemical in soil where it can subsequently make normal growth. Cotton and soybeans, for example, have this capacity in addition to some inherent tolerance. There is an apparent time lag for the root to be affected. Even at very high concentrations, under optimum growth conditions, one to three days may be required to arrest root tip growth. During such a period in the field, a cotton or soybean root could elongate appreciably and escape the chemical if incorporation is not too deep. This appears to be the result of the time required for the herbicide to diffuse to the meristematic cells and to accumulate in effective concentrations. When conditions for root growth are optimum, it is possible for root tips of larger diameter literally to grow away from or outrun the herbicide. If, however, low temperatures greatly reduce growth rate and bio-inactivation rate in the root cortex tissue, inhibitory concentrations may accumulate in the meristem cells of normally resistant root tips. In most species, including many tolerant ones, SD 11831 stops lateral roots before they get started. This results in the so-called "root-pruning" of laterals in the soil zone where the herbicide is present. Grape cuttings have shown a high degree of inherent tolerance. Several varieties have been found to root normally in treated soil (Overbeek, in press).

Since SD 11831 is effective even when restricted to a shallow zone at the soil surface and does not leach readily, it can be used safely on most deep-seeded, transplanted, and established perennial crops, even though they may be inherently very sensitive. In these cases the depth of incorporation should be governed by the depth of the crop seed placement or the weeds that might be present in the case of the established crops. The escape principle may have a place with squash, cucumbers, and even small grains.

Some crops in which SD 11831 is potentially useful are:

Cotton	Blackeye peas	Sweet potatoes
Soybeans	English peas	Grapes
Peanuts	Watermelons	Caneberries
Safflower	Small grains	Tree crops
Alfalfa	Carrots	Turf
Field beans	Red clover	Nursery stock
Lima beans	Potatoes	Tobacco
Various crucifers	Bell peppers	Rice Dry bed or Transplanted

FIELD EXPERIENCE

In the past season SD 11831 has been evaluated by many cooperators in the United States in many types of pre-emergence treatments. In sandy soils, rates of 0.5 lb/ac have given good weed control; 0.75-1 lb/ac have generally given effective weed control on loamy type soils throughout the cotton belt in the United States. Weeds in heavier textured soils that are reasonably low in organic matter (< 5%) have required 1-1.5 lb/ac, while the black soils in the North Central region of the U.S. may require rates greater than 2-3 lb/ac. This increased rate requirement is due in part to absorption by the organic matter making less of the applied dosage available. Also, these soils appear to have a greater capacity for inactivation of the herbicide through bio-degradation. The chemical has generally been most effective when incorporated in the surface inch of soil. Deeper incorporation has tended to reduce effectiveness at the lower rates, probably due to dilution in the soil. Normal cultivation with sweeps or chisel shanks that stir rather than invert the soil has not affected herbicidal activity. In fact, cultivation can remove tolerant broadleaved species which, when cut off and brought up into the treated zone, fail to re-establish even under ideal moisture conditions.

Pre-emergence surface applications have, at times, been as effective as preplant incorporated treatments. Their effectiveness appears to correlate with the interval between chemical application and the first rain. Rain, no doubt, causes shallow penetration, but also appreciably lowers surface soil temperatures and thus prevents or delays losses from the soil. In areas and seasons where rains are frequent, SD 11831 may be effectively used without mechanical incorporation. Overhead sprinkling has also been sufficient to incorporate the chemical.

SOIL RELATIONSHIPS

Understanding the action of pre-emergence herbicides in the soil has recently been greatly aided by measurement of certain physico-chemical parameters. The partition coefficient (Kp) of a chemical between soil and water has been studied for some time (Sherburne et al., 1954); results varied widely between soils and were of limited value. When, however, the distribution coefficient between soil organic matter and water (Kp (om/w)) was studied, it was found that there was little change in the Kp (om/w) of non-ionic compounds in soils ranging from 0.25% to 40% organic matter (Lambert et al., 1965). With SD 11831, the Kp (om/w) has been found to be in the range of 400 to 500 compared to about 70 for diuron. The leaching rate and application rate requirement of a compound are dependent in the main on this distribution ratio. It is thus useful in predicting performance in soil where organic matter and water contents are known.

Leaching rate varies inversely with Kp (om/w) and thus SD 11831 is not readily displaced by percolating water. It has been found to move only about $\frac{1}{2}$ inch in a sandy loam soil with 1% organic matter with three inches of applied water. This is compared to 3.3 inches movement of diuron. SD 11831 would be expected to leach even less in soils of higher organic content. This property is important to "escape selectivity" and to herbicidal activation requirements.

The application rate required for a given response is a direct function of Kp (om/w) and thus higher rates would be required in high organic soils. Tests have shown that on a peat soil, the rate required is over four times that on a sandy loam with 1% organic matter.

The persistence of any pre-emergence herbicide in the soil is important both from the standpoint of length of period of weed control and possible carry-over into subsequent crops. Under moist soil conditions during the cropping season in California, half of SD 11831 is lost from the soil in 35 days. Disappearance rates for SD 11831 have been found to vary with both temperature and moisture content of the soil. In an air-dried soil stored at 22°C, half of the chemical was lost in 54 days.

Loss of a compound from the soil surface is an important consideration for pre-emergence soil active compounds. Factors which can contribute to such loss are volatility, photo decomposition, thermal decomposition, and water vapor co-distillation. Half of SD 11831 was lost after seven days in tests under high sunlight conditions in California in which daytime soil surface temperatures were greater than 55°C. In other tests under similar conditions, delaying incorporation by four days reduced, somewhat, the effectiveness of 0.75 lb/ac applications on a sandy loam soil. In the same tests, treatments with incorporation delayed two days were as effective as those incorporated immediately. In these studies conditions were more severe than would be encountered in normal use practices in most crops, so timing of incorporation should not be even this critical. Because of its low volatility, vapor loss would not be expected to contribute greatly to the loss of SD 11831 from the surface of the soil. However, all of the other factors mentioned appear to be implicated in the loss of this compound. Thus, in the absence of rain, mechanical incorporation is necessary to insure against the loss of chemical from the soil surface.

Based on these considerations one can see that the period of effectiveness obtained with SD 11831 will vary with the rate of application as well as the climatic and soil factors. Prevention of weed establishment for two to three months has been obtained with 0.75 lb/ac applications. Regarding carry-over, in California mid-September applications of 3 lb/ac injured barley planted the following March 23, while 1 lb/ac caused no adverse effect. Neither rate of application affected sugar beets planted six weeks later on May 7. In a sandy loam soil, spring applied treatments of 1 lb/ac and under had no detectable effect on barley seeded in the fall following disking. Two and 4 lb/ac applications, however, injured the barley. In a similar test applications as high as 2 lb/ac had no adverse effect on corn planted a year later following a fall disking and normal seed bed preparation. Four lb/ac treatments seriously stunted the corn roots. Thus, for crops treated in the spring, with the summer season for dissipation, carry-over from reasonable dosages should not be a problem.

COMMERCIAL STATUS

Federal registration for use in cotton and soybean fields in cotton-growing areas of the U.S. was obtained in March of 1966. Registrations for several additional crops are being pursued.

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FIELD EVALUATION IN GREAT BRITAIN DURING 1963-1966 OF TRIFLURALIN AS A SELECTIVE SOIL-ACTING HERBICIDE

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Summary Trials with trifluralin are described; results show a high selectivity in the *Brassicae*, particularly transplanted crops. Incorporated into the soil prior to transplanting 1 lb/ac controls most of the major weeds in these crops. *Matricaria* spp., *Senecio vulgaris*, *Capsella bursa-pastoris* and other *Cruciferae* are resistant. The need for extremely thorough incorporation, and ways of achieving this, are discussed. It is concluded that the optimum depth of incorporation is 2 in. and this is best achieved by rotary cultivation. It is suggested that efficiency is related to soil temperature and is reduced under cold wet conditions. Further work is necessary to determine the potential of trifluralin in sown *Brassicae*. Trials in potatoes show insufficient tolerance of incorporated rates giving acceptable weed control. Trifluralin is active against *Oxalis* spp. but further work is necessary to determine optimum doses and times of treatment.

INTRODUCTION

The acceptance of herbicides as an adjunct to the production of profitable crops is widespread; at times, however, the need and desire to use a herbicide has not been matched by the availability of suitable products. We feel that such a condition existed in 1962 in the horticultural brassica market when we first received technical data on trifluralin (Anon., 1961). It appeared that this herbicide, with a very low mammalian toxicity: >10,000 mg/kg acute oral LD_{50} male rats, could be tolerated by such brassicas as cabbage, cauliflower, brussels sprout and was, therefore, worthy of examination in this respect. At a later date other uses were examined: in particular, application in potatoes and for control of such pernicious perennial weeds as *Agropyron repens* and *Oxalis* spp.

METHOD AND MATERIALS

Trifluralin was used as 'Treflan*', containing 4.8 lb a.i./Imp. gal.

Application in the earlier trials was with either an Oxford Precision Sprayer or a Van der Weij logarithmic sprayer. Spray volumes varied between 20-50 gal/ac. Later trials were sprayed either by these machines or commercially available farm spraying machines. Estimation of weed survival was made from counts of individual weed species taken from random throws of quadrats in treated plots and expressed as a % survival by calculation against similar counts taken from untreated plots. The % crop seedling survival or shoot emergence was similarly calculated.

RESULTS

1963-64

Initially eight trials examined the activity of 4 lb/ac trifluralin as a pre-emergence surface spray:- 4-fold replication, in Suffolk, Kent and Worcs. during April 9 to June 1; 3 soil types: clay loam, loam and sandy loam. Tilth at sites 1 and 3 was poor. Percent weed survival ranged from 21% in early April to 12% in June. The tolerance of brussels sprouts, cabbage and dwarf beans was good with 90% to 100% survival of seedlings.

* Registered Trademark of Eli Lilly and Company.

Two further trials examined the feasibility of dose reduction by incorporation of trifluralin into the soil:- 4-fold replication, one on loam, the other on sandy loam in May; incorporation by handrake, 3 in. tines, 3 passes immediately prior to sowing cabbage; tilth good.

Mean % weed survival:-

2 lb/ac	incorporated	18%
2 lb/ac	surface spray	31%
4 lb/ac	surface spray	19%

Capsella bursa-pastoris, Solanum nigrum tolerated all doses; Chenopodium album, Polygonum convolvulus, Stellaria media, Veronica spp., Urtica urens and Poa annua were susceptible to 2 lb incorporated. Cabbage seedling survival ranged from 99% with 2 lb surface to 71% with 2 lb incorporated.

The mean % weed survival in April on 4 different soil types where 2 lb/ac trifluralin was incorporated by handrake, as above, was:-

sandy loam 12%   loam 13%   fen peat 35%   clay loam 48%

The tilth on the clay loam sites was poor.

1965

The earlier trials had shown that incorporation of trifluralin could enable lower doses to be employed. Therefore, in 1965 three doses were used (0.5 lb, 1 lb and 2 lb/ac) and incorporation was carried out with normal cultivation machinery. Various brassica crops and potatoes were tested for tolerance to these rates.

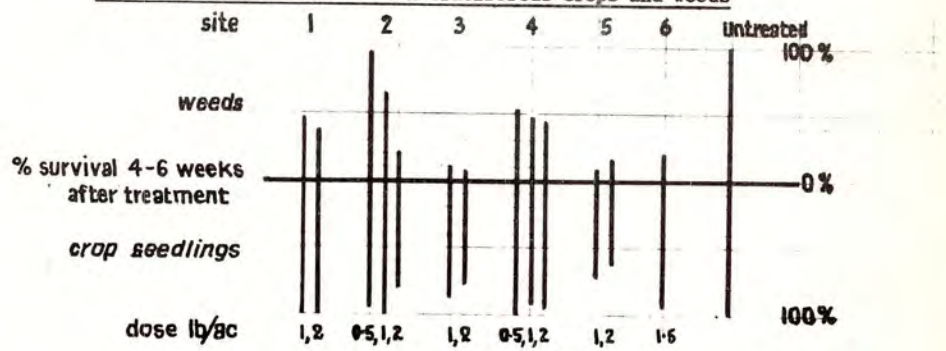
Table 1

Details of 1965 trials on cruciferous crops

site	crop	soil	date treated	date sown	incorporation
1	Turnip	sandy loam	Aug 9	Aug 9	tine & chain harrow set 3 in.deep
2	Swede	loam	May 6	May 6	double discs & chain harrow set 4in. deep
3	Kale	clay loam	Jul 2	Jul 12	spring tine harrow set 2in. deep
4	Kale	loam	May 11	May 11	double discs & chain harrow set 4in. deep
5	Cabbage	loam	May 12	May 12	spike harrow set 2in. deep
6	Cabbage	organic soil	May 10	May 12	rotary cultivator set 2in. deep

Figure 1

Effect of trifluralin on sown cruciferous crops and weeds



Composite and cruciferous weeds tolerated 2 lb/ac; P.convolvulus was moderately controlled by 1 lb/ac whereas U.urens, P.annua, S.media, C.album, Veronica spp. were well controlled.

Further trials in 1965 with brassicas were carried out in Scotland (kale and swedes) and England (drilled cabbage, transplanted brussels sprouts and cauliflower). Transplanted crops tolerated 2 lb trifluralin/ac; seeded crops were checked at 1 lb per acre and severely checked at 2 lb. Weed control was better at 2 lb. S.vulgaris, Thlaspi arvense, C.bursa-pastoris, Sinapis arvense and Sisymbrium officinale tolerated 2 lb whereas Anagallis arvensis, P.annua, S.media, P.aviculare, P.persicaria, P.convolvulus and Veronica spp. were controlled by 1 lb/ac. Different incorporation methods did not affect results.

Results of the potato work are shown below. In the potato sites the incorporation machinery was set as deep as possible, anticipating that only treated soil would be exposed during any subsequent ridging over the tubers.

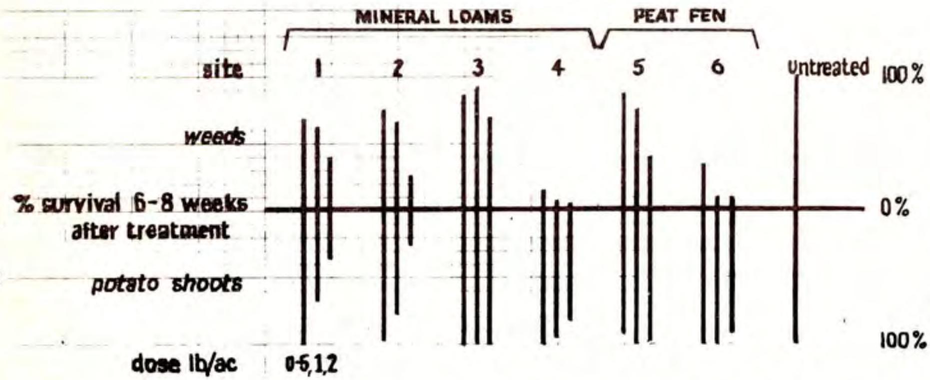
Table 2

Details of 1965 trials on potato crops

site	cultivar	soil	date treated	date planted	incorporation by
1	Majestic	loamy sand	Apr 6	Apr 6	rotary cult.set 6in. deep
2	Edwards	loam	Apr 9	Apr 9	double discs set 6in. deep
3	A. Pilot	sandy loam	Mar 16	Mar 16	rotary cult.set 11in. deep
4	Edwards	loam	Mar 31	Apr 5	duckfoot harrow set 5in. deep
5	Edwards	peat fen	Apr 1	Apr 13	spring tine harrow set 5in. deep
6	Edwards	peat fen	Apr 22	Apr 23	rotary cult. set to 6in. deep

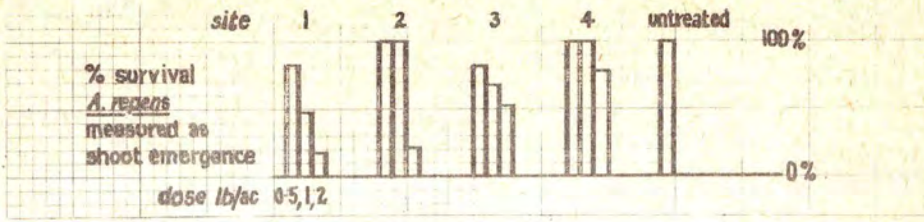
Figure 2

Effect of trifluralin upon potatoes and weeds



Observations made in 1964 indicated that trifluralin at 2 lb/ac reduced the infestation of Agropyron repens on two sites. Therefore, in 1965 detailed counts were made on sites 1 to 4 just before the potato haulm met in the rows. Results shown in Figure 3 overleaf.

Figure 3



1966

Both authors were able, late in 1965, to discuss their results in detail with workers in other European countries. As a result of this, and the publication of American research on the mode of action, elementary greenhouse trials were laid down to examine the effect on plant seedlings of trifluralin when placed in various horizontal layers in pots.

6 x 3 in. plastic pots were filled with layers of sandy clay loam, some dosed with trifluralin as below, for each of the 6 treatments (Test I) or 4 treatments (Test II). In each pot in Test I were sown 10 seeds each of Amaranthus tricolor and Lolium perenne; in Test II only L. perenne was sown. After sowing the pots were stood in metal trays in a greenhouse; watering was by sub-irrigation.

Test I. Doses of trifluralin were:- treatments 1 & 2 = 0.62 lb/ac; 3 = 0.56 lb/ac; 4 = 1.75 lb/ac and 5 = 1.0 lb/ac, mixed into the respective layers of soil as shown in the following Fig. 4.

Test II. A single dose of trifluralin, equal to 1.0 lb/ac, was mixed into a 0.62 in. layer of soil. In treatment 3 the treated layer was placed below the seed to the depth as shown by the dotted line in the figure below.

Figure 4

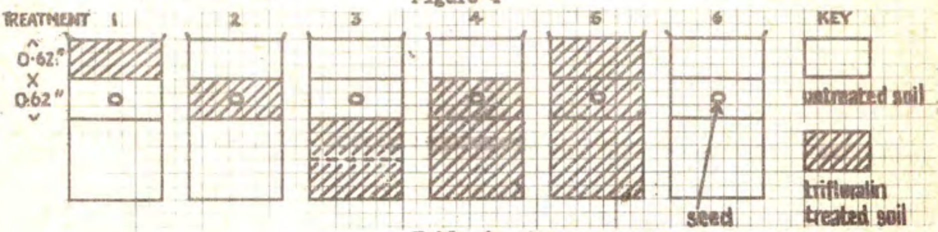


Table 4

Germination of seedlings following soil placement of trifluralin

treatment	mean no. emerged seedlings/pot 21 days after sowing		
	Test I		Test II
	L. perenne	A. tricolor	L. perenne
1	0	0	0
2	0	0	0
3	4.4	3.0	4.3
4	0	0	not tested
5	0	0	not tested
6	8.2	6.2	4.8

Further examination in Test I 21 days after the above observation showed that the plants in treatment 3 were severely checked in growth.

It appears from these tests that susceptible seedlings such as L.perenne or A.tricolor germinating in, or growing through, trifluralin contaminated soil will be killed whereas those germinating in, and growing through, clean soil will be checked only when their roots reach contaminated soil.

Following their 1965 results and those available from other countries the authors decided to examine further the application of 1.0 lb/ac trifluralin prior to planting brassicas. Results are shown below in table 4.

Table 4

Effect of pre-planting applications of trifluralin on weeds in cruciferous crops, 1966

site	crop	soil	date treated	date planted	incorporation and depth set	% weed survival
1	B.sprouts	loam	Apr 10	Apr 10	spiked harrow - 3 in.	6
2	B.sprouts	sandy loam	Apr 20	Apr 20	rotary cult. - 2 in.	10
3	Cabbage	clay loam	Apr 27	Apr 27	rotary cult. - 3 in.	22
4	B.sprouts	loamy sand	May 3	May 3	rotary cult. - 2 in.	18
5	B.sprouts	sandy loam	May 3	May 3	rotary cult. - 3 in.	16
6	B.sprouts	sandy loam	May 9	May 9	spiked harrow - 2 in.	28
7	Cabbage	loam	May 10	May 11	rotary cult. - 2 in.	15
8	B.sprouts	clay loam	May 20	May 20	spring tine harrow - 2 in.	24
9	B.sprouts	loam	Jun 8	Jun 8	spring tine harrow - 2 in.	14

At 1.0 lb/ac trifluralin controlled S.media, Lamium amplexicaule, U.urens, C.album, P.annua, P.aviculare, P.persicaria, L.purpureum. Composite and cruciferous weeds tolerated this rate.

Yields from the above crops are not yet available; inspections 2 months after planting revealed no check in vigour on any treated crop.

Control of Oxalis spp.

Oxalis spp appeared in 1964 to be susceptible to trifluralin. Small scale trials in 1965 and 1966 were carried out to determine optimum doses and times of application and specific susceptibility. If trifluralin was applied when there was emerged weed the trial area was first cultivated.

Table 5

Trials on control of Oxalis spp.

site	time	species	dose lb/ac	incorporated	survival
1 Channel Isles	July	O.incarnata	1.0	by rake	5% after 4 mths.
2 " "	"	" "	1.0	by vol.water*	7% after 3 mths.
3 Suffolk	Nov.	O.corymbosa	{1.0, 2.0}	rotary cult.	100% upon emergence 7mths. later
4 Sussex	Nov.	O.corymbosa	1.0	by rake	10% after 5mths.
5 Hampshire	June	O.corymbosa	1.5	rotary cult.	0% after 3 mths.
6 Cornwall	Sept.	O.latifolia	6.0	rotary cult.	10% after 9mths.

* application in glasshouse around tomatoes using about 700 gal water/ac

DISCUSSION

The purpose of these trials was the evaluation of trifluralin as a candidate pre-emergence or pre-planting herbicide. Marketing considerations limited the scope of the work mainly to such large acreage crops as brassicas and potatoes. Other crops, particularly umbellifers and legumes, tolerate efficient doses of trifluralin

(Anon., 1963) but we decided that there was little justification for the initial development of trifluralin for use in these crops as efficient products were available at an economic price.

Application methods and the effect of soil conditions

When the trials started we knew that trifluralin had no contact activity; experimental doses had been defined and expressed for either surface or incorporated applications; the activity of trifluralin was stated to increase if ihcorporated (Anon., 1961). We examined initially the activity of surface sprays and the trials (p.2) demonstrate 4.0 lb/ac is efficient. Incorporation was examined however because of the possible expense of treatment with 4.0 lb/ac. It was shown (p.2) that in the conditions of the trials 2.0 lb/ac incorporated can be as effective as 4.0 lb/ac applied to the soil surface. Subsequent trials further demonstrated the effectiveness of 1.0 lb compared to 2.0 lb/ac when both were incorporated.

Wright (1964) showed that volatilisation of trifluralin reduced its herbicidal effect; the amount of loss increased as the temperature increased from 10°C to 50°C. Losses were proportionally greater on sandy soil than on clays because of adsorption onto clay. Wright and Warren (1965) concluded that trifluralin was subject to photodegradation on the soil surface although there was less loss from the soil surface than from glass plates. The need for incorporation of trifluralin if low doses are to be used is therefore clear.

In our early trials we incorporated trifluralin with a hand rake - usually 3-fold cross raking; we consider we obtained adequate mixing to a depth of 1.0 in. We have doubts however as to the effectiveness of raking in very heavy or cloddy soils where it is unlikely that intimate mixing may take place. Certainly Zimmerman (1965) when discussing incorporation practice in the U.S.A. suggests that only power-driven equipment, i.e. rotary cultivator, will break up clods or achieve uniform depth in heavy soils.

In our later trials we used farm machinery to incorporate. We were unable to demonstrate the absolute superiority of any one piece of equipment as a means of incorporating trifluralin. We conclude from the published work of Holroyd (1964), Staniland (1964), Case (1965) and Zimmerman that whatever commercially available equipment is used for incorporation there will be unequal distribution of the chemical down the vertical profile and at times along the horizontal plane. There will also be a high concentration of the chemical in the top half of that depth of soil disturbed by the incorporation machinery. Of the available machinery we suggest that a power-driven rotary cultivator with 'L' blades is preferable for incorporation of trifluralin with the second best being 2 passes of a tandem disc harrow.

In the potato trials (table & fig.2) incorporation down to 6.0 in. was attempted; poor weed control resulted in the mineral soils from exposure and lifting of untreated soil when ridging the tubers. On the organic soil, site 6, with incorporation by rotary cultivation and shallow ridging weed control was better. Undue dilution, however, of herbicide in the soil mass, as in site 4, can lead to poor weed control.

Herbicidal action of trifluralin in mineral soils (p.2) tended to decrease as the clay fraction increased, due probably to three factors:- the more intimate mixing that is possible in light soils, the adsorption of trifluralin onto clay and the poorer diffusion of trifluralin through the mass of a cold, wet clay soil; Hartley (1960) found that diffusion of a volatile herbicide in the vapour phase will be slow under conditions of low temperature and poor aeration. At 2 lb/ac trifluralin gave inexplicably better weed control in organic soils than in clay loams (p.2).

Weed Control

Trifluralin 1 lb/ac, when efficiently incorporated not deeper than 2 in., will control P.annua, U.urens, S.media, C.album, Veronica spp., P.persicaria, L.amplexicaule & L.purpureum. P.aviculare, P.convolvulus are not always susceptible; S.nigrum and composite/cruciferous weeds are resistant. Increasing the dose to 2 lb improves the control of P.aviculare and P.convolvulus but does not materially improve the control of the others. Emergence of A.repens can be significantly reduced by 2 lb/ac, and 1 lb/ac can reduce vigour for at least one month after emergence. The control of Oxalis spp. is discussed later.

Glasshouse tests (table 4) and the work of Standifer and Thomas (1965) indicate that to obtain maximum herbicidal effect trifluralin should be mixed into the soil to such a depth that the seed germinates in the treated layer yet has maximum contamination of the plumule/coleoptile when germinating. Many common weeds in horticulture germinate from a depth of less than 2 in. (Chancellor, 1965) and therefore the machinery used to incorporate trifluralin should be set so that the maximum concentration of the herbicide is within the top 2 in. of soil and so obtain maximal effect.

Chancellor's work suggests a possible reason for some instances of variable control in light soils of weeds which are normally susceptible - namely incorporation to such a depth that the dilution of trifluralin in the soil mass is low with subsequent airflow over the moist, warm soil considerably increasing volatilisation (especially in the absence of clay particles), so causing severe depletion of the herbicide from the soil surface downwards to possible 1 or 2 cm. It is from this depth, as will be seen from Chancellor's work, that almost all the S.media and U.urens germinated in some years. Other possible reasons for poor weed control are uneven incorporation as already discussed, imperfect incorporation where the soil layers are inverted rather than mixed, and streaky incorporation resulting from one pass of such equipment as a spring-tine harrow (Case, 1965).

It is not known whether trifluralin at 1 lb to 2 lb/ac incorporated into the top 2 in. of soil, will give a satisfactory one-year control of Oxalis spp. and we have yet to investigate the effect on all the 5 species of Oxalis listed by Ivens (1966) as weeds found in Britain. However, we tentatively conclude that 1 lb/ac when applied during the growing season of O.corymbosa, and possibly O.incarnata, will give control of the weed for 3-4 months. Significant reduction in numbers over 2 years will not result from this dose but 1 lb/ac will reduce the competitiveness of these Oxalis spp. for a sufficient period to allow growth of annual crops without undue restrictions on subsequent sowings or plantings because of damaging levels of trifluralin remaining in the soil. Valuable work has also been undertaken by the NAAS, Mr. Goodchild and others, in the South West on the practical use of trifluralin. The results to some extent confirm our views that applications during the dormant period of Oxalis are not generally successful. Extended control of O.latifolia has beem achieved by 6 lb/ac and good control by 3 lb. On the other hand O.pes-caprae has been well controlled by doses down to 1.5 lb/ac (Clements, 1966).

Crop tolerance

The potato crop has not sufficient tolerance towards pre-planting incorporated treatments of trifluralin to warrant further investigation. Carrots (Allot, 1965) tolerate trifluralin at 1 lb/ac although radishes sown in organic soil treated with 1.5 lb/ac produced misshapen roots - best described as 'hourglass' shaped. Drilled brassicas have shown varied tolerance of 1 lb/ac; to establish the exact tolerance we wish to investigate further the optimum degree of mixing within the soil when related to time of year and soil conditions. Once this is known the potential value of the 0.5 lb - 1 lb/ac doses of trifluralin can be examined.

Brassica transplants tolerate 1 lb/ac and this dose, incorporated before planting, did not affect yields of brussels sprouts and cauliflower transplants in 1965 (p.3) and there is no indication in the 1966 trials, where yields have not yet been taken, of any vigour or growth suppression in treated cabbage and brussels sprouts. There is also no indication of trifluralin treatment affecting the flavour of processed brussels sprouts (Arthey, 1966). It is in this treatment of soil prior to planting that we see the greatest likelihood of commercial use because of the advantages pertaining to pre-planting treatment as opposed to post-planting.

Further development

Further work is necessary on the problems connected with incorporation before progress can be made in determining potential uses in sown brassicas. Methods of application should be examined to overcome the possible deleterious effect of cold soils on the herbicidal activity of trifluralin as many crops within the brassicas are sown or planted in the early spring when soil temperatures are below 50°F.

We believe that in Great Britain the practice of incorporating herbicides will grow; it is, however, clear to us that development of incorporation equipment designed for precise mix and depth control must run concurrently with the biological development of soil-acting herbicides before any real progress in the successful commercial adoption of the practice is accomplished.

The potentiality of trifluralin for control of Oxalis spp. needs development for it shows considerable promise and could well prove to be an economic and reliable answer to the problem of this pernicious weed. Apart from this it is doubtful whether there are economic uses on crops other than brassicas within the United Kingdom but this does not preclude the use of trifluralin as part of a herbicidal mixture where its weed spectrum and crop selectivity are complimented by another herbicide. We believe that the use of 'tailor-made' mixtures by farmers or contractors will increase rapidly and we contend that the use of trifluralin in such mixtures bears examination.

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VARIATION IN HERBICIDAL PERFORMANCE OF TRIFLURALIN ASSOCIATED WITH VARIOUS IMPLEMENTS USED FOR SOIL INCORPORATION.

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Summary Trifluralin has given more dependable and long-lasting weed control when incorporated with those implements that can be set to mix the soil to a depth of 2 - 4 in. compared with the weed control obtained when the mixing action extends to a depth of 1½ in. or less. Increasing the time lapse between incorporation of trifluralin and planting of the crop may permit the use of rainfall, irrigation, and final seedbed preparation to achieve greater dependability through more uniform incorporation with little additional expense.

The unpredictable performance of surface applied pre-emergence herbicides has been an important factor in impeding our progress in realizing the full potential of pre-emergence weed control. Soil incorporation has emerged as one of the ways in which greater dependability can be achieved. An examination of the results of various researchers suggests that the chemical and physical properties of an herbicide have a significant influence on its response to soil incorporation. The dependability of some compounds apparently has not been improved by soil incorporation and their activity may even be reduced. Other compounds have responded favourably to soil incorporation but the crop under consideration may lack sufficient physiological tolerance to permit deep incorporation. Differences in conditions and cultural practices from area to area have imposed additional limitations on the timing of application and implements which are optimal for incorporating a pre-emergence herbicide.

Since the initial observation that trifluralin responds to soil incorporation it has been the objective of researchers at Eli Lilly and Company to determine the optimal implements for incorporating this herbicide. It soon became obvious that there were differences in weed control when trifluralin was incorporated with different tools in the same experiment. Observations on the performance of numerous implements have been made under a wide range of conditions over the past three years. These data are summarized in Table 1.

Table 1.

Summary of weed control with trifluralin when incorporated with various implements.

Implement	Percent Weed Control
Rotary cultivator	85-100
Tandem disc	75-100
Bed conditioner (Do-All)	70-100
Rolling cultivator	65-100
Others	30-100
Surface spray	10-100

The ranges given here are estimates of performance based on observations made on numerous research plots and commercial applications of trifluralin on cotton and soybeans. These observations were made on plots and fields where trifluralin was applied at rates of 0.5-1.5 lb ai/ac depending on soil type. It is evident from this summary that trifluralin resulted in good pre-emergence weed control under certain conditions regardless of the method in which it was incorporated. This finding adds to the difficulty in evaluating an incorporation device because of the increased likelihood of making a wrong decision about the consistency of its performance.

It has been observed that environmental factors tend to exert important influences on the performance of incorporation devices. A high sand content in the soil has enhanced incorporation of trifluralin. Soils with the soil moisture near field capacity present less of an incorporation problem than excessively wet or excessively dry soils.

As a result of repeated observations under many different conditions we feel that certain specific comments can be made relative to the performance pattern of implements listed in the table.

Rotary Cultivator (tiller, powered rotary hoe)

The rotary cultivator and variations thereof have been the most consistently dependable implements for both band and broadcast incorporation of trifluralin when compared with other implements in the group under a wide range of conditions. Trifluralin has consistently resulted in 90 percent of better control of susceptible weeds when incorporated with this tool adjusted to a depth of 2-4 in. The rare cases of poor results have generally been attributable to improper adjustment or heavy soil which was excessively wet.

Tandem Disc

Trifluralin has performed well in a high percentage of the cases where it was incorporated with a tandem disc. Optimal results were achieved where two discings were made at right angles and the disc adjusted to cut 3-6 in. and pulled at 4-6 miles per hour. The tandem disc has been less dependable than the rotary cultivator in heavier compacted soils with excessive moisture and dry soils with large aggregates.

There are indications that it may be possible to improve the dependability of the tandem disc by adjusting the time of application in relation to land preparation and planting of the crop. Advancing the time of incorporation of trifluralin with the tandem disc up to as much as 3-4 months ahead of planting has resulted in good weed control under conditions where this method would have been inadequate or impractical at planting time. We feel this time lapse between application and planting promotes breakdown and reforming of soil aggregates by rainfall or irrigation so that the herbicide is inside as well as on the surface of the aggregates. Early application also permits further incorporation by drying and subsequent mechanical mixing during final seedbed preparation. In this way, we can achieve a level of incorporation at planting time that normally would not be attained until near mid-season.

Bed Conditioner (Do-All)

Many of the same things can be said for the bed conditioner as for the tandem disc. Interest in this implement is limited largely to the cotton and soybean growing areas of the lower Mississippi Delta.

Rolling Cultivator

The rolling cultivator has given consistently good results in widely divergent areas of the country when adjusted and operated properly. Optimal results are obtained when this implement is operated in loose soil at 6-8 miles per hour. It has been more variable than the rotary cultivator, tandem disc, and bed conditioner, especially when operated on compacted or cloddy soil. The compaction problem has been partially eliminated by applying hydraulic pressure to the unit.

Others

This group includes a number of ground-driven devices which do not have the capacity to mix soil to a depth greater than 1-1½ in. Many of these tools were designed for mounting on cotton and soybean planters to incorporate trifluralin in a band during the planting operation. In certain areas where light sandy soils prevail, good early season weed control has been observed; however, they have generally performed unsatisfactorily in heavy soils. The duration of weed control with trifluralin has generally been much shorter when the herbicide is incorporated with the tools in this group.

Research Summary

4,5-DICHLORO-2-TRIFLUOROMETHYL BENZIMIDAZOLE (CHLORFLURAZOLE) RESEARCH PROGRESS IN 1966

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INTRODUCTION

First information on the chemistry, mode of action and herbicidal properties of 2-trifluoromethyl benzimidazoles, and in particular of 4,5-dichloro-2-trifluoromethyl benzimidazole (chlorflurazole) was published in 1965 (Newbold et al.; Pfeiffer; and Jones et al.).

Chlorflurazole was described as a contact herbicide of moderate mammalian toxicity, formulated as a water-soluble salt, selective against annual broad-leaved weeds in cereals, flax and peas. Its contact effect, based on uncoupling of oxidative phosphorylation and inhibition of Hill reaction, was shown to be synergised by the addition of certain phenoxyaliphatic growth regulators (e.g. MCPA, mecoprop).

The synthesis of related compounds continued in 1966, simultaneously with a more detailed exploration of the biological properties and a large international programme on the field performance of chlorflurazole. It is obviously beyond the scope of this paper to review all results. This research summary therefore concentrates on the results obtained in two series of field experiments in the U.K. and in the three Canadian Prairie provinces. Yield experiments designed to test the dose/yield response of weed-free wheat and barley to chlorflurazole are also described.

OBJECTIVES AND METHODS

28 experiments were carried out in the Canadian Prairies and 22 in the U.K. The main objective was to study the dose/response relationship of chlorflurazole alone and chlorflurazole/hormone combinations over a wide variety of conditions, in order to select the optimum dosage level and herbicide combination.

Each experiment had 2 replications with a plot size of 20 yd^2. Each chlorflurazole treatment was applied at 4 rates. MCPA (at 12 oz in U.K. and 18 oz in Canada), mecoprop (at 24 oz), and commercial formulations of ioxynil (6 oz) + mecoprop and bromoxynil (4 oz) + MCPA (4 oz) were included as standards. Application volume was 20 gal/ac.

In addition, 4 yield trials were carried out in the U.K. on almost weed-free crops to assess the crop tolerance to high rates of chlorflurazole/MCPA combinations. The highest rate used was 64 oz chlorflurazole combined with 12 oz MCPA. The yield experiments had 6 replications and a plot size of 20 yd^2.

RESULTS

The percentage 'live growth' of weeds was assessed by scoring 2 - 4 weeks after treatment. At this time, weed destruction was not complete where hormone herbicides had been used but in most cases the chlorflurazole-based materials gave complete control. The following table presents the mean weed control values obtained in each of the two experimental series (U.K. and Canada). The similarity of performance is of interest.

Table 1

Percentage Growth Reduction of Mixed Weed Populations in Canada and the U.K. (assessed 2 - 4 weeks after treatment)

		Canada (28 expt.)	United Kingdom (22 expt.)
MCPA	) standards	46	24
Mecoprop	)	65	36
Ioxynil + Mecoprop	)	87	85
Bromoxynil + MCPA	)	82	-
Chlorflurazole	4 oz	29	24
"	8 oz	47	44
"	12 oz	58	64
"	16 oz	77	83
Chlorflurazole	4 oz + MCPA	66	65
"	8 oz + "	80	81
"	12 oz + "	89	91
"	16 oz + "	90	94
Chlorflurazole	4 oz + Mecoprop	79	69
"	8 oz + "	89	86
"	12 oz + "	95	94
"	16 oz + "	96	97

The following major conclusions can be drawn from the experiments:

1. The synergistic activation of chlorflurazole as described by Pfeiffer (1965) was strikingly apparent in all experiments. Activation was confined to leaf scorch and did not enhance hormone symptoms on weeds surviving shortly after spraying. Thus mixtures of, for instance, 12 oz chlorflurazole with MCPA or mecoprop have given effective control of most weeds whilst 16 oz chlorflurazole alone was much inferior.

2. An interesting feature of chlorflurazole activity was its speed of action; in several cases weeds were dying within a few hours of treatment.

3. Temporary scorch sometimes occurred on cereals. This was much more apparent with the hormone combinations than with chlorflurazole alone. Complete recovery however occurred within a few days and yields (as shown below) were not found to be affected.

4. Chlorflurazole showed unusually high activity against *Spergula arvensis*, *Stellaria media* and *Chrysanthemum segetum*.

The results as described above were confirmed in many countries. Exceptions were areas of very low atmospheric humidity and tough weed growth (examples South of France; Italy; East Oregon, U.S.A.). The use of an oil-based formulation is indicated in these areas.

The results of the yield experiments are summarised in the following table:

Table 2

Leaf Scorch and Grain Yield in Weed-Free Experiments

Herbicides	Rate in oz/acre	Mean of 2 Spring Barley expt. (6 repl. each)		Mean of 2 Spring Wheat expt. (6 repl. each)	
		% leaf scorch	Yield as % of control	% leaf scorch	Yield as % of control
Chlorflurazole	16	8	100	9	100
Chlorflurazole + MCPA	8 + 12	4	101	5	104
" + "	16 + 12	14	98	15	89
" + "	32 + 12	31	96	22	98
" + "	64 + 12	33	97	25	96
Control		0	100	0	100

Analysis of variance showed that yield differences were not statistically significant.

The results show the complete recovery of cereal crops after initial scorch and the absence of yield depression at more than 5 times the dosage considered for acceptable weed control (12 oz + MCPA).

Results on Other Crops

Much work was carried out in the U.K. and other countries on weed control in peas and flax, using a chlorflurazole formulation without wetting agent and without the addition of hormone herbicides. The results varied from excellent selective weed control to crop damage and failure to control weeds. Differences in climatic and growing conditions accounted for most of the variation. The results on Polygonum aviculare (knotgrass) were disappointing, probably due to the difficulty of wetting the leaf surface with the formulation used.

TOXICOLOGY

Although studies on rat, mouse, guineapig, hamster and hen showed acute oral LD 50's of acceptable nature, other species (cat, dog, sheep, pig, calf, rabbit, marmoset) showed appreciably lower oral LD 50 values, indicating a very wide inter-species variability. It is therefore extremely difficult at present to extrapolate from animal data to human safety during intensive use, and further work is clearly necessary on the subject. Cumulative and dietary toxicity in the rat have been shown to be low: for example, male and female rats have so far survived six months administration at 1000 ppm in the diet without significant toxic effects.

FUTURE WORK

In order to obtain further data on its herbicidal performance under different conditions, on the preferred formulations, on toxicology and on other properties, chlorflurazole will continue to be investigated during the coming year as a very interesting new potential herbicide.

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α-CHLORO-6-t-BUTYL-o-ACETOTOLUIDIDE (MONSANTO CP 31675)

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Summary Presentation of the response of 22 species to α-chloro-6-t-butyl-o-acetotoluidide as a time-of-planting soil-incorporated treatment indicates a high degree of activity but limited selectivity. Potato in pot and field experiments showed considerable tolerance. Grasses in the seedling stage are very susceptible but further investigation of a range of species did not show useful selectivity between them. Established grasses may be affected but only at higher doses. The growth of two perennial weeds, *Agropyron repens* and *Cyperus rotundus*, from rhizomes and tubers respectively is severely inhibited. More detailed studies are presented on the placement of this herbicide in the soil in relation to its phytotoxicity.

INTRODUCTION

The first formal notice of this herbicide was a Monsanto Technical Sheet 'CP 31675' dated February 1962. This did not disclose the chemical nature of the product but this is given, together with some information on chemical and physical properties, mammalian toxicity, and suggested uses in a Monsanto Technical Bulletin dated October 1964 (Anon., 1964). Since that time published information on the potentialities of this compound as a herbicide has been scanty, partly because the prospects for commercial production and development remained obscure. However this compound has some interesting properties and hence it seems desirable to draw attention to these by publication of the limited amount of results obtained at the Weed Research Organisation.

METHODS AND MATERIALS

Pot experiments

Almost all pot experiments used a sandy loam soil derived from the same field at the Weed Research Organisation, containing 3% organic matter and 13% clay. Plastic pots or tinplate containers were utilised. All spray applications were made using a special laboratory sprayer embodying a fan nozzle moving at a constant speed applying 25-30 gal/ac, according to the experiment. Mixing of soil for incorporation treatments was done by repeated pouring through a large funnel or shaking in a closed tin before returning the soil to the pot. All pots were maintained in the glasshouse. Due to the diversity of experiments involved other details are given in connection with the reporting of individual experiments under 'Results'.

Field experiments

The field experiments were conducted on a sandy loam soil at the Weed Research Organisation. Spray applications were made at a volume rate of approximately 20 gal/ac using an Oxford Precision Sprayer.

RESULTS

Pre-emergence selectivity

The earliest information suggested that this compound was a soil-acting herbicide for use prior to weed emergence. Therefore the response of a wide range of species to this herbicide incorporated into the soil at the time of planting was investigated in a greenhouse experiment in 1963. The objective was to observe the behaviour of a diversity of species when exposed to this herbicide and to elucidate any interesting selectivities. In order to ensure that the germinating seed was freely exposed to the herbicide and that depth of sowing was not a factor in response, the herbicide was incorporated throughout the 2.5–3.0 in. depth of soil in the containers and watering was largely by sub-surface irrigation.

Due to the need to use CP 31675 as a standard for comparison of a number of later, related compounds it featured in two further experiments of the same type. The results from all three experiments were in general agreement. Those from the third such experiment are presented in Fig. 1. These assessments of survival of plants and of the fresh weight of vegetative growth above ground level were made at an interval of 18 to 35 days after sowing, this time depending upon the speed of growth of the species concerned.

CP 31675 showed a high degree of activity in the sandy loam soil, to which was added J.I. base fertiliser and ground chalk. 0.33 lb/ac was sufficient to produce a complete kill of the most susceptible species, perennial ryegrass, and to reduce growth of a number of other species to a very low level. In such an experiment ideal conditions are provided for the expression of phytotoxicity and slightly higher doses would be needed to give the same effects on the same soil in the field. However, a related compound, α-chloro-N-isopropylacetanilide (CP 31393), which has subsequently gone into commercial usage as a soil-acting herbicide (Selleck et al, 1965), was compared directly with CP 31675 in the present experiment. On this basis CP 31675 appeared many times more active than CP 31393.

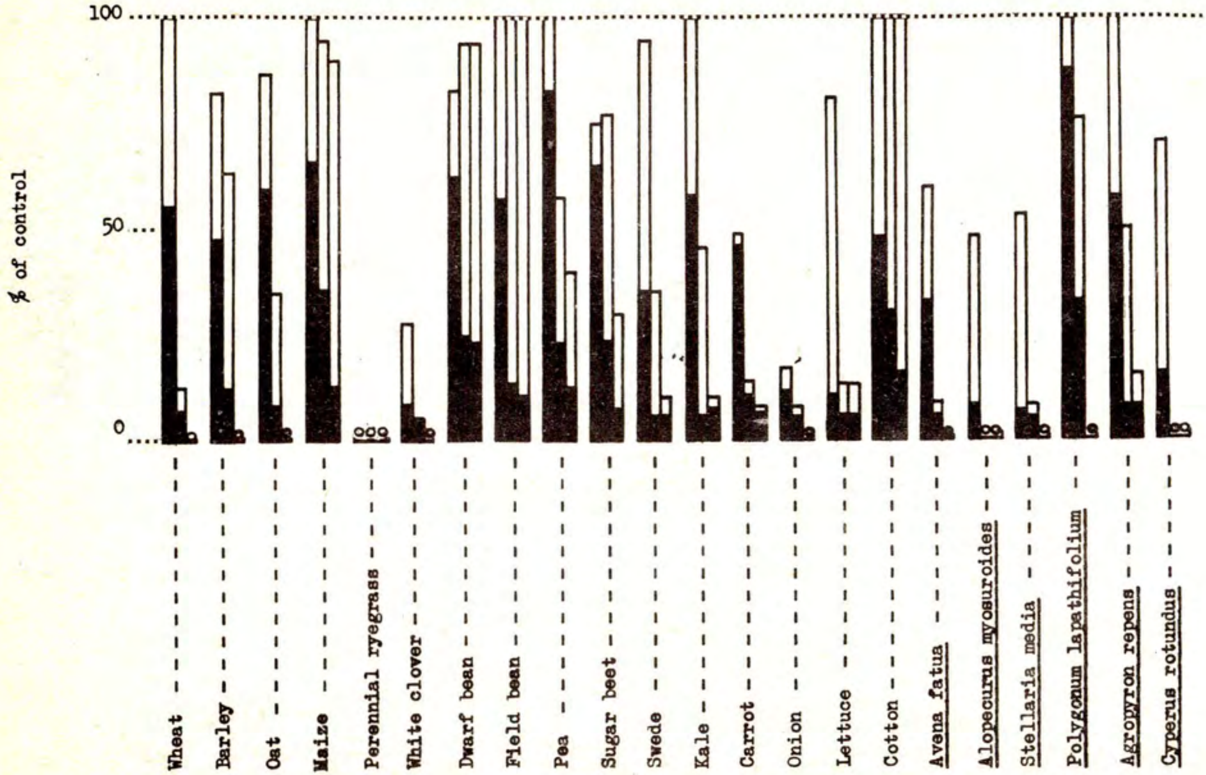
Effects of CP 31675 on susceptible plants ranged from a complete suppression of emergence to a stunting of growth shortly after emergence. This herbicide appears to be one of a number which can cause distorted and stunted shoot growth through the trapping of newer leaves within the earlier leaves, particularly in grasses.

Small-seeded grasses were the most susceptible of all species tested. Most of the smaller-seeded broad-leaved species were susceptible. One of the more striking features was the apparent importance of seed size. The cereals were more resistant than other grasses. The most resistant species of all were maize, dwarf bean, field bean, pea, cotton and *Polygonum lapathifolium*. All except the last-named have large seeds. However the range in degree of response and the dose needed to produce effects between the most susceptible and most resistant plants was such as to suggest that there was inadequate selectivity for reliable field use in the annual crops tested. This does not preclude the possibility that there may be other annual crops that do show a high degree of resistance or that deeper-rooted perennial crops may show sufficient tolerance to permit use of CP 31675 for weed control.

Resistance of potato

One crop in which a herbicide such as this could be of value is the potato. The inherent resistance of King Edward potato to CP 31675 was ascertained in a pot experiment in comparison with 19 other soil-acting herbicides. The technique involved the planting of suberised single-sprout tuber cores into soil with which the herbicide has been thoroughly mixed throughout its bulk. Fuller details of the general procedure are given in Holly (1962). The plants were maintained in the greenhouse for 8.5 weeks for observation of any treatment effects on growth.

Fig. 1 The response of 22 species to CP 31675 at 3 doses (L to R: 0.33, 1.0 & 3.0 lb/ac). The open histogram represents the survival of plants; the solid portion of the histogram represents their fresh weight. 0 indicates all plants died.



Doses of CP 31675 were 0.36, 1.4 and 5.7 lb/ac incorporated through a 6 in. depth of soil. At the middle dose there was no effect on the fresh weight of shoot, the number of stolons per plant, number of tubers per plant or the fresh weight of tubers per plant (60g/plant at end of experiment) as compared with untreated controls. At the highest dose however there was severe inhibition of vegetative growth and tuber initiation. The soil used was from the same source as that in the experiment illustrated in Fig. 1. The high degree of control of a wide range of species obtained in that experiment at 1.0 lb/ac under non-competitive conditions, taken in conjunction with the present experiment suggests the existence of considerable selectivity between potato and weeds in the 0.5-1.5 lb/ac dose area. In consequence CP 31675 was included as one of 6 new herbicides singled out as worthy of more detailed investigation of their potentialities for use in potato.

The resistance of potato to CP 31675 was confirmed in a preliminary field experiment with King Edward potato on a sandy loam soil in 1964, using twofold replication of 0.0025 ac plots. Doses of 1, 2 and 4 lb/ac were applied (a) to the soil surface and rotovated in immediately before planting chitted tubers and formation of a rounded ridge, or (b) to the surface of the ridges 16 days later when the shoots were still 1-2 in. below the surface, and the weeds were just starting to emerge. 2 and 4 lb/ac at either date gave good control of a mixed population of annual broad-leaved species, including Stellaria media and Fumaria officinalis. In mid-summer a small reduction in vegetative vigour of the potato was evident at 4 lb/ac. However, at harvest all treated plots gave yields of the same order as the untreated control or higher as shown in Table 1.

Table 1.

Potato tuber yield in cwt/ac following treatment with CP 31675

	Method of application	
Dose (lb/ac)	Incorporated pre-planting	Post-planting, shortly before emergence
1	131	112
2	137	149
4	154	161
Untreated control	119	

Susceptibility of perennial weeds

The response of the two perennial weed species Agropyron repens and Cyperus rotundus, as shown in Fig. 1, is of interest (the latter was included for its subtropical and tropical importance). At 1 lb/ac there was some emergence of shoots of A. repens but these virtually ceased to grow, and there was little production of new rhizome. At the same dose emergence of C. rotundus was completely prevented. About 4 weeks after planting C. rotundus tubers in treated soil, tubers exposed to 1 and 3 lb/ac were dug up and examined. These original tubers all appeared to be alive and hence they were replanted in untreated soil, whereupon they all sprouted and produced extensive vegetative growth. Apparently the herbicide had prevented effective sprouting without impairing the ultimate viability of the tuber. A similar situation held with A. repens at the higher doses, where replanting of the original two-node sections of rhizome in untreated soil after a similar time interval led to new vegetative growth.

In another pot experiment Cyperus rotundus tubers were held in treated soil for a much longer period of time after doses of 1, 3 and 9 lb/ac had been incorporated to a 4 in. depth at the time of planting. Six weeks later there had been no emergence of shoots even at the lowest dose, in contrast to the vigorous growth of untreated controls. By 22 weeks after treatment there were a few vigorous shoots at 1 lb/ac but only weak shoots at the higher doses. Final observations were made 32 weeks after treatment when shoot weight was 36, 16 and 11% of control and number of new tubers was 16, 6 and 4% of control respectively for the three doses in order of increasing amount.

Effectiveness in inhibiting growth of A. repens was confirmed in another pot experiment in which doses of 0.33, 1.0 and 3.0 lb/ac were incorporated into a 3 in. depth of the same sandy loam soil. Two-node sections of rhizome were planted at 0.5 in. depth. Untreated controls made vigorous vegetative growth. Measurement of fresh weight of this growth 22 days after spraying showed a reduction to 17% of control at the lowest dose and no growth at all at the other doses. The pots were then kept for a further 9 weeks. At 0.33 lb/ac vegetative growth was resumed after cutting for the fresh weight determination, and substantial new rhizome growth had been made during this time. At 1 and 4 lb/ac no growth had been made at the end of this period, 12 weeks after setting up the experiment. The original rhizome fragments were examined and these showed no signs of growth, although there was still some living tissue between the nodes.

Further aspects of the response of A. repens to CP 31675 were investigated in a pot experiment using two-node rhizome sections planted into the same type of soil in which the herbicide had been incorporated at 4 doses. The primary objective was to elucidate whether root or shoot entry from the soil was the more effective in producing inhibition of growth. In one set of containers the herbicide was incorporated in the upper 1.2 in. of soil which overlay another 1.2 in. of untreated soil; the rhizomes were planted 0.3 in. below the treated layer and watering was by sub-irrigation to prevent leaching. Thus entry into the treated plant had to be almost wholely through the shoot as it started to develop and push into the treated soil, unless this herbicide possessed a high ability for diffusion in soil. The other set of containers was set up in the reverse order with 1.2 in. of treated soil below 1.2 in. of untreated soil and the rhizomes planted 0.3 in. above the treated layer. Watering was from the surface. Hence entry into the plant had to be almost wholely via the root system. Fresh weight of shoot growth above ground level was determined 33 days after setting up the experiment and is presented in Table 2. Each figure is based on 4 replicates. These results show no substantial difference in response consequent upon the positioning of the herbicide.

Table 2.

Fresh weight of shoots of A. repens as % of appropriate control

Dose (lb/ac)	0.5	1.0	2.0	4.0
Herbicide above rhizome	32	6	4	5
Herbicide below rhizome	33	13	4	1

Investigation of the underground portions at this time showed that where the herbicide was positioned above the rhizome, shoots had grown into the treated zone and then died; secondary shoots had then developed from the node and also died. The length the shoot reached before death decreased with increasing dose. Where the herbicide was positioned below the rhizome more shoots reached the surface at the lower doses. Root growth was affected by both types of application.

Rhizome sections were then washed and replanted in untreated soil. At all doses new vegetative shoots were eventually produced but with more delay and less vigour than with the controls. Ultimately some 3 months after the start of the experiment vegetative growth was variable at all doses but in some replicates was indistinguishable from controls.

Effect of positioning in the soil

A further pot experiment suggested that the effect of herbicide positioning in the soil was more complex. In one set of treatments CP 31675 was applied only to the surface of soil in which two-node sections of rhizome of A. repens had been planted 0.5 in. deep on the preceding day, with all subsequent watering by subsurface irrigation to discourage leaching. There was no effect at doses of 0.33 and 1.0 lb/ac and only slight damage to emerging shoots at 3.0 lb/ac. By contrast, where the same doses had been incorporated through the 3 in. depth of soil in which the rhizomes were planted and the pots watered by a combination of overhead and subsurface irrigation, no live shoots were present 4 weeks later when 1.0 lb/ac was used. Even 0.33 lb/ac showed a severe effect. Similarly with wheat 3.0 lb/ac as a soil surface application had no effect whereas 1 lb/ac incorporated gave complete kill and 0.33 lb/ac incorporated caused very severe damage. With dwarf bean there was only a small increase in effect with incorporation. This effect ranged from slight to moderate damage at the lowest dose to very severe growth inhibition at 3.0 lb/ac. A different result was obtained with other species in the same experiment. There was no major difference in response to surface or incorporated applications in the case of Polygonum amphibium growing from rhizome sections or kale from seed. With both species the response ranged from little or no effect at the lowest dose to very severe growth inhibition at the top dose. With perennial ryegrass there was virtually complete kill at 0.33 lb/ac from both types of application, so that a difference at still lower doses is not precluded.

Selectivity between grasses

Because of the high toxicity of CP 31675 to certain germinating grasses and the practical interest in chemicals showing selectivity between weed and crop grasses, a pot experiment compared the response of 11 grass species and 1 forage legume. Doses of 0.125, 0.25 and 0.5 lb/ac were incorporated into a 1.2 in. depth of the usual sandy loam soil. Seeds were planted into this soil and watering was from overhead. Effects were assessed in terms of number of live plants and the fresh weight thereof about 6 weeks later. Severe effects were produced on all species at 0.5 lb/ac and on all except Poa annua at 0.25 lb/ac. Taking into account particularly the effect on fresh weight of shoots at all three doses the species can be ranked in order of increasing susceptibility as follows:

Poa annua < S 100 white clover = S 59 red fescue (Festuca rubra) = Holcus lanatus = S 143 cocksfoot (Dactylis glomerata) = Alopecurus myosuroides < Poa trivialis < sheep's fescue (Festuca ovina) = S 215 Meadow fescue (Festuca pratensis) < S 50 timothy (Phleum pratense) = S 23 perennial ryegrass (Lolium perenne) = Agrostis tenuis.

The range of response between the two extremes was not large and there is little indication of any useful pre-emergence selectivity between these seedling grasses.

However the question arises as to whether seedling grasses can be controlled in stands of established grasses. Accordingly, the response of 9 grasses and white clover to CP 31675 was investigated in a field experiment. The plants were well established in rows sown the previous year on a sandy loam soil. The strains used were the same as in the pot experiment. Doses of 1, 2 and 4 lb/ac were applied to one set of plots in July and to another set in October. Assessments based on scoring for the amount of vegetative material present were made at intervals up to 48 weeks after treatment.

Treatments applied in July were generally less severe than those applied in

October and recovery was more rapid. 1 lb/ac had relatively little effect on any species at either time of application but 2 and 4 lb/ac depressed the growth of most species. The effects reached a maximum about 10 weeks after the July treatment and were followed by a rapid recovery. Approximately 20 weeks was needed for the development of the full effect from October application and was again followed by recovery.

Species tending to be more resistant than average were white clover, red fescue and _Poa trivialis_. Species tending to be more susceptible than average were cocksfoot, perennial ryegrass, timothy, meadow fescue and _Holcus lanatus_. Sheep's fescue and _Agrostis tenuis_ were intermediate in response.

DISCUSSION

The present results verify the high activity of CP 31675 as a soil-acting herbicide on a wide range of species. However amongst the seeded crops no instances of a high degree of tolerance which would form the basis of a reliable selectivity were elucidated, though there is a tendency for larger-seeded plants to be more resistant. Nevertheless some possibilities exist for employment in established perennial crops and in crops such as the potato. The present work demonstrates the inherent resistance of potato to CP 31675, thus confirming a suggestion made when the herbicide was first announced (Anon., 1964). The investigation of the response of germinating grasses disclosed that it was the weed grasses that tended to be the more resistant. However, established grasses such as those used for seed production, though not wholely tolerant of overall applications, may have sufficient resistance to allow use of CP 31675 for the control of annual grass and other weeds.

The response of perennial weeds as exemplified by _Agropyron repens_ and _Cyperus rotundus_ is particularly interesting. There is a capacity for prevention of successful shoot growth from buds on underground rhizomes or tubers in the treated soil. This persists only as long as the rhizome or tuber is exposed to the herbicide, as shown by the cessation of the suppressive effect on transfer to untreated soil. CP 31675 has only a moderate capacity for persistence in soil (Hocombe, _et al_, 1966). Nevertheless the effect may be sufficiently great and long-lasting to protect a crop against such a perennial weed during the period when competition between weed and crop has the greatest economic repercussions.

The present investigations indicate the importance of positioning of this herbicide in the soil in controlling the degree of response by both seeded and perennial species. In some instances surface application without incorporation was less effective but the fact that this does not apply to all species suggests that the explanation is not the simple one of loss by volatilisation or decomposition when the herbicide is left exposed on the soil surface. However, the results suggest that some degree of incorporation may be advantageous in certain situations, though in others it might detract from selectivity.

If CP 31675 becomes commercially available more detailed work on its potentialities, both for annual and perennial weed control, in this country and abroad, would seem to be justified.

Acknowledgments

Thanks are due to many people who contributed to the successful conduct of these experiments, among them C. Parker, M.E. Thornton, P.T. Atkey, D.H. Bartlett and A. Oswald. The Monsanto Company kindly provided the necessary samples of herbicide.

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Research Summary

SALTS OF MECOPROP AND DICAMBA WITH OLEYL PROPYLENEDIAMINE

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INTRODUCTION

Substituted phenoxyaliphatic and benzoic acids currently available for weed control in cereals are usually applied in the form of their water-soluble alkali metal or amine salts after emergence of crop and weeds. Some, e.g. 2,4-D, have been used pre-emergence (Anderson and Wolf, 1947) and others, e.g. 2,3,6-TBA, are extremely persistent in the soil. It is, therefore, interesting to speculate upon the possibility that hitherto unknown derivatives of the phenoxyaliphatic and benzoic acids might possess properties that would render them persistent as soil applied herbicides. Fischer (1958) and Harwood et al. (1959) point the way by describing how phenoxyaliphatic acids may be converted cheaply to substantially water-insoluble, oil-soluble forms by salt formation with organic amines which are themselves derived from naturally occurring long chain aliphatic carboxylic acids. Their preliminary studies suggested that such salts should be absorbed easily by the leaves of undesirable plants, also that they should be tenaciously adsorbed on the finely divided sand and organic humus present in many soils.

We have therefore followed and have extended their work, and this note briefly indicates our progress in investigating possibilities of applying such salts for (a) pre-emergence weed control in cereals, (b) post-emergence weed control in cereals, (c) suppression and control of bracken (*Pteridium aquilinum*) and docks (*Rumex* spp.).

FORMULATIONS

Salts of mecoprop and of dicamba with di- or tri-amines, also with primary, secondary, tertiary amines, ethoxylated amines, and beta-amines - all derived from long aliphatic hydrocarbon chains - have been prepared. These salts are only slightly soluble in water, but all are readily soluble in many liquid hydrocarbons and have been formulated as emulsifiable concentrates. This summary is concerned with oleyl propylenediamine salts in two emulsifiable formulations, whose active ingredients were equivalent respectively to:

(i) mecoprop 200 g/l with dicamba 12.5 g/l (Code FPL2)
(ii) dicamba 200 g/l (Code FPL3)

FPL2 was tested for weed control in cereals, FPL3 for suppression and control of bracken and docks.

CEREALS

Pre-emergence residual weed control

In preliminary trials on certain fine sandy loams e.g. at Snettisham and Easton-on-the-Hill, and on skirt-fen soils e.g. at Methwold Hythe, applications of FPL2 at rates equivalent to 18-36 oz mecoprop/ac with 1.1-2.3 oz dicamba/ac pre-emergent of wheat, barley, oats provided excellent control of *Tripleurospermum maritimum* spp. *inodorum*, *Chenopodium album*, *Poa annua*, *Capsella bursa-pastoris*, *Stellaria media* and *Polygonum* spp. with no significant damage to the crop. On many other soils, especially on light sandy soils, the degree and duration of weed control as measured by general weed counting were variable to a puzzling degree.

In the laboratory we have determined the degree to which these soils adsorb oleyl propylenediamine salts of mecoprop and of dicamba from their dilute aqueous solutions. These laboratory measurements have been made after air-drying and crushing samples of the test soils to pass a 2 mm mesh. A measured volume of the prepared soil sample (5.5 ml) is brought to equilibrium by shaking for 15 minutes with 25 ml of an aqueous standard solution of the oleyl propylenediamine salt of mecoprop or of dicamba. After centrifuging the mixture, the equilibrium concentration of the oleyl propylenediamine salt is determined by absorption spectrophotometry at 2280 Å for the salt of mecoprop and at 2750 Å for the salt of dicamba. The degree of adsorption of the oleyl propylenediamine salt of dicamba on soils from the trial sites varied over the range 10% to 35%.

As results of this year's field trials are being received there is beginning to emerge a direct correlation between the degree of adsorption as measured for the soil in the laboratory and the ability of FPL2 to provide at the respective trial site persistence of general weed control throughout the cereal growing season. However, the variability of weed control as between the various trial sites is sufficient to warrant the opinion that salts of oleyl propylenediamine with mecoprop and dicamba are unlikely to be commercially useful for pre-emergence weed control throughout the main cereal growing areas of the United Kingdom.

Post-emergence weed control

In 34 other preliminary field trials FPL2 was applied post-emergence to wheat, barley, oats at stages of growth varying from 3 to 5 leaves and at rates equivalent to 16-36 oz mecoprop/ac with 1.5-2.3 oz dicamba/ac. Irrespective of soil type the higher application rates (equivalent to mecoprop 24-36 with dicamba 1.5-2.3 oz/ac) controlled those weeds enumerated in the previous sub-section together with Galium aparine, Sinapsis arvensis, Veronica spp; furthermore Chrysanthemum segetum and Fumaria officinalis were well controlled.

At many trial sites were plots amongst which ears of wheat or barley suffered some malformation. In some trials this objection was associated with the application of FPL2 at the highest rates and/or at too early a stage, e.g. at the 3-leaf stage, of the crop. At many trial sites malformation and phytotoxicity were insignificant when FPL2 was applied at the 5-leaf stage. Further experiments are needed to ascertain the circumstances in which ear distortion and crop phytotoxicity are minimal.

BRACKEN (Pteridium aquilinum) and DOCKS (Rumex spp.)

During April/May 1966 in England and June/July 1966 in Scotland FPL3 and dicamba-dimethylamine salt have each been applied to bracken just before the fronds were fully developed. In a series of trials FPL3 was applied at 1-4 lb dicamba a.i./ac alongside dicamba-dimethylamine salt at the same rates. At the higher rates within these ranges bracken fronds were killed, and the emulsifiable FPL3 formulation was 30% more effective than the aqueous dimethylamine salt. It is, of course, too early to report on regrowth at these trial sites. Production of FPL3 is only a little more expensive than that of the dimethylamine salt of dicamba so that, if further assessments of these preliminary trials confirm their early promise, FPL3 would deserve more extensive evaluation for bracken control.

In the United Kingdom and also in western Norway many trials are in progress to determine whether FPL3 is superior to dicamba-dimethylamine salt for suppression of broad-leaved dock. So far results show no superiority at equivalent rates a.i. Further assessments will be made of regrowth of docks on trial sites.

Acknowledgments

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THE USE OF HERBICIDES IN THE BRITISH SUGAR BEET CROP

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The elimination of hand labour in the sugar beet crop during the harvesting period - now virtually complete - has resulted in an even greater need to reduce the peak demand for spring labour associated with establishing weed free stands of single plants. The complementary requirements of growing the crop without hand labour - already a necessity in limited areas where labour for singling is simply not available - and the need to reduce production costs, serve to emphasise the outstanding importance of adequate weed control and indeed confirms the vital role which herbicides have to play in the production of the sugar beet crop.

Already a number of farmers who are practising almost complete mechanisation freely admit that without herbicides they would not be able to handle a sugar beet crop, whilst others would be faced with the possibility of reducing their contracted acreage.

The graph, compiled from statistics collected from all sugar beet growers with a contract of three acres or more, indicates the very rapid increase in herbicide usage that has taken place over the past two years. This information is based on the total acreage sprayed with each product and it is possible that a few growers have used more than one material on the same field. For example, a wild oat killer followed by a contact pre-emergence spray. However, the number of times when this has happened is probably small and is likely to be offset by the acreage sprayed by growers with contracts under three acres which is not included in the totals. The figures may therefore be regarded as reasonably accurate ones.

The rapid increase - from under 23% in 1964 to over 54% this year - has been largely due to the much wider use of residual soil-acting materials which now account for approximately 85% of the sprayed acreage.

In considering the use of herbicides on sugar beet in this country, it is as well to bear in mind some of the practical agronomic problems which have to be overcome in the development of a suitable product.

The elimination of broad-leaved weeds in a broad-leaved crop presents a considerable challenge which is intensified by the close botanical relationship between some of the most commonly occurring weed species (e.g. Fat Hen and Orache) and the crop itself. The margins of selectivity are, therefore, very finely balanced as compared with those appertaining to cereal crops, and thus the development of suitable selective contact materials has been relatively slow.

During the period under review there has been a wide variation in the use of non-selective materials applied pre-emergence. This variation undoubtedly reflects the difficulties which are inherent in the use of contact herbicides in sugar beet in that in some seasons the opportunities for spraying are severely curtailed by adverse land or weather conditions. Despite the undoubted efficiency of modern contact herbicides, there remains the problem of timing the application to ensure a maximum kill, and this presupposes that the weeds emerge prior to the crop. As a company we do not advocate the 'stale-bed' technique for we believe that it is vital to the successful establishment of a full braird to drill the seed into a moist seed-bed immediately following cultivations.

The pre-emergence non-selective contact herbicides may well continue to fill an important role on the peat soils where weed growth is prolific and soil acting materials generally unsuitable due to the high organic levels.

Limitations in the use of non-selective contact chemicals has led to widespread interest in the development of residual herbicides applied either at the time of drilling or soon after. In general the contact activity of these materials is very small, weed destruction depending on the chemical being absorbed from the soil into the growing tissues. This mode of action depends for success on a number of factors, several of which are outside the control of the user and hence serious doubts must arise as to whether this technique can be looked upon as the final answer to weed control in sugar beet. We must surely hope that materials can ultimately be developed which will give adequate weed control independent of soil type and moisture levels.

The use of residual herbicides in this country has been on a somewhat less extensive scale than on the Continent, and this can probably be explained by the much greater diversity in soil types on which we are attempting to grow the crop. Our records indicate that slightly more than 21% of the crop is grown on land ranging from clay loams to organic peat soils, soils on which few, if any, of the available materials can be confidently recommended at economic rates. On the lighter soils their use is complicated by the need to relate dosage rate to soil type, and this has led some companies into providing a soil sampling service so that accurate application rates can be recommended. Farmers are, in the main, fully satisfied with the services provided, but of course, certain costs are involved and these have to be met in the price of the material.

Recommendations from most manufacturers on the use of soil acting herbicides generally include a reference to the fact that applications following early drilling tend to have a better chance of success than those following late sowings when the possibilities of adequate rainfall are very much reduced. Indeed, we have experienced seasons when it has been possible to pinpoint a definite date after which the degree of weed control has been seriously impaired, and this has invariably coincided with a dry period. It may, therefore, be appropriate to remember that the past three seasons have been comparatively favourable, certainly to early drillings, in that there has been sufficient moisture with no prolonged periods of drought such as were experienced in the early 1950's, and which if repeated in the future, could well produce an entirely different pattern of weed control.

The soil acting chemicals have tended to be expensive - at least by the time they have reached the farmer - and owing to the dictates of economic necessity the practice of band spraying has been evolved. Many outstandingly good results have been achieved using this technique and a number of farmers have succeeded in stabilising or even reducing the overall costs of spring work despite increases in labour charges. Of greater significance, however, is the fact that hoemen have been able to increase their output, and thus many farmers have successfully handled the crop despite reductions in the available labour force.

Apart from the limitations imposed by soil and weather conditions, the extension in the use of residual herbicides has undoubtedly suffered from a lack of appreciation on the part of both band-sprayer manufacturers and farmers of the need for extreme accuracy in application if maximum weed control coupled with minimum crop damage is to be achieved. Numerous cases have been brought to our notice where crop damage has been caused through excessive dosage rates being applied. In some instances this has resulted from faulty equipment, whilst in others, the operator failed to comply with the manufacturer's instructions.

Fortunately both of these problems are gradually being overcome, the former by equipment manufacturers paying much greater attention to detail, and the latter through education. Here the value of instructional courses for machine operators allied to the personal contact of representatives of chemical companies and of our own field staff cannot be over-emphasised.

Though farmers have had to accept the techniques of band-spraying as the most economical way of using the residual herbicides, there is genuine interest in the possibilities of returing to the comparative simplicity of overall applications.

Such a development would be welcome not only on the grounds of eliminating the need for specialised equipment, but also by virtue of simplifying drilling operations. Where sowing is carried out using the larger multi-row drills - 10, 12 and 15 row units are becoming more numerous - the responsibilities of the operator can be considerably eased by removing the band-spraying equipment to a separate outfit. In addition, this is likely to improve the drilling output, an important factor, as contract size becomes larger.

Successful overall application might well lead to a reduction in the amount of mechanical weed control necessary. And here there appears to be scope for research to determine whether, in the absence of weeds, tractor hoeing is essential to the well-being of the crops.

We have come to accept that in the cultivation of sugar beet no operation can be viewed in isolation. This is particularly true of our attempts to solve the problem of spring mechanization when a number of inter-acting factors have to be considered in arriving at a final solution. For example, we know that the use of herbicides has reduced the level of seedling emergence in many crops where the individual plants have themselves apparently been unaffected. On unreplicated plots on the site of this year's National Sugar Beet Spring Demonstration herbicide applications carried out by personnel from the individual chemical companies resulted in reductions in seedling emergence ranging from nil to 44%. Fortunately the sprayings were carried out on crops sown at relatively close spacing and despite the reduced emergence there were still sufficient seedlings available to establish a satisfactory plant population.

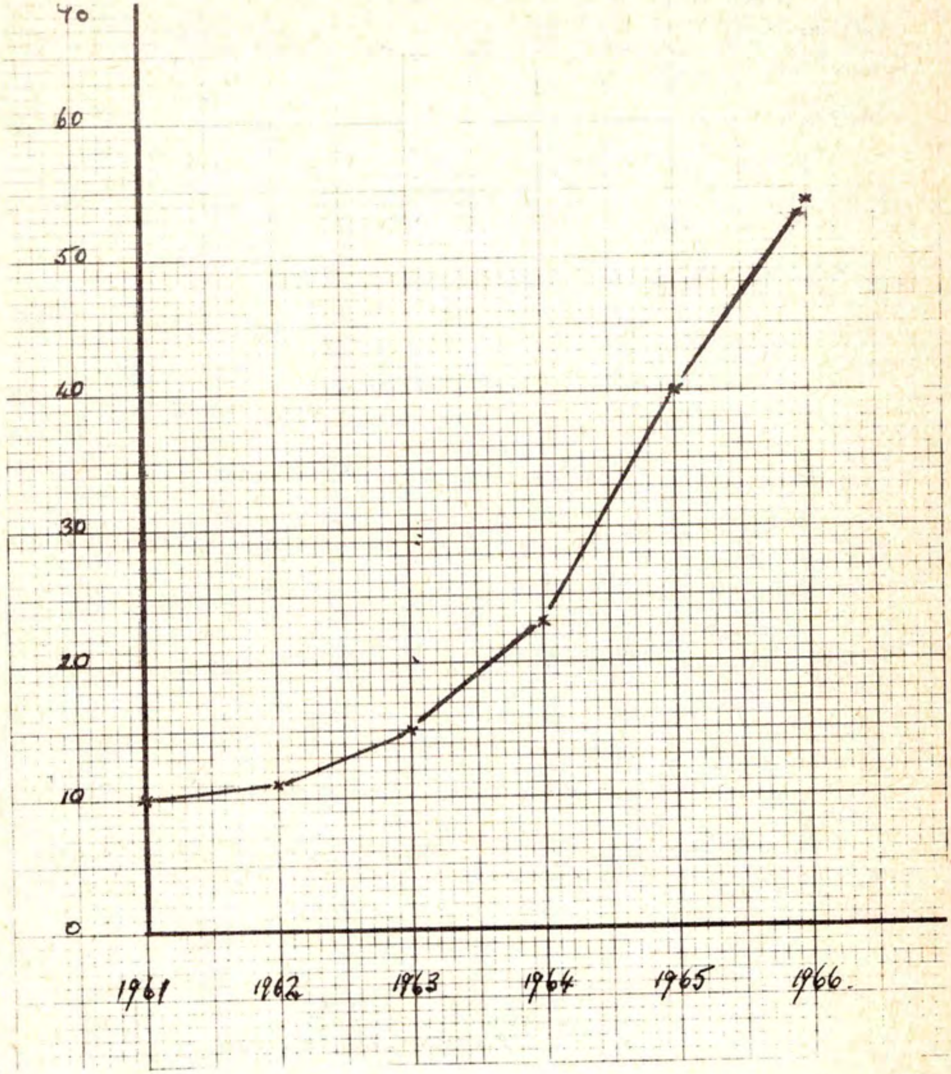
The position might well have been less satisfactory if 'planting-to-stand' had been attempted with the initial sowings at 6" - 9" spacing. This latter technique is attracting the attention of many growers who see it as a simple if somewhat risky answer to eliminating hand labour in the crop. If such an approach is to be given a reasonable chance of success, it is obvious that seedling losses of the order recorded above are not acceptable, particularly if yields are to be maintained at their existing levels.

In this country the use of post-emergence materials other than salt and nitrate of soda remains virtually in the experimental stage. Apart from the desirability of removing yet another operation from the peak period of sowing time, post-emergence materials, if successful, would present the grower with the opportunity to control weeds when they had appeared in his crop, as opposed to embarking on a policy of insurance as is the case with the pre-emergence residuals applied at or immediately after drilling.

Additionally, there is often the need to destroy late germinating weeds following the use of band-sprayed residual materials. Such weeds, whilst not necessarily affecting the growth of the crop, can cause difficulties at harvesting time and their control by means of a post-emergence application would be a welcome addition to the range of weed control techniques available.

Looking to the immediate future, it seems probable that the use of herbicides in the sugar beet crop will continue to expand at a fairly rapid rate. The unsuitability, in terms of high organic matter or clay content, of a number of the soil types on which the crop is grown, may well set initial limits to the acreage sprayed but it is to be hoped that new materials will soon be developed which will lead to sugar beet growers on all soil types having a full range of materials at their disposal.

ACREAGE OF BRITISH SUGAR BEET CROP RECEIVING HERBICIDES EXPRESSED AS % OF TOTAL CROP.



THE USE OF HERBICIDES IN SUGAR BEET IN THE NETHERLANDS

Ir. H.J. de Bruin [1]

The cultivation of sugar beet in the Netherlands covers an area of roughly 90,000 hectare. The beet is grown on a variety of soil types, i.e. marine clay, river clay, sandy soils and 'dal' soils. These soils can roughly be characterised as follows.

Marine clay

This contains from 20 - 50% silt and clay and has a humus content of 2 - 3%. Local humus contents of up to 15 or 20% may occur. Roughly 70% of the sugar beet is grown on marine clay soils. These soils are situated along the coast of Zeeland, Holland, Friesland and Groningen, and in the Ijsselmeer polders.

River clay

The percentage silt and clay varies from 25 to 65% with a humus content of roughly 2%. River clay is not directly comparable with marine clay. It is clearly different in the composition of the clay minerals; this is borne out also in the much sharper action of the soil herbicides on the plants. Sugar beet cultivation on these soils amounts to only 5% of the total sugar beet acreage, found along the main rivers Rhine, Waal, Maas and Yssel.

Sandy Soils

These occur in different types. Sugar beet is mainly grown on good moisture retaining loamy sandy soils with a humus content of 3 - 5% and around 10% silt and clay. In addition, sandy soils with a humus content of 5 to 8 or 10% are used for beet culture. These soils will be later referred to as humus rich sandy soils. All in all, the sandy soils are used for about 20% of the sugar beet acreage. One finds these soils in the eastern parts of the country.

'Dal' soils

These are excavated high peats consisting of the upper 'younger' peat mixed with the sandy sub-soil. They have very high organic matter contents ranging from 8 to 20% or even higher. The remainder is coarse sand. Around 5% of the sugar beet is grown on this type of soil situated in the north east part of the country.

In summary, therefore, it appears that sugar beet is grown in Holland mainly on marine clay poor in humus and in addition on soils differing widely in their humus content.

1. Rijkslandbouwconsulent voor Plantenziekten, Wageningen.

The Weed Complex

The weed complex varies according to soil type. In the following discussion perennial weeds have not been considered.

Marine and river clay

The main weeds in this case are chickweed (Stellaria media), may-weed (Matricaria spp.), grasses (Gramineae) such as meadow grass, blue grass, (Poa annua) and also foxtail or black grass (Alopecurus myosuroides), black nightshade (Solanum nigrum), buckwheat spp. (Polygonaceae) such as knot-grass (P. aviculare) spotted persicaria (P. nodosum) and mustard spp. (Cruciferae), such as shepherd's purse (Capsella bursa pastoris) and pennycress (Thlaspi arvense L.). In addition one finds on the lighter clay goosefoot spp. (Chenopodiaceae) such as white goosefoot (Ch. album) and salt bushes (Atriplex spp.).

Sandy soils

Here the dominant weeds are chickweed (S. media), white goosefoot (Ch. album) shepherd's purse (Capsella bursa pastoris) and field pansy (Viola tricolor spp. arvensis). In addition, sand spurry (Spergula arvensis), meadow grass (P. annua) and buckwheat spp. (Polygonaceae) are of importance.

'Dal' soils

The main weeds in this case are chickweed (S. media), meadow grass (P. annua) and buckwheat spp. (Polygonaceae) in particular waterpepper (p. hydropiper, shepherd's purse (C. bursa pastoris) hemp nettle (Galeopsis tetrahit) and white goosefoot (C. album).

The development and use of chemical products

During the period 1950 to 1960 short acting contact herbicides (such as pentachlorophenol) were occasionally used pre-emergence to the crop. These applications have never become of great importance. The results were usually disappointing because only a small proportion of the weeds are present before the emergence of the crop. The best results were obtained on the lighter soils. Methods to improve the results by increasing the interval between preparation of the soil for seeding and the actual seeding operation, thus providing extra time for the weeds to develop, have not been very successful.

After 1960 endothal appeared as the first product with a greater persistence followed soon by a combination of endothal with IPC. Both products are used during sowing. Roughly at the same time the combination of dimexan with BiPC and OMU came on the market, a product that is applied shortly before emergence of the beet. These products have been in use now for some years. The results obtained have been variable mainly due to weather conditions (rain) but also due to variation in weed species and soil type. Nevertheless, under practical conditions they were in general considered to be satisfactory. The scale of application however remained limited.

In 1963 the product Pyramin was introduced for commercial use. In several respects it appeared to be superior to the products already on the market. Finally in 1966 Venzar (lenacil) became available for commercial use.

It is estimated that in 1966 roughly 75 - 80% of the sugar beet acreage is treated with herbicides. Favourable performance and the need to economise on labour have been the main causes of this rapid increase.

Factors influencing the activity of the product

1. Soil texture

It has been established on clay soils that the activity of some products declines with increase in the proportion of silt and clay. Pyramin does not always give reliable results on clay soils when the percentage of silt and clay exceeds 45%. Increase of the dosage to 5 or 6 kg per hectare does not give any significant improvement. The combination of endothal and IPC, however, gives good results even on heavy soils provided the dosage is increased and adapted.

2. The humus content

Table 1. - Influence of humus content on herbicidal activity

(2 trials on 'dal' soil 1965)

10 = no weeds present

Product [2]	11% humus	16% humus
Pyramin 5 kg	2	3.5
Endothal + IPC 35 1	7.2	7.9
Venzar 2 kg	7.9	7
Venzar 3 kg	7.5	8

The observations were made shortly before thinning.

The action of endothal + IPC and of Venzar appear to be far less dependent on the humus content than in the case of Pyramin. On sandy soils with more than 5% humus one finds the same trend.

3. The Weed Complex

Perennial weeds cannot be controlled with the products available. Recently work has been carried out on the application of TCA for control of couch grass (*Agropyron repens*). The results of these trials are not yet known. Pyramin kills a great number of weed species but acts only moderately against grasses such as foxtail (*A. myosuroides*) bluegrass (*P. annua*), goose-grass (*Galium aparine*), knot-grass (*P. aviculare*) and certain speedwell spp. (*Veronica spp.*). Venzar fails against field pansy (*V. tricolor spp. arvense*) and buckwheat spp. (*Polygonaceae*) particularly water pepper (*P. hydropiper*). Also certain speedwell spp. (*Veronica spp.*) are not very susceptible. Endothal + IPC acts only moderately on goosefoot spp. (*Chenopodiaceae*) and mustard spp. (*Cruciferae*).

4. The moisture content of soil

Good performance of the products requires the soil to be moist for a prolonged period. On soils which are normally moisture retaining the activity is reliable and only to a small degree dependent on rainfall.

2. The dosages given here and elsewhere in this article refer to commercial products currently available in the Netherlands.

On rapidly drying soils the amount of rain greatly influences the results. The quantities required cannot be indicated accurately. In 1965 the products gave satisfactory results on all soil types as a result of good moisture supply The moisture supply is illustrated in the Table below which gives the amount of rain (in mm) over the period 1st March to 20th May.

Table 2

(dec. = 10 day period)

	March			April			May	
	1st. dec.	2nd. dec.	3rd. dec.	1st. dec.	2nd. dec.	3rd. dec.	1st. dec.	2nd. dec.
1. Marine clay (north)	2.8	20.6	21.1	18.7	59.3	14.5	61.7	11.0
2. Marine clay (middle)	1.9	14.3	27.8	14.7	37.5	19.8	52.1	9.2
3. Marine clay (south west)	1.1	13.9	44.5	2.3	40.5	19.8	55.2	1.8
4. Sand (south east)	2.2	11.2	30.6	4.0	56.1	45.3	44.0	6.3
5. Sand and 'dal' soil (north east)	2.4	14.4	22.7	17.5	57.3	22.3	64.3	8.1

A regular moisture supply appears to be beneficial to the results. The 1966 results confirm this.

5. Time of application

Nearly all products were applied during or immediately after sowing of the crop. With regard to Pyramin, various times of application were further investigated, namely immediately after sowing; immediately before emergence of the crop and after emergence when the first real leaves develop. In the latter case we investigated also the effect of adding a wetting agent (Citowett) to the product. The results can be summarised as follows.

The best results are obtained with Pyramin when applied during or shortly after sowing. One can then take advantage of the maximum amount of rainfall and the persistence is adequate. The application after emergence was disappointing with some exceptions. Moreover, the weed is then killed so slowly that it interferes during thinning. The application of a wetting agent gave little improvement. Application after emergence of the crop is, therefore, considered worthwhile only as an emergency measure.

6. Soil treatment

The treatment of the soil used for growing beet aims to achieve a high water-retaining capacity. Sowing early and on soil which is only superficially treated offers the best perspective in this respect. Incorporation of the products is not used in Holland. Neither is it being investigated. However, in the drier areas this may well be required. If the soil has good structure then mechanical treatment of the surface during growth of the crop is best deferred as long as possible or eliminated altogether. Germination of the weed is thus avoided as much as possible. Investigations at the Institute for Rational Sugar Production give the impression that the crop will not be unfavourably influenced by this.

Persistence of the products

Table 3. Assessment of herbicidal activity shortly before thinning of the beet and 12 weeks after (indicated in brackets) (1965 trials)

	Sandy soil with low humus content		Sandy soil rich in humus	
Pyramin 4 kg	9	(8)	9.9	(8)
Endothal + IPC	8.3	(6)	7.3	(6.2)
Venzar 2 kg	7.5	(7.5)	9.4	(7.4)
Venzar 3 kg	8.5	(8.2)	9	(9)

From these figures it appears that the persistence of endothal + IPC is much shorter than that of Pyramin and Venzar. These products can keep the crop free from weed during the whole season. The activity of Venzar was demonstrated clearly when an experimental field had to be ploughed over after which turnips were sown. The turnips suffered severe damage. During 1966 the persistence of Pyramin caused in several cases difficulty when the beet crop failed for one reason or another. All other crops for instance potatoes, wheat, cabbage, which were sown or planted 6 to 8 weeks after, suffered heavy damage. It is now being investigated which crops with the exception of maize, can be grown in such cases without too much risk. The possibilities seem to be fairly limited.

Influence of the products on crop yield

The table below gives some data obtained from trials on different types of soil.

Table 4 - Number of plants and yields on different soil types expressed in relative figures (1965 trials)

Product	Clay 25% silt low humus content		Low humus content sand		Humus rich sand	
	Plants	Yield	Plants	Yield	Plants	Yield
Pyramin 4 kg	98.4	97.4	102	102	108	101
Endothal+ IPC clay 30 l sand 20 l	103.3	90.8	100	100.4	103	105
Venzar 2 kg	90.6	94.4	99	93.3	107	101
Venzar 3 kg	88.5	92.2	79	84.2	99	109
Untreated	100	100	100	100	100	100

The figures show clearly that Pyramin influences the yield not at all or only very slightly. Endothal + IPC also has no unfavourable effect on the number of plants but when used in higher dosages the growth inhibition is prolonged and affects the yield. The dosage is governed to a great extent by the soil type and the humus content. On soils poor in humus Venzar will give a reduction in the number of plants and at application rates of 2 and 3 kg, this is reflected in the yield. In soils rich in humus Venzar has no unfavourable effect on the yields and the number of plants is hardly influenced at all.

Factors causing damage

1. Soil type

Light soils poor in humus are more likely to give rise to damage. This applies for all products. From various trials and observations in practice it appears that the use of Venzar (2 to 3 kg per hectare) is risky on soils with less than 6% humus. Lowering of the dosage on soils poor in humus to 1 and 1½ kg per hectare provided only a moderate herbicidal effect. On soils with less than 6% humus the risks become less as the silt and clay content increases. Exact limits cannot yet be indicated in this case. Pyramin has caused damage on very light soils with a silt and clay content lower than 18%. Reducing the dose from 4 to 3 kg per hectare, decreases the risk of damage considerably. On light soils poor in humus, the amount of rain governs very strongly the extent to which damage is likely to occur.

2. Condition of the crop

When the beet crop has been weakened for one reason or another damage can easily occur. In several cases this has been demonstrated in practice as indicated below. On part of a plot treated with Pyramin heavy damage occurred with clear Pyramin symptoms. It appeared that in this case the beet seed had been treated with too high a dose of insecticide (lindane). On the other part of the plot where no insecticide had been used, the crop developed normally. Early in 1966 damage of beet occurred fairly widely on marine clay caused by a rather high salt concentration in the top soil as a result of fertiliser treatment. The damage was clearly much more marked on those parts which had been treated with herbicide. This phenomenon was observed with Pyramin as well as with Venzar.

Use of and results obtained with the products under practical conditions

The following section summarises the performance observed with the most important products in normal agricultural practice. They agree quite well with the results obtained on experimental plots.

Pyramin

Marine clay soil

The product is in general used in quantities of 3 to 5 kg. per hectare. On very light clay soils poor in humus 3 kg per hectare appears to be sufficient; as the soil becomes heavier the dose had to be increased to 5 kg per hectare. In most of the cases around 4 kg per hectare is used. On soils with more than 40 to 45% silt and clay and a humus content of a few per cent, results are clearly inferior. On heavy clay with high humus content (5 to 10%) the results are unsatisfactory. On river clay the results appear to be less dependent on the texture of the soil. The weed assortment and the humidity of the soil only appear to determine the results.

Sandy soils

Pyramin gives in general excellent results also on these soils. However, they tend to become less favourable when the humus content is higher than 5%. Increase of the dosage to over 5 kg gives only little improvement.

'Dal' soils

On these soils Pyramin performs in general only moderately to poor as a result of the high organic matter content. Also the weed complex is less suitable for this product. It is, therefore, less suitable for these soils and is only used on a very limited scale. In those cases where Pyramin acts less satisfactorily on clay, sand or 'dal' soil efforts have been made to improve the performance by the addition of 2 to 5 kg of IPC. It seems possible in this way to eliminate the shortcomings mentioned to a large extent. However, insufficient information is available for a reliable conclusion on this point.

Endothal + IPC

This product has come into use for those cases where Pyramin fails. It is often applied on heavier clay soils rich in humus and on 'dal' soils. On sandy soils the use is very limited. In addition, this product is applied when grass weeds (e.g. Alopecurus myosuroides) are dominant. The marked growth inhibition which is initially observed on the soil types mentioned, particularly in the case of heavy rain, is hardly if at all reflected in the yields.

Dimexan + OMU + BiPC

The product is now only in use on a limited scale on light clay soils with high moisture retention capacity. In the case of heavy rain prolonged inhibition of the crop can occur, which is often reflected in lowering of the yield. It is expected that the use of this product will decrease still further.

Endothal

This product is now only used occasionally, mainly for specific weed problems where grasses (Gramineae) dominate. Its main merit appears to be its favourable cost which is much lower than that for Endothal + IPC.

Venzar

The product was submitted in 1966 for use in the Netherlands on soils with a humus content higher than 6%. The results have on the whole been disappointing. On sandy soils the field pansy was inadequately controlled, also the control of buckwheat spp. left much to be desired. Particularly the control of water pepper (P. hydropiper) which occurs frequently on 'dal' soils proved unsatisfactory. On clay soils with a low humus content Venzar was used experimentally under practical conditions. Weed control proved in general to be excellent. On lighter soils, however, there is the risk of crop damage. It is difficult to give a sound judgement on this product as yet, particularly in view of the rather unfavourable weather conditions in 1966.

The influence of the weather conditions

The results obtained in 1966 with the various products were worse than in previous years. The smaller amount of rainfall was probably mainly responsible for this. This again indicates that the moisture content of the soil has a decisive influence. The impression gained so far is that under rather dry conditions Endothal + IPC gives better results than the other products.

The application of the products

The products are usually applied over the whole area. Practical experience has shown that weeds in between the rows cause much work, particularly in a wet summer. Row spraying is, therefore, done only very occasionally. Only Endothal + IPC are used by band spraying. The grower is forced to do this in view of the high cost of the product.

REVIEW OF CURRENT BELGIAN WORK ON POST-EMERGENCE TREATMENTS

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SUMMARY

Trials carried out since 1964 on post-emergence treatments have shown the possibility of destroying weeds which have passed the cotyledon stage.

A mixture of pyrazon and Citowett (a wetter with a polyglycol aryl alkyl ether base) destroys or checks the development of broad-leaved weeds, especially Chenopodium album, even if a period of dry weather immediately follows the treatment.

The pyrazon + TCA and pyrazon + dalapon mixtures tried out this year give promise of a widening of the herbicide activity of pyrazon, especially on grass weeds.

Although the application of these products gives some signs of phytotoxicity to the beet, it does not seem to have any lasting effect on the crop. The slight falling off noticed in the early stages of growth is of far less importance than reduced plant-stand caused by pre-emergence herbicides, particularly since sugar beet practice is tending increasingly towards drilling to a stand.

It seems, therefore, that pyrazon + TCA mixtures and, even more, pyrazon + dalapon mixtures, will make it possible to save beet fields infested by annual weeds and especially Alopecurus myosuroides. Some hectares treated with these mixtures in Belgium have already given promising results.

INTRODUCTION

In recent years the labour shortage in Belgium has caused an extremely rapid development in spring mechanisation towards mechanical thinning and drilling to a stand.

Results obtained with pre-sowing and re-emergence herbicides are generally excellent, but they are insufficient in many cases to keep the crop clean until the spaces between the rows are closed. The grower is, therefore, obliged to carry out hand cleaning which adds quite a bit to his costs. Post-emergence herbicide treatment therefore seems to be the indispensable complement to the pre-emergence treatment.

Although many fields mechanically thinned and drilled to a stand are sprayed with pyrazon (the only post-emergence product approved for sale in Belgium), many farmers fail to spray their beet early enough and therefore often obtain only mediocre results. Although pyrazon applied in post-emergence almost completely destroys some weeds such as Matricaria chamomilla, Stellaria media, Lamium purpureum and amplexicaule, Poa annua, Polygonum persicaria and lapathifolium, Sinapis arvensis up to the 4 - 6 leaf stage, the same does not apply to Chenopodium album, Solanum nigrum and Alopecurus myosuroides. These together with other less important weeds, are less susceptible to pre-emergence application.

Therefore, the Sugar Beet Institute, in collaboration with the Station de Phytopharmacie de l'Etat at Bemboux, has undertaken since 1964 a series of tests with a view to increasing the herbicidal properties of pyrazon and lenacil on more mature weeds.

In 1964, the first trials carried out with pyrazon mixed with Citowett (a wetter with polyglycol aryl alkyl ether base), even though carried out under dry conditions, gave very good results on Chenopodium album which was already well established (6 to 8 leaves). A reduction of 75% in weight was obtained, while the quantity of pyrazon was reduced to 2.4 kg/ha instead of the 4 kg/ha generally used. These tests were followed up in 1965 by trying wetters other than Citowett with pyrazon and lenacil; here we obtained a reduction of 80 to 85% in weight of weeds, whichever wetter was used.

In 1966 our work has been concerned with wetters mixed with pyrazon and lenacil and with mixtures of pyrazon + TCA and pyrazon + dalapon. These last experiments are the subject of this paper.

METHODS AND MATERIALS

The following products and mixtures of chemicals were tried :

- Pyrazon W.P. 80%
- Chlorpyazon W.P. 80% (H 176 - 1)
- Pyrazon W.P. 80% + Citowett
- Pyrazon W.P. 80% + TCA W.S.P. 80%
- Pyrazon W.P. 80% + dalapon W.S.P. 74%
- Lenacil W.P. 80%
- Lenacil W.P. 40%

The test was carried out on loamy soil with the following mechanical analysis:

<2	μ: 9.8%
2-20	μ: 23.7%
20-50	μ: 53.9%
>50	μ: 12.6%

This soil contained 1.73% of humus.

Sowing was carried out on the 28th April with a precision drill, the space between seeds being 6.4 cm. The plots were 10 x 2.7 m. with 5 replications.

The chemicals were applied on the 26th May with a knapsack sprayer. The pressure was maintained at a constant 2.5 atmospheres by small CO_2 bottles. This sprayer was connected to a 2.7 m. boom equipped with 5 nozzles (Bray 733.00). The quantity of water per hectare was 450 litres.

At that date, the beet had reached the 2 - 6 leaf stage. The main weeds were : Chenopodium album (4 - 6 leaves), Stellaria media (4 - 10 leaves), Lamium purpureum and amplexicaule (2 - 6 leaves), Matricaria chamomilla (2 - 6 leaves), Alopecurus myosuroides (2 - 8 leaves).

On the 14th June, nineteen days after the treatment, the beet seedlings (250 per quadrat) and the weeds (over an area of 5 square metres per quadrat) were harvested in plastic bags. After sampling, the beet and weeds were weighed fresh.

The rainfall is shown in table 1. It will be noted that for the period between the treatment date (T) and the weighing date (W) there was relative dry weather with maximum soil temperatures often above 40°C.

RESULTS

A. Effect on Beet

A series of visual assessments of the growth of the beet seedlings showed that while certain treatments, such as pyrazon + Citowett, pyrazon + TCA and pyrazon + dalapon had fairly pronounced signs of phytotoxicity, these did not persist, and the crop quickly recovered. Nevertheless, it must be said that the pyrazon + dalapon mixture, applied 4 kg + 7 kg/ha, checked beet growth for a longer time.

Weighing the beet nineteen days after treatment confirmed these observations.

Table 2

Treatments	Assessments			Weighing
	1st June	10th June	30th Aug.	14th June
Untreated	100	100	100	100
Pyrazon: 3.2 kg/ha	99	100	99	100
Chlorpyrazon: 4 kg/ha	98	99	98	100
Chlorpyrazon: 8 kg/ha	98	100	98	100
Pyrazon: 2.7 + Citowett: 21/ha	92	98	98	92
Pyrazon: 3.2 + TCA: 4.8 kg/ha	85	96	98	90
Pyrazon: 3.2 + dalapon: 2.6 kg/ha	92	97	100	95
Pyrazon: 3.2 + dalapon 5.2 kg/ha	85	90	98	75
Lenacil (80%): 1.6 kg/ha	100	100	98	100
Lenacil (40%): 1.6 kg/ha	100	100	99	100

B. Effects on Weeds : See table 3.

Chlorpyrazone appeared ineffective against grass weeds and insufficient as regards Chenopodium. (Used at 5 kg/ha).

The pyrazon + Citowett mixture gave a good kill of broadleaved weeds, particularly Chenopodium album. The growth of Alopecurus myosuroides was checked but after a while the weeds recovered.

On broadleaved weeds, the pyrazon + TCA mixture was about as effective as pyrazon + Citowett mixture but the former was slightly better as regards grass weeds, Poa annua in particular.

With the pyrazon + dalapon mixture used at 4 kg + 3.5 kg/ha, the herbicide effect was better than that obtained with the above-mentioned mixtures, especially as regards Alopecurus. Here, however, it should be noted that in the pyrazon + TCA and pyrazon + dalapon mixtures, the dose of pyrazon/ha was 12% more than that used in the pyrazon + Citowett mixture. With a dose of 3.2 + 5.2 kg/ha of pyrazon + dalapon mixture, the phytotoxic effect on the beet was very significant without a corresponding increase of weed control.

The two lenacil formulations used in this trial were very disappointing this year because they only gave moderate control of both grass and broadleaved weeds.

DISCUSSION

These tests show that pyrazon used in post-emergence without wetter is insufficiently active on grass and Chenopodium, especially if a period of dry weather follows the application of the product. With a wetter, the weed control is considerably increased on broadleaved weeds and particularly on Chenopodium.

TCA and dalapon mixed with the pyrazon are more effective, especially on grass weeds. Dalapon seems to be more effective than TCA. These products activate the pyrazon contact herbicidal properties, as a wetter would, not only by controlling grassy weeds but also having a synergistic effect on the action of pyrazon on broadleaved weeds.

Foliage absorption of lenacil by weeds is very slight and very slow. This makes this product even more sensitive than pyrazon to the weather conditions following the treatment. If the ground remains moist during the week following the treatment, the herbicide effectiveness is excellent (1965). This year the dry period and strongsun following the application, was prejudicial to root absorption by the weeds, which continued to develop during this period.

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TABLE 1.

RAINFALL AND MAXIMUM TEMPERATURES MEASURED AT SOIL LEVEL

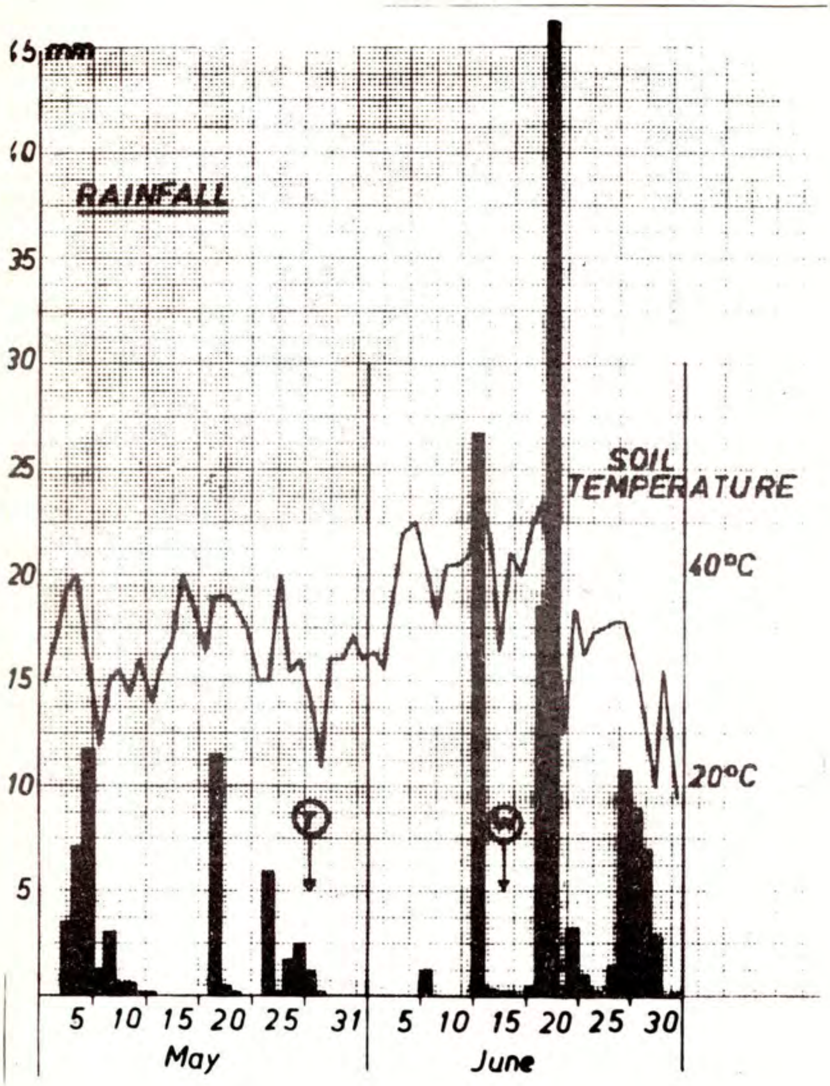
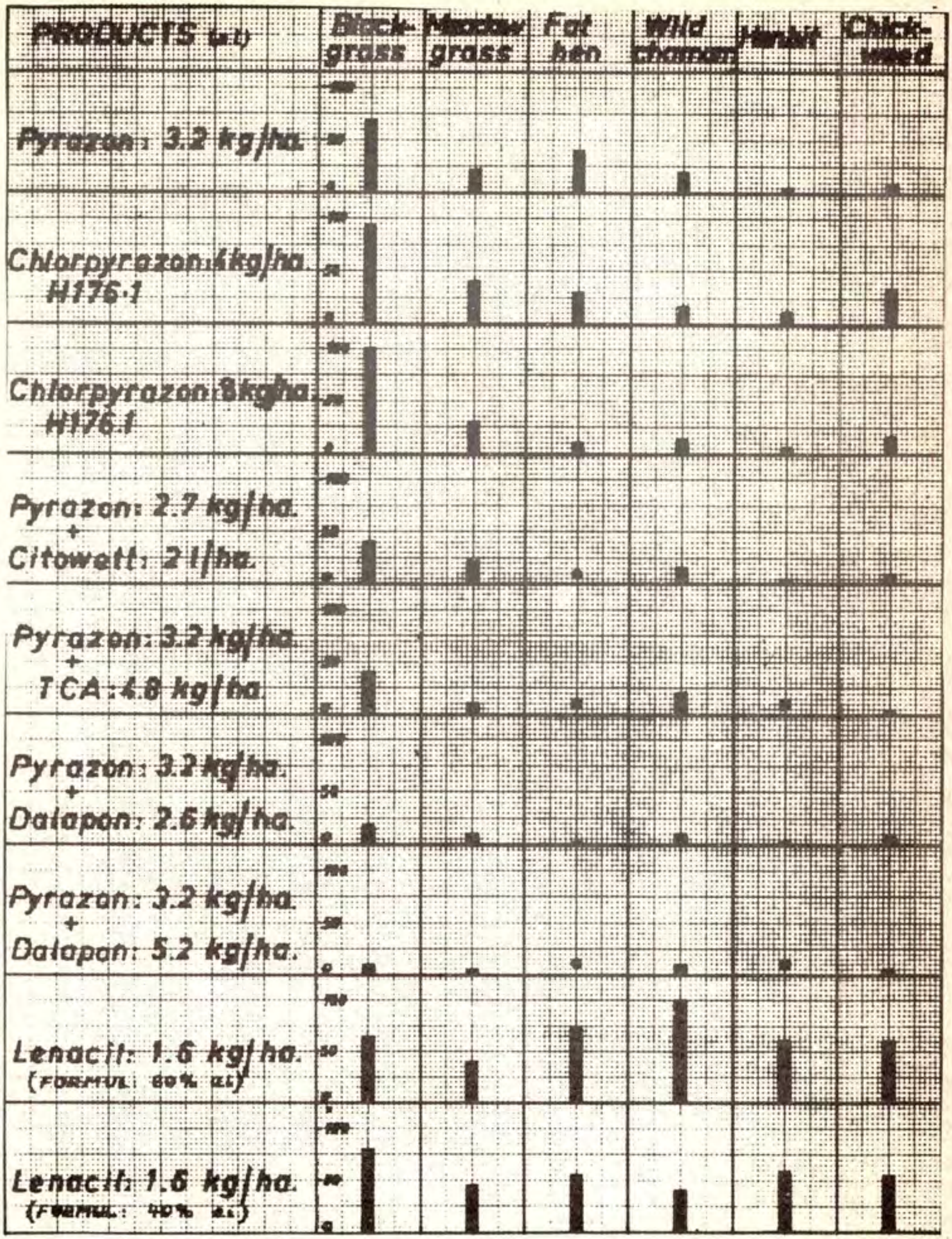


TABLE 3

PERCENTAGE REDUCTION IN WEIGHT OF WEEDS, COMPARED WITH THE UNTREATED REFERENCE PLOT



HERBICIDE TRIALS WITH SUGAR BEET IN NORTHERN IRELAND

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Summary Experiments are described in which pyrazon, lenacil, diuron/propham and endothal/propham were incorporated into the soil immediately before sowing sugar beet or applied as overall surface treatments shortly after sowing. There was a suggestion that soil incorporation enhanced herbicide activity on medium to heavy soils but reduced it on light soils. In other trials the effect of pre-emergence applications of a number of herbicides including pyrazon, lenacil, diuron/propham and endothal/propham were compared at several sites. No crop damage was recorded and each herbicide gave an adequate weed control although there was again a suggestion that herbicide activity might be affected by soil type. Post-emergence treatment showed that under Northern Ireland conditions sugar beet can tolerate pyrazon from the cotyledon stage onwards.

INTRODUCTION

In anticipation of an extension to the sugar beet acreage in Northern Ireland a weed control trial was initiated in 1963. Following some promising results more extensive trials were conducted in 1964 and 1965 to examine the value of a number of herbicides in sugar beet on several soil types under local conditions. It has been suggested (Cussans 1964) that the activity of some sugar beet herbicides, e.g. lenacil is increased by soil incorporation. Consequently several trials were designed to give a direct comparison between the effect of the soil incorporation of herbicides and surface application shortly after sowing.

It has been reported (Lush et al 1962), (Cussans 1962), that pyrazon shows some selectivity when applied as a post-emergence treatment to sugar beet but that pre-emergence application might be preferable. Under some circumstances a post-emergence treatment might be necessary. Whilst most trials concerned pre-emergence applications a trial was designed in 1965 to examine the tolerance of sugar beet to post-emergence treatments at different growth stages.

This paper summarises the results of the 1964 and 1965 trials.

METHOD AND MATERIALS

In 1964 soil incorporation was compared with surface applications of pyrazon, lenacil, endothal/propham, and diuron/propham at two sites. Incorporated herbicides were applied immediately before sowing and raked into the soil by hand. Surface treatments were applied overall after sowing.

In 1965 a similar trial was conducted at three sites in which pyrazon and lenacil were incorporated into the soil by tine harrowing immediately before sowing and applied as overall surface treatments after sowing.

In these trials the herbicides were arranged in a factorial design with the soil treatments with four replicates in 1964 and three in 1965.

A herbicide screening trial in 1965 compared pre-emergence applications of pyrazon, lenacil, endothal/propham and diuron/propham. This trial which was conducted at two sites was designed as a randomised block with three replicates.

All herbicide treatments were applied overall with a knapsack sprayer in a spray volume of 50 gal. per acre.

Weeds were recorded by scoring on a scale from 0 - 5 where 0 = weeds absent and 5 = weeds dominant. Weed counts were also recorded in which a 12 in. quadrat was used thrown at random three times per plot.

Sugar beet was harvested by hand in November and the weight of washed beet was recorded.

RESULTS

Soil incorporated applications

Details of the results of these trials are given in Tables 1, 2 and 3. From Table 1 it may be seen that in 1964 the diuron/propham mixture at 10 lb/ac on a heavy loam soil at Loughgall and at 6.25 lb/ac on a medium loam at Loughry reduced sugar beet yield slightly whilst lenacil at 1.0 lb/ac at both sites increased yield. At Loughry these variations in yield reached statistical significance when compared with the unsprayed control. Soil incorporation of herbicides did not affect yield significantly but there was a suggestion that incorporation increased yield slightly at Loughgall but reduced it at Loughry on the lighter soil.

Weed scores at Loughgall five weeks after the herbicide application show that the diuron/propham mixture gave the most satisfactory control and that two months after treatment weed control effects had been largely dissipated except with the above herbicide which still showed some effect and lenacil which showed some effect at 1.0 lb/ac and an appreciable control at 2.0 lb/ac.

A weed score at Loughry seven weeks after treatment shows that pyrazon at 3.0 lb/ac, diuron/propham and lenacil at 1.0 lb/ac gave a similar degree of weed control.

On the heavy soil at Loughgall soil incorporation improved the general level of weed control slightly but on the lighter Loughry soil weed control was better with surface applications.

Table 1

Effect of soil incorporation of herbicides on sugar beet yield and weed control

Date of treatment		Loughgall 1.5.64			Loughry 15.5.64	
		Yield washed sugar beet tons/ac	Weed scores 10.6.64	Weed scores 8.7.64	Yield washed sugar beet tons/ac	Weed scores 9.7.64
Herbicide	Dose lb/ac a.i.					
No herbicide		14.04	3.64	4.99	16.40	4.50
Pyrazon	3.0	16.02	2.62	4.12	16.57	2.75
Endothal/propham	(see note)	15.50	2.90	4.28	16.22	3.37
Diuron/propham	" "	14.61	1.40	3.12	15.85	2.62
Lenacil	0.5	14.71	2.62	4.25	16.39	3.12
Lenacil	1.0	15.42	2.12	3.62	16.91	3.00
Lenacil	2.0	14.83	2.00	2.90	-	-
Standard error of difference between two treatment means		N.S.	-	-	0.43	-
Herbicide application.						
Soil incorporated		15.09	2.48	4.00	15.61	3.39
Not incorporated		14.94	2.60	3.64	17.16	3.11
Standard error of difference between two treatment means		N.S.	-	-	N.S.	-
G.M.		15.01	-	-	16.39	-
CV%		9.08	-	-	9.08	-

Note: 1. Lenacil was not applied at 2.0 lb/ac at Loughry.
2. Endothal/propham (Murbetex) was applied at 21 pints/ac at Loughgall and 14 pints/ac at Loughry.
Diuron/propham (dipro) was applied at 10 lb/ac at Loughgall and 6.25 lb/ac at Loughry.

Table 2 shows that lenacil at 4.0 lb/ac significantly reduced yield compared to other herbicides on the light soil at Strabane in 1965. Lenacil at 1.0 lb/ac gave a significantly higher yield than the other herbicides at Strabane. There were no significant differences in yield between herbicides at the other sites.

Soil incorporation of herbicides had no effect on yield at Loughgall and Loughry but at Strabane it gave a significantly higher yield than non-incorporation.

Table 2

Effect of soil incorporation of herbicides on sugar beet yield

		Yield of washed sugar beet Tons/ac		
Date of treatment		Loughgall 30.4.65	Loughry 6.4.65	Strabane 30.4.65
Herbicide	Dose lb/ac a.i.			
Pyrazon	3.0	16.37	15.87	12.86
Lenacil	1.0	15.81	16.31	13.72
Lenacil	2.0	19.00	16.30	12.02
Lenacil	4.0	17.21	15.83	9.95
Standard error of difference between two treatment means		N.S.	N.S.	0.87
Herbicide application.				
Soil incorporated		17.17	15.17	12.73
Not incorporated		16.16	15.37	11.52
Standard error of difference between two treatment means		N.S.	N.S.	0.49
G.M.		14.29	15.20	12.13
CV%		14.05	14.80	12.44
Unsprayed control		15.87	14.25	12.20

Table 3

Effect of soil incorporation of herbicides on weed control

		Loughgall 30.4.65		Loughry 6.4.65		Strabane 30.4.65
Date of treatment		Total weed count 8.6.65	Log 1 + x	Total weed count 11.5.65	Log 1 + x	Weed scores 8.6.65
Herbicide	Dose lb/ac a.i.					
Pyrazon	3.0	25.00	2.32	71.00	2.84	1.7
Lenacil	1.0	25.66	2.37	12.50	2.06	1.7
Lenacil	2.0	13.33	2.06	6.18	1.30	0.8
Lenacil	4.0	15.66	2.06	8.50	1.77	0.3
Standard error of difference between two treatment means		-	N.S.	-	0.26	-
Herbicide application.						
Soil incorporated		14.05	2.10	33.22	2.20	2.0
Not incorporated		22.39	2.28	16.55	1.91	1.3
Standard error of difference between two treatment means		-	N.S.	-	N.S.	-
GM		-	2.19	-	2.05	-
CV%		-	13.14	-	22.42	-
Unsprayed control		68.5	-	177.2	-	5.0

Note: 1. Log. 1 + x transformation was used for statistical analysis of the weed counts.

2. A weed count was not conducted at Strabane.

As Table 3 shows lenacil at 1.0 lb/ac gave a superior weed control to pyrazon at 3.0 lb/ac at Loughry where the main weeds were Poa annua (annual meadow grass) Senecio vulgaris (groundsel) and Polygonum persicaria (red shank). At Loughgall - principal weeds Poa annua and Polygonum persicaria - and Strabane - principle weeds Fumaria officinalis (fumitory), Poa annua, Chenopodium album (fat hen), Galeopsis tetrahit (hempnettle) these two treatments gave similar results.

Soil incorporation had no significant effect on weed control but there were indications that incorporation of herbicides might give a better weed control on the heavy Loughgall soil and that on the lighter Loughry and Strabane soils non-incorporation may be preferable.

Surface pre-emergence applications

Table 4 outlines the results with respect to sugar beet yield and weed control of several pre-emergence herbicides applied shortly after sowing.

Table 4

Effect of herbicides on yield of sugar beet and weed control

Date of treatment		Loughgall 7.5.65			Loughry 14.4.65		
		Yield washed sugar beet Tons/ac	Total weed count 8.6.65	Log 1 + x	Yield washed sugar beet Tons/ac	Total weed count 11.5.65	Log 1 + x
Herbicide	Dose lb/ac a.i.						
Unsprayed control		15.6	156.67	3.00	17.67	292.33	3.38
Pyrazon	3.0	16.0	95.00	2.88	16.67	193.67	3.24
Pyrazon	4.5	16.8	45.00	2.51	16.73	91.33	2.89
Endothal/propham	(see note)	19.2	46.33	2.52	16.90	29.00	2.40
Diurcn/propham	" "	16.9	78.33	2.77	15.83	28.00	2.26
Lenacil	1.0	15.7	68.33	2.76	15.50	63.33	2.78
Lenacil	2.0	18.0	47.33	2.42	15.83	37.33	2.50
Lenacil	4.0	17.4	58.67	2.71	15.20	22.33	2.25
Standard error of difference between two treatment means		N.S.	-	0.13	N.S.	-	0.24
GM		16.67	-	2.73	16.15	-	2.81
CV%		11.04	-	9.80	11.24	-	10.46

Note: 1. Log 1 + x transformation was used for statistical analysis of the weed counts.
2. Endothal/propham (Murbetex) was applied at 21 pints/ac at Loughgall and 14 pints/ac at Loughry.
Diuron/propham (dipro) was applied at 6.0 lb/ac at Loughgall and 7.0 lb/ac at Loughry.

It is evident from Table 4 that no herbicide affected crop yield at either site.

Lenacil at 1.0 lb/ac gave a better weed control than pyrazon at 3.0 lb/ac at Loughgall where the principal weeds were Poa annua (annual meadow grass), Senecio vulgaris (groundsel), Stellaria media (chickweed) and Polygonum persicaria (red shank) and at Loughry where the principal weeds were Poa annua and Stellaria media.

At Loughgall endothal/propham and diuron/propham gave a similar weed control to lenacil at 1.0 lb/ac and at Loughry they were comparable to lenacil at 2.0 lb/ac and lenacil at 4.0 lb/ac respectively.

Post-emergence applications

Following an initial trial in 1964 in which a post-emergence application of pyrazon applied immediately after singling at the 4th true leaf stage had no adverse effect on yield a trial was designed in 1965 to assess the tolerance of sugar beet to post-emergence herbicides at various growth stages.

Table 5 shows that sugar beet can tolerate pyrazon at 3.0 and 4.5 lb/ac applied at various growth stages from the cotyledon stage. It also showed a degree of tolerance to simazine at 0.75 lb/ac at the four true leaf stage and later but was severely damaged by a higher dose of simazine and by both doses applied at the cotyledon stage.

Table 5

Effect of post-emergence herbicide applications on the yield of sugar beet

Stage of growth at herbicide application		Yield of washed sugar beet Tons/ac		
		Cotyledon	4th true leaf	Post-singling
Herbicide	Dose lb/ac a.i.			
Pyrazon	3.0	17.23	19.70	22.00
Pyrazon	4.5	19.26	20.56	19.87
Simazine	0.75	12.00	18.00	16.60
Simazine	1.5	7.97	9.80	9.20
Standard error of difference between two treatment means			N.S.	
GM			16.05	
CV%			11.79	

DISCUSSION

The suggestion in 1964 that herbicide activity varied with soil type in that on heavy soils soil incorporation gave better results than non-incorporation whilst on light soils the reverse was the case was supported by similar results in 1965. The 1965 weed control also suggests that the herbicidal activity of lenacil is increased on light soils. This is supported by the yields on the light soil at Strabane which was the only site where there was a significant reduction in yield from lenacil.

This result is in agreement with earlier work with lenacil (Cussans 1964) which showed higher activity on light soils.

From the available evidence it would seem that soil incorporation following pre-sowing treatments may not be the most successful method of application for all soil types.

Spraying was carried out relatively late in the season in most of these trials. This may partially explain the relatively poor weed control for example at Loughry in 1964 when a dry period followed spraying. In general, however, late application has not prevented an adequate weed control which can probably be attributed to the wet climate of N. Ireland which would not apply in many sugar beet growing areas of the U.K.

In these trials lenacil at 1.0 lb/ac appeared to be rather more consistently satisfactory than pyrazon at 3.0 lb/ac but both materials showed that they are capable of providing an adequate weed control up to singling time when applied under Northern Ireland conditions shortly after sowing. Endothal/propham and diuron/propham mixtures also gave similarly satisfactory results when applied according to the manufacturers recommendations.

An experiment in 1965 showed that pyrazon can be applied as a post-emergence treatment at various stages of growth of sugar beet at doses up to 4.5 lb/ac. Simazine was included in this trial to provide a comparison with a herbicide which could be expected to produce appreciable toxicity. A surprising degree of tolerance was shown, however, at the later growth stages to the lower dose of simazine.

Before conclusions can be drawn concerning post-emergence treatments further trials will be necessary on a number of sites especially as trials elsewhere (Lush et al 1964) have suggested that under U.K. conditions pre-emergence treatments are likely to be most effective.

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FURTHER STUDIES WITH HERBICIDAL COMBINATIONS CONTAINING MEDINOTERB ACETATE FOR SUGAR BEET

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Summary Pre-emergence applications of Murbetex A1 at 20 pt/ac (27.5 l/ha) and MC 14PA1 at 12½ lb/ac (13.75 kg/ha) in the U.K., and Murbetex A1 at 6-15 pt/ac (8-20 l/ha) in the Netherlands resulted in successful weed control in sugar beet trials on organic soils. Weeds which were well controlled include Stellaria media, Chenopodium album, Polygonum spp., Sinapis arvensis, Urtica urens, and Veronica spp. Dosage rates for successful use of both mixtures depends on the sum of organic matter and silt/clay present in the soil.

INTRODUCTION

Following previous work in 1965 (Emery et al), extensive trials were carried out in many countries in 1966 using slightly altered formulations. These trials covered a wide range of soil types and climatic conditions. Results confirmed previous findings that medinoterb acetate extended the spectrum of weed control of the standard endothal/propham mixture, particularly in the case of organic soils or drought conditions as previously observed. This paper deals with the particular case of organic soils covered by trials in the U.K. and the Netherlands. Although organic soils only comprise a small proportion of the total area of the sugar beet crop, they do pose the greatest problem in weed control by virtue of the heavy weed growth and the inability of many herbicides to work efficiently on organic soils. Absorption by the organic matter precludes the use of many of the herbicides used on mineral soils, while the value of contact pre-emergence herbicides is restricted to the control of weeds germination before the beet.

METHODS AND MATERIALS

Murbetex A1:	(referred to as Murbetol A1 overseas)		
	propham	15% w/v	
	endothal acid	7.5% w/v	formulated as an
	medinoterb acetate	3.3% w/v	aqueous suspension
MC 14PA1 :	propham	30% w/w	formulated as a
	medinoterb acetate	15% w/w	wettable powder

In the Netherlands Murbetex A1 only was used in 12 grower trials where the organic matter content was above 5%, but in all cases the % of soil particles below 16 μ was negligible. Dosage ranged from 6-15 pt/ac (8-20 l/ha), being proportional to the organic content of the soil. In the U.K. Murbetex A1 at 20 pt/ac (27.5 l/ha) was compared with MC 14PA1 at 12.5 lb/ac (13.75 kg/ha) in 28 grower trials of 1 acre per treatment of which 18 yielded full results, and 3 small plot trials (A) which were applied using a Van der Weij sprayer (modified to give finite rates). These rates were used on all soils where the organic matter content was greater than 10% and in all cases the content of soil particles less than 16 μ was at least 20%.

In most of the trials, application was made overall within 3 days after sowing. In some cases application was by band sprayer at time of sowing and in a few, where comparison was with a contact herbicide, the application was delayed until shortly before emergence of the crop.

Assessments were made shortly before singling. In the Netherlands treatments were visually graded and in the U.K. counts of 6 quadrats of 200 in^2 (1,292 cm^2) per treatment were taken, major weeds being assessed separately. 6 counts of 50 in (125 cm) per treatment were taken of beet stand. Vigour of both weeds and beet was visually assessed.

Site details including soil and rainfall data are given in Tables 1 and 2.

Table 1

Site No.	Site District	% Organic Matter	Dosage l/ha	Date Sprayed	Rainfall inches: Max. Daily in 1st wk.	Weeks after spraying 1st	2nd	3rd
B.5	Hoogeveen	16	16 & 20	6.5	0.1	0.1	0.1	0.7
B.6	Hoogeveen	18	18	9.5	0.1	0.1	0.1	0.7
B.7	Hoogeveen	12	12	3.5	0.1	0.1	0.1	0.7
B.8	Onstwedde	6	8	22.4	0.1	0.4	0	0
B.9	Musselkanaal	15	15 & 19	4.5	0.1	0.2	0	0
B.12	Assen	8	10	30.4	0	0	0	0
B.13	Assen	8	10	5.5	0	0	0.2	0.2
B.14	Assen	15	14 & 18	6.5	0	0	0	0.2
B.15	Fochtelo	11	12	12.5	0	0	0.1	0.1
B.1	Vathermonder	14	14	23.4	0.1	0.4	D	0
B.2	Emmercompascuum	8	10 & 15	22.4	0.1	0.4	0	0

Table 2 occurs on next page.

RESULTS

The effect of the experimental herbicides on the principal weeds of organic soils are shown in Table 3 and Table 4 for those cases where they occurred in significant numbers at the various trial sites. The heading Polygonum spp. includes P.persicaria, P. lapathifolium, P. convolvulus and in the Netherlands P.hydropiper.

In addition to the weeds shown in the tables, other important weeds occurred in large numbers at one or two sites only. Space does not permit their inclusion in the tables. These weeds were Lamium purpureum, Senecio vulgaris and Galeopsis tetrahit which were well controlled and Avena fatua of which control was variable. Other species sometimes accounted for a significant proportion and while these have not been listed separately, they are included in the total weed control figures in Table 4.

Table 2

U.K. Site Details

No.	Site Location	Soil Data: % <16µ	Soil Data: % Organic	Spraying date	Max. daily 1st wk.	Rainfall inches, Weeks after spraying: 1st	2nd	3rd
26*	Glazebury Lancs	20	49	28.5	0.2	0.4	0.1	0.6
64	Soutnery Norfolk	23	65	2.5	0.4	0.8	0.2	0.6
107	Swaff. Prior Cambs.	55	11	4.4	0.1	0.3	0.6	0.7
110	Sonam Cambs.	42	12	12.4	0.4	0.8	0.5	0
141	Metnwold Norfolk	20	19	28.4	0.2	0.2	0.8	0.4
10	Swaff. Prior Cambs.	60	10	30.3	0.2	0.3	0.2	1.0
106	Waterbeach Cambs.	20	11	14.4	0.4	1.5	0.5	0.1
108	Sommersnam Hunts.	22	49	16.5	0.3	0.5	0.1	0
A48	Horncastle Lincs.	22	40	16.5	0.4	0.5	0.2	0
144	Boston Lincs.	35	20	14.5	0.3	0.4	0.3	0
A17	Wereham Norfolk	33	33	6.4	0.3	0.7	1.2	0.5
7	Brigg Lincs.	20	14	15.4	0.3	1.0	0.3	0.3
11	Littleport Cambs.	30	17	29.4	0.2	0.2	0.5	0.3
33	Morton Lincs.	25	10	28.4	0.2	0.2	0.8	0.2
65	Hilgay Norfolk	48	13	7.4	0.2	0.3	0.9	0.4
81	Doncaster Yorks.	27	44	28.4	0.2	0.2	0.8	0.5
92	Ramsey Hunts.	47	21	27.4	0.1	0.1	0.3	0.8
99	Haddennam Cambs.	55	16	26.4	0	0	0.6	0.1
155	Manea Cambs.	40	33	27.4	0.1	0.1	0.3	0.8
166	Sonam Cambs.	22	31	24.4	0	0	0.5	0.2
A40	Manea Cambs.	45	34	27.4	0.1	0.1	0.3	0.8

* red beet site

Table 3

Efficiency of weed control by Murbetol A1 on organic sand soils

Site No.	Dosage l/ha	Polygonum spp.	Stellaria media	Chenopodium	Poa annua
B.5	16	+ +	+ +		+ +
	20	+ + +	+ + +		+ + +
B.6	18	+ +	+ +	+ +	+ +
B.7	12	+ +	+ +	+	+ +
B.8	8	+ +	+ +	+ +	
B.9	15	+ +		+ +	+
	19	+ + +		+ + +	+ + +
B.12	10		+	-	
B.13	10	+ +	+ +	+ +	+ +
B.14	14	+ +	+ +	+ +	+ +
	18	+ + +	+ + +	+ + +	+ + +
B.15	12	-	-	- Veronica spp.	-
B.1	14	+ + +	+ +	+ +	+ +
B.2	10	+ + +	+ +		+ +

+ + + = very good. + + = good. + = borderline

\- = less than 50% Dominant weeds underlined.

In some trials the level of control of certain species was well below expectation, with some inexplicable anomalies but, as can be seen from the tables, the principal weeds were, in most cases, adequately controlled. P. convolvulus proved somewhat more resistant than the other Polygonum species.

The control of C. album was in some cases almost nil or less than adequate. This was predominantly the case with low dosage rates on the sand soils or on the heavier organic silts where the dosage rate used was undoubtedly too low. In a few cases lack of control of C. album was associated with periods of very heavy rain during the first week or two after treatment. However, despite the poor results obtained in some trials, the experimental mixtures proved more successful than the comparative herbicides in 32 cases, equal in 10 and inferior in only 5. Details are given in Table 5.

Some anomalous results in both directions are undoubtedly due to uneven distribution of weeds, notably sites 92, 99, 108, 110 and 144. In most cases the vigour of the remaining weeds was very markedly reduced.

In no trials were the beet seedling stand or vigour reduced.

Table 4

Weed control by Murbetex A1 (A1) and MC 14PA1 (14P)
Showing number of seedlings in untreated and % control in treated plots

Site No.	Polygonum spp.			Stellaria media			Chenopodium album			Urtica urens			Capsella b.pastoris			Sinapsis arvensis			Total weed control	
	Unt	A1	14P	Unt	A1	14P	Unt	A1	14P	Unt	A1	14P	Unt	A1	14P	Unt	A1	14P	A1	14P
26	152	80	84	33	70	46				15	87	60							75	70
64	116	97	96	22	82	0				201	95	68							90	75
107	88	81	72	37	97	97	96	68	88	231	97	78	20	95	100	171	80	74	85	90
110	179	50	82	14	93	93	14	65	29	196	89	0	42	93	100				70	45
141							166	42	45	141	92	88							70	50
										Veronica spp			Poa annua							
10	39	18	28	35	97	57				59	66	31	32	47	69	219	35	82	45	60
106	78	64	62	58	43	9							23	70	22	161	90	80	75	55
108	136	54	38	134	68	73	108	0	39	..			91	69	0				50	45
A48	136	68	81	134	86	68	91	65	61				18	78	83				80	80
144				46	0	5	135	42	49	69	0	23							20	25
													Solanum nigrum							
A17	31	77	58				53	40	47	10	90	60	12	100	100				70	70
7	68	22	60	14	79	79	19	6	37										25	60
11				19	79	100							78	72	50				75	60
33	314	93	97				106	100	95										95	95
65	16	44	50	74	88	76													80	65
81	74	100	83	217	98	83	30	73	46										95	75
92	36	33	11				24	38	54										50	45
99	51	13	10				14	0	0										10	30
155	575	81	86				127	99	94										85	90
166	112	63	73	150	45	93	13	77	100										55	85
A40	436	50	69				212	0	67										30	85
										U.urens			P.annua							
Mean		60	63		72	63		48	57		92	59		66	44		68	79	63	65
										Veronica spp.			Capsella							
											52	38		94	100					
													Solanum							
														86	75					

Table 5

Comparison herbicides

	Performance	propham/ chlorpropham/ fenuron	propham/ diuron	BiPC/ cycluron/ dimexan	paraquat/ diquat	lenacil	pyrazon	pyrazon/ propham	endothal/ propham
Murbetol A1	>	3	0	2	3	10	3	5	2
	=	0	1	0	0	1	0	2	4
	<	0	1	0	0	0	0	1	2
MC 14PA	>	3	0	1	3	-	-	-	-
	=	0	1	1	0	-	-	-	-
	<	0	1	0	0	-	-	-	-

DISCUSSION

The U.K. soils varied considerably in their composition - ranging from 20-60% particles $<16\mu$ and from 10-65% in organic matter. The sum of the two ranged from 34-88%, while the dosage rate used was constant. It is clear from the results that many of the sites were under-dosed. A scatter diagram of good and bad results plotted against organic matter and silt content indicates a high proportion of failures where the sum of these values exceeds 65%. It is considered that above this value an increase of 20% in the dosage rate should be used. Evidence from small plot trials and accidentally overdosed grower trials shows that there is a large safety margin at this level.

In the Netherlands trials where the rate was based on organic matter content, it was evident that the dosage rate at the lower levels was too low, in particular with respect to the control of C. album.

Many of the poor results can be attributed to abnormal adverse weather conditions. For example, in cases of drought the propham failed to control P. annua or S. media, whereas with excessive rain during the first week the activity of the medinoterb acetate against C. album was reduced. The one weed against which the binary mixture was less active was U. urens.

With a herbicide applied to the soil two factors can influence the effect - the nature of the soil and rainfall after application. It is simple enough to adjust dosage rate to suit the soil but not to suit an unpredictable rainfall. With mixtures of the type described in this paper, heavy rain can influence the action of the compnents in opposite directions. Some rain is necessary to wash endothal or propham into the soil for them to work and only grossly excessive rain will have an adverse effect. Medinoterb acetate, however, acts at the soil surface and excessive rain will reduce or eliminate its action. There is some overlap of activity between the three components, but, in general, lack of rain can be expected to reduce control of grasses, S. media, Lamium spp., and Veronica spp., while excessive rain can be expected to reduce control of C. album and S. arvensis. These differential effects are largely reflected in the trials described.

In comparison with the other herbicides used in the trials the subject herbicides invariably proved more effective than lenacil or pyrazon, as was to be expected on organic soils, or pre-emergence contact herbicides. The tripartite mixture was somewhat better than a pyrazon/propham mixture and equal to the standard endothal/propham mixture used at almost double the rate. The experimental mixtures were equal in one and marginally inferior in one trial to the propham/diuron mixture.

For the future it is proposed to increase the medinoterb acetate in Murbetol A1 to 4.2%, intermediate to the concentration used in 1965 and 1966 and also to increase the rate of use at the lower end on the organic sands, while for the organic silt soils the rate will be assessed on a sum basis. It is considered that these alterations will eliminate the poor results other than those beyond control.

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THE INFLUENCE OF MOISTURE ON THE ACTION OF PYRAZON

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SUMMARY

Evaluation of German field trials showed that weed control with pyrazon was better where rainfall was greater than 10 mm compared to less than 10 mm (shortly after treatment). On the other hand, continuous rainfall in Spring 1965 had caused beet injury in few cases on light soils. The dosage rate for sandy soils was, therefore, reduced to 2,5 kg/ha.

In California high amounts of irrigation appear to have at least partly contributed to the beet damage this Spring. The conclusion of this experience is that the first irrigation should be limited to about 12,5 - 25 mm (ca. ½ - 1 inch) per set. When up to a maximum of 25 mm is supplied good weed control with pyrazon is still obtainable.

INTRODUCTION

Some factors which can influence the selectivity of pyrazon in sugar beet has already been discussed on occasion of the 7th British Weed Control Conference (Beinhauer et al., 1964). In particular these factors were: type of soil, fertilizing, seed dressing with insecticides, seeding depth, technique of application as well as incorporation of pyrazon. As a result it was shown, that pyrazon alone normally does not cause any injury to beet. However if other factors which are detrimental to the growth of beet, coincide with the pyrazon treatment, crop injury or stand reduction might result.

Recent experience in Germany and California lead the authors to think it worthwhile devoting additional study to the important factor of soil water relations. In this connection the influence on selectivity as well as on herbicidal effect of the product should be discussed. We shall try to find an answer to the question of the amount of water necessary for optimal effect of pyrazon.

METHODS AND MATERIAL

This evaluation is based on German field trials as well as on practical applications in California. The material used was technical 1-Phenyl-4amino-5-chloropyridazon-6, formulated as an 80% wettable powder, known as Pyramin, hereinafter referred to as pyrazon.
The rates of application in Germany were 3,2 kg/ha pyrazon whereas in California dosage rates of 3 - 5 kg/ha had been used.
Assessment of beet injury and weed control in the German trials was made according to the following scale:

Scale =	% injury	% weed control
1	0	100
2	2,5	97,5
3	5	95
4	10	90
5	15	85
6	25	75
7	35	65
8	67,5	32,5
9	100	0

Performance in the U.S. treatments runs from 0 - 10;

Crop: 0 = no injury or stand reduction
10 = complete kill of beet

Weed control: 0 = no effect
10 = complete control

The amount of rainfall and irrigation is given in mm (25 mm = 1 inch).

RESULTS

At first the results of the trials carried out in Germany from 1963 - 66 will be discussed.

Table 1

The influence of different amounts of rain on selectivity and weed control of pyrazon

	Total rain in mm		
	less than 10	10 - 20	more than 20
Crop injury 1 - 9	1,2	1, 1	1,2
Weed control 1 - 9	4,6	3, 1	3,0
Number of trials	192	57	37

The selectivity of the average of all trials was not impaired whilst the weed control by means of increasing rainfall was, no doubt, improved. Although rainfall in some trials was above 20 mm there were only few cases of injury on lighter soils. This was the case in the wet Spring of 1965 where 3,2 kg/ha of pyrazon on sandy soils caused inhibition of the beet stand. For this reason the dosage rate on sandy soils was decreased to 2,4 kg/ha pyrazon.

The question of optimal or maximal moisture is much more important in arid regions where moisture is supplied to soil mainly by sprinkler and/or furrow irrigation. For the clarification of this problem we refer to practical field applications in California in Spring 1966, which partly led to beet injury or stand reduction. All these cases have been compiled by Fertig (1966). Table 2 shows a survey on injury rating dependent on the method of irrigation or watering.

Table 2

Selectivity of pyrazon due to the method of irrigation or watering

Method of irrigation or watering	Total number of fields	Number of fields within the injury category										
		0	1	2	3	4	5	6	7	8	9	10
Sprinkler	29	....	.... .	..	.		.		...	..		...
Furrow	14	....		..	.	.						.
Rain	6	.....							.			

These figures show that comparatively more beet plots had been damaged by sprinkler irrigation than by furrow irrigation or rainfall. The ratio between the fields without and with injury is as follows:

sprinkler irrigation	12 : 17
furrow irrigation	9 : 5
rain	5 : 1

The reason for the injury by Sprinkler Irrigation is that large volumes of water are put down each time the crop is irrigated, resulting in leaching of pyrazon into the root-zone of the beet.

Table 3 illustrates this particular problem from American practical field applications of pyrazon; the degree of injury is correlated with differing quantities of water supplied.

Table 3

Rain plus sprinkler irrigation and their influence on beet injury

Total rain and sprinkler irrigation mm	Total number of fields	Number of fields in the injury category 0	1	2	3	4	5	6	7	8	9	10
12,5	2	2										
19	2	2										
25	5	5										
31	3	1					1		1			
38	7	5							1	1		
50	6	3	1				1		1			
63	2	2										
75	4	2						1			1	
88	1								1			
100	2	1								1		
112,5	6	1		2	1							

This table shows that there was severe damage and thinning in those cases only in which the quantity of rain or irrigation exceeded 30 mm. However, it should be stressed that water is not considered the sole factor concerned, since damage was restricted to the lighter soils. On heavier soils damage was hardly observable. Moreover, the date for beet planting which normally is in November/December had to be postponed to January/February due to adverse weather conditions.
The weed control, however, shows no dependence on the different amounts of irrigation or watering. Lower rates of irrigation (i.e.) 12,5 - 25 mm) activated pyrazon to the same degree as higher rates (25 mm).

Table 4

Rain plus sprinkler irrigation and there influence on weed control of pyrazon

Table 4

Rain plus sprinkler irrigation and the influence on weed control of pyrazon

Total rain and sprinkler irrigation mm	Total number of fields	Number of fields within weed control category										
		0	1	2	3	4	5	6	7	8	9	10
12,5	4								1		2	1
25	4	1						1		1		1
31	2								1		1	
38	11									2	5	4
50	5							1		3	1	
75	2									1	1	

DISCUSSION

Sufficient soil moisture is indispensable for good weed control with pyrazon. In the moderate climatic zone of Central Europe normal rainfall amounting to 20 - 30 mm within the first 2 - 3 weeks after treatment in general ensures control. As to the selectivity of pyrazon there is normally no risk on medium heavy soils of injury, unless further factors influence the development of the beet in a disadvantageous manner.

On sandy soils, however, injuries and thinning may occur after continuous rainfall. By limiting the dosage rate to 2,5 kg/ha this risk can be diminished.

In arid areas, where irrigation for the cultivation of beets is necessary the amount of water brought to the soil is to be regulated. On light soils the application of pyrazon is really risky, if too much water is being applied as happened in California this Spring. In California normal irrigation amounts to 38 mm (ca.1,5 inch), in many cases to 50 - 100 mm (ca. 2 - 4 inches) For safety's sake the quantity of water should not exceed 25 - 30 mm (ca. 1 - 1,25 inch) per set. As was proved by the investigations those quantities are entirely satisfactory for a good weed control.

Reference

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PRE-EMERGENT HERBICIDE WEED CONTROL IN SUGAR BEET

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Summary Field experiments were carried out with pre-emergent herbicides in sugar beet in 1965 and 1966.

In 1965 the effect of pyrazon on weed control and yield was studied in relation to dose rate, soil incorporation and soil moisture. In 1966 weed control comparison was made using four treatments, pyrazon, lenacil, dinexan + BiPC + OMU, fenuron + chlorpropham + propham, each applied at two dose rates.

Pyrazon appeared to give 90-95% control of annual weeds in 1965 without adverse effect on sugar beet. Lenacil was the most effective herbicide in 1966, but it appeared to reduce the population of sugar beet significantly.

INTRODUCTION

A number of herbicides have recently been appraised in sugar beet. Pyrazon introduced by Fischer (1962) was the subject of several reports at the 7th British Weed Control Conference (1964). Experiments with a uracil were described by Cussans (1964) and Erskine (1965) gave a summary of farm experiences with herbicides in sugar beet.

METHOD AND MATERIALS

The experiments were carried out at Harper Adams College. Applications of herbicides were made overall with a knapsack sprayer fitted with a pressure control valve, at volume rates of 20-40 gals./ac. The soils were light to medium sandy loam with pH levels between 6 and 7 and composition by weight of about 70% coarse and fine sand and $2\frac{1}{2}$-$3\frac{1}{2}$% organic matter.

Plot size was 5 rows by 5 yds., and assessments were made in the middle three rows only. Assessments of the number of weeds and sugar beet plants per unit area were made when the crop was at about the 4-leaf stage (15/5/65 and 23/5/66) and again (14/6/65 and 6/7/66) 4-6 weeks later. Counts were made using a one ft^2 quadrat at ten random positions in each plot.

In experiment 1 (1965) water was applied by spraylines fitted with deflector nozzles. Soil incorporation was achieved by light raking to a depth of $\frac{1}{2}$-1 in. The sugar beet was harvested in September and samples were taken for sugar determination.

RESULTS

Experiment 1,1965 Sown 22/4

The experiment was a 2^3 factorial with 4 replicates and the following treatments -

Pyrazon (P) Dose rates P_1 = 2.2 P_2 = 3.2 lb. a.i./ac.
Soil incorporation (C) C_0 = not incorporated C_1 = incorporated
Soil moisture (I) I_0 = no applied water I_1 = applied water after spraying

The results are summarised in Table 1

Table 1

No. of weeds and beet plants at emergence, and yield of washed beet

Treatment	Mean no. per ft^2 weeds	Mean no. per ft^2 sugar beet	Mean yield $lb/12\ yd^2$
$P_1C_0I_0$	5.12	12.1	114.0
$P_1C_1I_0$	7.25	10.9	111.8
$P_1C_0I_1$	5.75	11.0	106.8
$P_1C_1I_1$	6.50	11.3	110.8
$P_2C_0I_0$	2.00	9.6	111.0
$P_2C_1I_0$	4.62	10.5	108.3
$P_2C_0I_1$	2.12	11.0	110.5
$P_2C_1I_1$	3.62	9.9	105.3
Mean	4.6	10.8	109.8
S.E.	± 0.98	± 2.19	± 3.28

Weed counts in adjacent unsprayed control areas gave a mean of 48.8 weeds/ft^2 By comparison $P_1C_0I_0$ controlled 89.7% and $P_2C_0I_0$ 95.9% of the weeds.

The main weed species present on this site were Chenopodium album L., Polygonum Convolvulus L., Polygonum aviculare L., Poa spp.L., Urtica urens L., Galium aparine L., and Stellaria media Vill.

The results show that the higher level of herbicide (P_2) gave significantly superior weed control than the lower level (P_1) Soil incorporation reduced the effectiveness of the herbicide under these conditions and gave significantly poorer weed control at 5% level.

Application of water by irrigation after spraying had no significant effect on herbicide activity. Rainfall during the week of drilling was 0.21 in. and in the two weeks following was 0.34 and 1.04 in. respectively and soil moisture appeared to have been favourable for the herbicide.

There were no significant effects from treatments on number of sugar beet plants at emergence. However mean number of plants was slightly but not significantly lower for P_2 and growth of some plants appeared to be checked at the higher level of pyrazon. Only one or two weeds per plot were present after singling.

Experiment 2. 1966 Sown 28/4

This experiment was a 8 x 3 randomised block design with the four herbicide treatments each applied at two dose rates.

Data on the number of weeds present at the time of sugar beet emergence was analysed by multiple range test (Duncan 1955). The results are summarised in Table 2.

The significant differences are indicated. Thus treatment 1 was significantly different from 7 and 8. Treatment 2 was significantly different from 7 and 8.

Table 2 shows that the lower dose rates of dimexan + BiPC + OMU and fenuron + propham + chlorpropham gave significantly inferior weed control to all other treatments.

The main weeds present were Chenopodium album L., Veronica persica Poir and Viola spp. Others present were Polygonum aviculare L., P.convolvulus L., Poa spp L., Urtica urens L., Galium aparine L., Stellaria media Vill., Euphorbia helioxopia L., Senecio vulgaris L., Matricaria inodora L., and Fumaria officinalis L.,

Adjacent unsprayed areas indicated that the number of weeds present was 61.1/ft^2, and this suggested that treatment 1 had controlled 95% and treatment 8, 70% of the weeds.

Table 2
Mean no. Weeds/ft^2

Treatment	Dose rate/ac.	Weeds	No.of means	SSR[1]	LSR[2]	Significant Differences
1. Lenacil	1.6 lb a.i.	3.4	8	3.43	10.83	
2. Pyrazon	2.8 lb a.i.	4.2	7	3.40	10.73	
3. Lenacil	1.2 lb a.i.	4.6	6	3.37	10.64	
4. Dimexan + BiPC + OMU	10 pt. product	7.0	5	3.33	10.51	
5. Fenuron + propham + chlorpropham	10 pt. product	7.7	4	3.27	10.32	
6. Pyrazon	1.6 lb a.i.	10.3	3	3.18	10.04	
7. Fenuron + propham + chlorpropham	5 pt. product	15.3	2	3.03	9.56	
8. Dimexan + BiPC + OMU	5 pt. product	18.7				

1 Significant Studentised Range   2 Least Significant Range

The number of sugar beet plants per unit area were assessed at emergence and the number of weeds per unit area assessed after singling. The results are summarised in Table 3.

Table 3
Mean no. of weeds and beet plants/ft^2

Treatment	Sugar Beet	Weeds (log x X 10)
1	2.4	0.318
2	3.5	0.619
3	2.1	0.759
4	3.3	1.332
5	3.5	1.399
6	3.2	1.063
7	3.2	1.457
8	3.2	1.835
Mean	3.06	1.098
S.E.	± 0.32	± 0.191

The results suggest that lenacil significantly reduced the plant population of sugar beet, but the fact that the lower dose rate (treatment 3) depressed plant population more than the higher dose rate (treatment 1) may indicate that other factors were involved.

Lenacil and pyrazon at the higher dose rates gave significantly superior weed control to their lower dose rates. The results show that compared to lenacil and pyrazon, dimexan + BiPC + OMU, and fenuron + propham + chlorpropham were less persistent.

DISCUSSION

In 1965 pyrazon applied at 3.2 lb per ac. and not soil incorporated gave significantly superior weed control to all treatment combinations at the lower level of 2.2 lb/ac. and compared to adjacent unsprayed areas pyrazon treatments appeared to control 90-95% of annual weeds without adverse effect on the sugar beet population. Differences in weed control between treatments did not result in differences in yield or sugar percentages of washed beet. Irrigation had no effect on weed control by pyrazon in 1965, presumably because of the relatively moist soil conditions. No advantage in weed control was gained by soil incorporation of pyrazon under these conditions.

In 1966 soil moisture conditions favoured the activity of residual herbicides. Lenacil appeared to be the most effective herbicide, and pyrazon the second most effective. Weed control measured at emergence of beet apparently ranged from 70% by the lower dose rate of dimexan + BiPC + OMU to 95% by the higher dose rate of lenacil.

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PRELIMINARY STUDIES WITH HERBICIDES IN SUGAR BEET

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Summary In 1965 pyrazon gave 74–86% control of annual weeds without adverse effect on sugar beet. In 1966, control by three residual herbicides ranged from 85–93%. Lenacil gave significantly better weed control than 'herbon gold' and pyrazon, but the latter showed the greatest safety margin to the crop.

It is suggested that precision drilling of multigerm seed at 3 in. spacing plus overall application of a residual herbicide, compared with 1½–2 in. spacing plus mechanical cleaning, may result in a saving of 50% in time, without reducing the cost of spring work. With monogerm seed plus residual herbicides costs may be reduced by 25%.

INTRODUCTION

Results of experimental and commercial use of pyrazon and lenacil under a range of soil and climatic conditions were reported at the Seventh British Weed Control Conference (1964), and factors influencing the selectivity of herbicides in sugar beet were discussed.

After field observation trials with pyrazon in 1965, it was decided to examine the commercial possibilities of minimizing spring work and cost of production in sugar beet through the use of herbicides on typical sandy loam soils in the West Midlands.

METHODS AND MATERIALS

1965 Experiments Two observation areas, each of ½ ac. on separate sites A and B. Overall application of pyrazon at 2.4 lb. a.i. in 40 gal./ac. by boom sprayer 2–3 days after planting.

1966 Experiments (a) A 5 x 5 latin square. Plot size 5 rows x 4 yd. Overall application by knapsack sprayer fitted with pressure control valve. Volume rate 40 gal/ac. Details of the experiment are given in Table 1.

Table 1

Details of experiment (planted 28/4/66)

Treatment	Dose/ac.	Date applied
1. Pyrazon	2 lb a.i.	29/4
2. Lenacil	1.2 lb a.i.	29/4
3. 'Herbon Gold'	5 pints product	29/4
4. Diquat + paraquat	¼ + ¼ lb a.i.	5/5
5. Control (unsprayed)		

Weeds were assessed on 23rd May, 2nd and 29th June. Plots were singled on 8th and side-hoed on 14th June.

(b) Observation areas in adjacent crop. Multigerm sugar beet precision drilled at 3 in. spacing and sprayed overall with pyrazon at 2 lb a.i. in 40 gal./ac. by boom sprayer. Monogerm precision drilled at 3 in. and 6 in. spacing and sprayed overall with lenacil at 1.2 lb a.i. in 40 gal./ac.

Soil types In both years soils were light to medium sandy loams with pH levels between 6 and 7. A typical soil analysis (% by wt.) is :- organic matter 2–3, coarse sand 40, fine sand 30, silt 14, clay 14.

Rainfall In both years more than 1½ in. of rain was recorded within one month of spraying.

The main weeds present in order of frequency were :-

1965 Site A Chenopodium album, Polygonum aviculare L, P.convolvulus, Poa spp., Stellaria media,
Site B Urtica urens, Fumaria officinalis, P.aviculare, Poa spp., Galium aparine.
1966 Matricaria spp., Poa spp., P.aviculare., C.album, Veronica spp., Viola spp., P.convolvulus, Spergula arvensis, P.persicaria, Stellaria media, Sinapsis arvensis, Anagallis arvensis.

RESULTS

1965 The effect of treatments on weeds and sugar beet assessed on 12/5 by taking random quadrat samples in treated and adjacent untreated areas are summarized in Table 2.

Table 2

Mean no. of weeds and sugar beet plants/yd^2

	Sprayed		Unsprayed control	
	Weeds	Sugar beet	Weeds	Sugar beet
Site A	6.6	83.4	48.8	83.6
Site B	18.3	75	70	86.2

The results suggest that pyrazon gave 74-86% control of annual weeds without affecting beet establishments.

1966 Weed assessments were analysed using a natural logarithm scale to give greater precision. The results are summarized in Table 3. Actual number of weeds corresponding to the logarithm scale are given in brackets.

Table 3

Mean num er of weeds/yd^2 (log. scale)

Treatment	Date 23/5	2/6	29/6
1	1.4911 (31)	1.5184 (33)	0.9472 (9)
2	1.1505 (14)	1.1304 (13)	0.9063 (8)
3	1.2651 (18)	1.2025 (16)	1.2278 (17)
4	2.1063 (128)	2.3377 (217)	1.5971 (40)
5	2.2261 (168)	2.4010 (252)	1.6140 (41)
S.E.	0.07	0.10	0.04

The residual herbicides pyrazon, lenacil and 'herbon gold' gave significantly better weed control throughout than diquat + paraquat and unsprayed control treatments. Lenacil was significantly superior to pyrazon until 29/6 and to 'herbon gold' at the 1st and 3rd assessments.

The mean number of sugar beet plants/yd^2 per treatment assessed on 23/5 were (treatments in brackets) :- (1) 95, (2) 85, (3) 87, (4) 91, (5) 100. Differences were not significant but observations indicated that lenacil and 'herbon gold' checked beet initially. Final plant population in each year ranged from 25-30 thousand/acre.

DISCUSSION

Pyrazon apparently controlled 74-86% of annual weeds under favourable soil moisture conditions in 1965 without adversely affecting the crop. The difference in weed control between sites was due mainly to the presence of resistent Fumaria officinalis on site B. On both sites Galium aparine and P.aviculare showed resistance.

In 1966 conditions favoured soil acting but not contact herbicides. Until singling lenacil (93%) gave superior annual weed control to 'herbon gold' (90%) and pyrazon (85%). By contrast diquat + paraquat (20%) achieved only marginal control due to the bulk of the weeds emerging after the beet. Three weeks after singling and cleaning, lenacil and pyrazon appeared to be twice as efficient as 'herbon gold' and this superiority was confirmed by observations on 24/8. They were clearly more persistent than 'herbon gold'.

The main weeds showing resistance to the residual herbicides were :-

pyrazon Viola spp., P.aviculare., Veronica persica. Poir., Anagallis arvensis.

lenacil Veronica persica. Poir. Viola spp., P.aviculare.,

'herbon gold' Viola spp., P.aviculare., Chenopodium album., Matricaria spp., The two latter weeds may have escaped control by later germination.

Lenacil and 'herbon gold' appeared to check sugar beet more than pyrazon.

A similar degree of weed control was achieved in the commercial crop in 1966 with pyrazon and lenacil. With multigerm seed precision drilled at 3 in. spacing and sprayed overall hand singling proceeded twice as fast as with multigerm seed precision drilled at 1½-2 in. spacing and cleaned mechanically. At current hand singling costs of £12/ac., in theory, herbicides at £6/ac., may not reduce the cost of spring work, but can save valuable time at singling and reduce subsequent cleaning work. With monogerm seed, costs of spring work may be reduced by 25%.

Reference

7th BRIT. WEED CONTROL CONF. (1964) **Var.** Session VIII (a) Sugar Beet and Vegetables 2 635-678.

THE CONTROL OF WEEDS IN SUGAR BEET WITH A NEW GRANULAR HERBICIDE.

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Summary.

The band application of a granular preparation of thiuron and chlorpropham was evaluated under field conditions during 1966. Treatments were made by means of a Microband applicator mounted on the drilling unit. The dosage levels applied ranged from the equivalent of 0.2 lb. per acre chlorpropham plus 1.0 lb. per acre thiuron to five times that amount. No significant reduction in plant population, plant vigour or yield of roots was observed. Weed control at the low dosage rate was found to be satisfactory in all cases and included control of Chenopodium album, Stellaria media, Sinapis arvensis and Polygonum spp. Rainfall within the first four weeks after application was not found to be a critical factor regarding weed control or crop safety. Excessive rainfall did reduce the period of residual weed control.

Introduction.

The substituted thiourea, 3-methylphenyl-N.N'-dimethylthiourea, has demonstrated selective herbicidal properties which have been found to be especially useful when the chemical has been used in conjunction with chlorpropham. In particular the combination of five parts of the thiourea compound with one part of chlorpropham had been demonstrated to possess useful selective herbicidal properties. Sugar beet had been found tolerant of this mixture at dosage levels in excess of five pounds per acre applied prior to emergence. Experimental work since 1963 led to the formulation of this mixture as a 16% active granule to be applied in the form of a band immediately after drilling. This formulation was applied at two dosage levels at each of twelve sites located in Norfolk and Cambridgeshire using standard commercially available equipment. The results from the trials together with data from replicated experiments are the subject of this report.

Method and materials.

In each of the trials a Webb five row precision drill was used in the dual role of planter and vehicle for the granule applicators. Three Microband units were mounted on the drill so as to provide a granule delivery point immediately behind the second roller. "Fish tail" attachments to the granule delivery pipes gave each outlet a spread of seven inches when mounted within one inch of the soil surface. In practice the effective band width was found to be influenced by the depression in the soil made by the roller. The variation in the actual dosage level both across and along the length of the band has been investigated but these and other results will be reported elsewhere.

Measurements of the effective weed control zone in the various trials gave an average band width of six inches but all of the dosage figures quoted in this report are based on the theoretical application.

Each trial covered an area slightly in excess of three acres and contained two rates of application, namely 15 lb. and 23 lb. per acre of granules. These rates were equivalent to 2.7 and 4.14 lb. per acre of active chemicals applied overall. In all cases the beet rows were 20 inches apart but the drilling depth varied from ½ to 1½ inches. The seed used was rubbed and graded in all but two of the trials where pelleted seed was employed.

Details of the locations and applications are given in Table 1.

Table 1.

Trial No.	Location.	Drilling Date.	Inches rain 21 days post drilling.	Soil organic matter %
1	Woodbastwick	18th April	0.64	4.36
2	Abington	6th April	2.1	5.14
3	Oxborough	27th April	1.37	6.64
4	Titchwell	21st April	2.4	4.2
5	Walsingham	18th April	0.2	6.17
6	Abington	27th April	1.6	5.14
7	Whichingham	18th April	-	8.2
8	Roall	12th April	1.2	10.8
9	Wissington	8th April	-	47.53
10	Swaffam Fen	8th April	-	39.6

The first assessments were made within seven days of beet emergence and these involved counting beet and weed seedlings in a one yard band. Counts were made in each twenty-two yard length of beet row selected at random from each group of five rows.

At the 4-leaf stage a second assessment was made of weed numbers of the various species present. Yard runs of unsingled plants were sacrificed to provide data on the average weight of plants from areas receiving 2.7 lb. per acre active ingredients compared with untreated plants.

Results.

Application of the granular material was found to be a simple operation unaffected by variations in prevailing weather conditions. This was demonstrated on several occasions when rain changed a dry seed-bed into a moist clay during the preparation of a trial. In the trial located at Woodbastwick in Norfolk an eighteen day rain free period followed the drilling operation but no reduction in weed control occurred.

A similar trial at Titchwell received 0.75 inches of rain within four hours of the trial being completed. The assessments of weed control and crop vigour showed no significant variation in results at either of the two dosage levels.

The small variation in the soil organic matter content found in trials 1 to 8 (given in Table 1) did not appear to influence crop safety or weed control, but the high organic soils in trials 9 and 10 reduced herbicidal efficiency.

In all of the sites the mixture of thiuron and chlorpropham was well tolerated by sugar beet apart from the high dosage rate of 6 lb per acre which retarded growth in the early stages of development of beet plants in two of the trials.

The trial located at Walsingham contained an area of Agropyron repens, this weed was controlled by the 4.14 lb per acre application and reduced by 65% from the 2.7 lb per acre treatment.

Overall weed control was effective at all dosage levels with Chenopodium album and Stellaria media demonstrating high sensitivity. Matricaria matricarioides Sinapis arvensis, Polygonum spp were present in the majority of the trials and were well controlled at levels above 1.2 lb per acre

Table 2.

Effect on weeds (counts as % control)

Dose lbs/acre a.i.	Chenopodium album	Polygonum spp.	Stellaria media
2.7	0	7	0
4.14	0	11	0
Control	100	100	100
Trial 4.	66 plants sq.yd.	154 plants sq. yd.	34 plants sq. yd.

Table 3.

Effect on sugar beet.

Dose lbs/acre a.i.	Germination as % control	wt at 4-leaf stage as % control	wt. at harvest % control.
2.7	108	97	115
4.14	93	91	95
Control	100	100	100
Trial 4.	193 plants / chain.		

Table 4.

Trial results.

Trial No.	Dose lb/acre a.i.	% control dicot.weeds	% control Ch.album.	% Control St.media.
1	2.7	83	94	81
	4.14	89	90	86
2	1.2	81	84	77
	2.7	92	100	89
	4.14	89	100	82
	6.0	97	100	94
3	2.7	82	94	-
	4.14	98	89	-
4	2.7	88	93	87
	4.14	88	91	89
5	2.7	89	100	81
	4.14	90	98	83
6	2.7	78	85	86
	3.9	87	87	81
7	2.7	92	86	84
	4.14	83	85	76

Discussion.

The use of a granular preparation for weed control in sugar beet has been investigated under farm conditions on a variety of seed beds. There has been a consistent degree of selectivity and weed control. Under field conditions a dosage rate of 2.7 lb per acre of the active material is suggested as the optimum treatment, this is equal to 45 lb per acre of granules applied overall.

FIELD DEVELOPMENT OF LENACIL* IN THE U.K.

FOR WEED CONTROL IN SUGAR BEET

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Baywood Chemicals Limited

Summary This paper covers development work with lenacil as a residual herbicide in sugar beet from 1963 to 1966. A series of replicated trials over a range of soils were conducted to investigate dosage rate, crop tolerance and weed control. Yield trials showed no significant difference between treatments, although some check to beet emergence occurred on light soil. Weed spectrum trials undertaken with lenacil controlled a wide range of the more important weeds found in sugar beet. 68 farmer usage trials were carried out in 1965, applied mainly by band sprayer at rates ranging from 1.2 to 2.4 lb lenacil per ac, depending on soil type. Results showed good weed control with no adverse effect on the crop and confirmed that lenacil was a promising herbicide for sugar beet under the range of field conditions tested. In 1966 further trials were carried out to investigate the use of lenacil on sands but variable results occurred and further work is required.

INTRODUCTION

The discovery of the substituted uracils was announced in 1961 by E. I. Du Pont de Nemours & Co. (Inc.) (Varner 1961). One of this group was found from early screening trials to show premise as a pre-emergence herbicide for sugar beet. This material was coded Du Pont 634 and is now known as lenacil, having the full chemical name of 6, cyclohexyl-2,3,4,5,6,7,-hexahydro-5,7-dioxo-4,6-diazaindene, also known as 3 cyclohexyl-5,6-trimethylene uracil.

The material was formulated as an 80% wettable powder, the active ingredient having a solubility in water of 6 ppm at 25°C. Lenacil has a low mammalian toxicity. Further physical and chemical properties are given in the product Data Sheet, Anon (1965). This herbicide is primarily absorbed by the roots of weeds and although the mode of action has not been fully elucidated, work by Hoffman '_et al_' (1964) and Hilton '_et al_' (1964), reported inhibitions of the Hill reaction which would suggest that the main effect is interference with photosynthesis.

Trials results supplied by Du Pont Co. (U.K.) Ltd. suggested that lenacil was a promising herbicide for pre-emergence use in sugar beet. The first work published in the U.K. (Cussans (1964) confirmed the above results and also suggested that soil incorporation would enhance activity under certain conditions. Similar experiments were also conducted in several European countries from 1962 onwards and results have been published by Gautier (1965); Hill '_et al_' (1965); Schoell (1965) and Anon (1964).

Trials were initiated by Baywood Chemicals Ltd. in 1963 and this paper covers the development of lenacil from this stage to limited commercial sale in 1966.

In addition to work on sugar beet, field trials have been carried out by the authors on red beet and mangolds. Work has also been conducted in the U.K. with lenacil on soft fruit, bulb and ornamental crops.

* Lenacil is the approved common name by the Weed Society of America for 6, cyclohexyl-2,3,4,5,6,7,-hexahydro-5,7-dioxo-2,4-diazaindene

The trials reported in this paper were designed to provide data for the Agricultural Chemicals Approval Scheme and to gain sufficient information for commercial usage. These trials are divided into four main sections:

I) Yield trials 1963-65; II) Weed spectrum trials 1965
III) Farmer Usage trials 1965; IV) Supplementary information 1966.

METHOD AND MATERIALS

The product used throughout the trials was a free flowing w.p. containing 80% lenacil. All rates are expressed in terms of active ingredient. The formulation mixed readily with water and with adequate agitation no detectable residues were found in spray tanks, and during use in agricultural band sprayers no nozzle blockage occurred. The same formulation was introduced commercially in 1966.

Sites were distributed throughout the main sugar beet growing areas of England with particular care to cover the more important soil types.

Small plot trials were replicated with individual plots of 1/100 ac, overall application being made by pressurised sprayer, using 40 to 50 gal/ac. Incorporation was carried out by field harrows pre-drilling, and by rake for post-drilling treatments.

Farmer usage trials of approximately 1 ac covered a range of drilling dates, seed spacings, varieties and weather conditions. Normal band spraying equipment was used in all but 3 sites which were sprayed overall. In most cases these trials were supervised by Baywood personnel.

Assessments

(i) Pre-singling counts: Braird and weed counts were conducted at each site by taking at random either 12 quadrats (18x4 in.) for small replicated plots or 20 quadrats (25x4 in.) for the farmer usage trials. The number of each weed species was recorded for all plots. Beet and weed vigour scores were carried out at the same time as the weed counts, using a visual assessment score.

(ii) Post singling counts: Mid-season population counts were made by taking at random ten ½-chain lengths of row per plot or treatment.

(iii) Soil analysis: Representative samples from the top 2 in. of soil were taken from each site. Initially soil was assessed according to visual appearance and texture to act as a guide to an appropriate dosage rate. Subsequently a mechanical analysis was carried out in our own laboratory. The soil was then classified on the basis of sand, silt and clay content, Pizer '*et al*' (1957). Organic matter was determined on the sample using a dichromate method.

(iv) Rainfall data: Rainfall figures were obtained for the first 28 days after spraying, from the nearest local recording centre.

(v) Yield: The centre rows of each plot were lifted, topped and weighed. A sample was then taken for dirt-tare and sugar determination.

RESULTS AND DISCUSSION

I. Yield trials - 1963-65

Twelve replicated trials were carried out to investigate the relationship between dosage rate and crop tolerance.

Beet emergence counts revealed that the optimum damage rate for beet tolerance was related to soil type and varied from 1.2 lb on light sandy soils up to 4.8 lb on a heavy loam. At rates above 1.2 lb in the first site (coarse sand) some check and reduction in beet numbers occurred and this could have been due to high rainfall after drilling and the high porosity of the soil. At high dosage rates on some trials a slight veinal chlorosis was noticed but this had disappeared by singling time.

Lenacil applied at drilling time gave good control of Stellaria media, Polygonum aviculare, Tripleurospermum maritimum, Polygonum convolvulus, Senecio vulgaris, Spergula arvensis and Chenopodium album. Good control of annual grass was also obtained. Variable to poor control of Veronica spp., Urtica urens, Lamium amplexicaule.

Seven of these trials were carried through to harvest (Table 1). Yield differences were not statistically significant at 5% level.

Table 1

Summary of Yield Results (1963-65)

(a = yield of beet tons/ac: b = sugar cwt/ac)

Soil type		Rate of lenacil lb/ac						Control	A/V
		1.2	1.6	2.4	3.2	3.6	4.8		
Coarse sand	a)	13.0	12.8	12.4	14.1	-	-	16.0	N/S
	b)	43.8	42.2	41.8	42.0	-	-	54.0	
Loamy coarse sand	a)	22.1	18.0	19.8	-	-	-	21.7	N/S
	b)	76.2	62.4	69.2	-	-	-	74.2	
Very fine sandy loam	a)	-	21.0	20.9	-	18.5	-	21.5	N/S
	b)	-	66.8	64.0	-	60.0	-	68.4	
Loam	a)	22.9	21.5	17.3	-	-	-	18.5	N/S
	b)	71.4	74.0	68.8	-	-	-	67.2	
Loam	a)	-	-	20.9	20.0	-	20.0	21.1	N/S
	b)	-	-	71.4	68.4	-	71.0	73.2	
Silty clay loam	a)	-	-	17.0	15.3	-	16.8	15.7	N/S
	b)	-	-	56.0	50.8	-	55.6	52.3	
Clay loam	a)	-	-	-	-	-	16.9	12.8	N/S
	b)	-	-	-	-	-	54.6	40.9	

In these trials pre-drilling incorporated treatments at half rates were also compared with surface applied treatments at half rates. These treatments gave relatively poor weed control by comparison (except in one late-drilled trial). This may have been due to the high rainfall encountered or the method of incorporation. In one late drilled trial, however, good results were obtained. There were no yield reductions found from these incorporation treatments.

II. Weed Spectrum Trials 1965

These trials were carried out to gain information on the effect of varying rates of lenacil on a range of weed species. The dosage rates were related to soil type and an incorporation treatment at a decreased rate was included where possible (Table 2). In Trial 7 the appropriate rates were doubled to give additional data on crop tolerance. Rainfall for 28 days after treatment ranged from 1.39 to 2.69 in.

The results on sands (mean of 4 trials) show a slight reduction in beet emergence which increased with dosage rate. However, mid-season counts indicated no increase in final plant population. In Trial 7, where double rates were used, all treatments showed a reduction in stand up to 30% and this was still reflected in the mid-season counts. This emphasised that overdosing could cause a reduction in beet stand. Beet seedling vigour was not affected except at the higher rates and even these effects were of a temporary nature.

Table 2

Weed Spectrum Trials - 1966

Soil type	Treatment lenacil lb/ac	No. of emerged beet as % control	July count as % of control	% weed control
Coarse sand	0.6 lb incorp.	102.7	103.0	60.5
and	0.8 lb)	95.5	106.5	80.5
Loamy coarse	1.2 lb)surface	90.8	105.0	85.6
sand	1.6 lb)	82.0	102.8	91.2
(Trials 1-4)				
Very fine	0.8 lb incorp.	93.0	101.0	67.2
sandy loam	1.2 lb)	87.0	104.0	89.7
(Trial 5)	1.6 lb)surface	105.0	105.0	89.7
	2.4 lb)	84.0	107.0	87.9
Sandy clay	1.2 lb)	122.0	105.0	40.0
loam	2.4 lb)surface	112.0	102.0	84.0
(Trial 6)	3.2 lb)	106.0	92.0	84.0
Fine sandy	1.2 lb incorp.	85.0	89.0	92.0
loam	1.6 lb)	90.0	97.0	92.0
(Trial 7)	2.4 lb)surface	80.0	88.0	100.0
	3.2 lb)	70.0	99.0	100.0

Lenacil showed a high level of weed control over a range of species and the results indicated appropriate rates for commercial applications on various soil types.

The main species controlled were Chenopodium album, Stellaria media, Poa annua, Polygonum aviculare, Polygonum convolvulus, Tripleurospermum maritimum, Spergula arvensis and Anchusa arvensis. Weed species which showed resistance were Urtica urens, Viola arvensis, Veronica persica and Veronica hederifolia.

III. Farmer Usage Trials - 1965

Lenacil was used in 68 farm strip trials in 1965. In most cases it was compared with an existing sugar beet herbicide and frequently with an untreated area. Three rates of lenacil were selected for use in these trials in accordance with soil type, as follows:

1.2 lb/ac for light soils
1.6 lb/ac mostly for Lincolnshire 'silts'
2.4 lb/ac for loams

Organic soils and clays were avoided owing to their high absorptive properties.

The soil types covered by the 68 trials are given in Table 3. The range of total sand (coarse and fine sand - 2.0 to 0.02 mm) is given for each texture class since space does not permit the full analysis to be given. The sites were predominantly on the light range of soils which correspond fairly well to the general pattern of sugar beet growing in the U.K. The majority of soils had less than 3% organic matter and this meant that most of the sites did not suffer from the possible 'locking up' of chemical by this soil constituent.

Range of O.M.	Less than 1%	1-2%	2-3%	3-4%	Over 4%
No. of sites:	2	27	28	7	4

Table 3

Summary of Soil Types

Texture class	No. of sites	Range of total % sand
Sand	11	80-89
Loamy sand	28	70-84
Sandy loam	12	58-80
Very fine sandy loam	6	64-70
Loam	4	52-69
Sandy clay loam	7	38-67

It is known that adequate precipitation is necessary following the surface application of residual herbicides in order to obtain optimum herbicidal action. Mean rainfall for the 4-week period after early drilling was 2.12 in. compared to 1.93 for the later ones. Comparison of 1965 rainfall with a 29 year average for the Norwich area showed an increase of 76% for March, 78% for April and 9% for May. Many areas had a similar wet spring and whilst the high rainfall possibly enhanced weed control, these conditions were particularly useful for testing crop tolerance. Two late drillings had insufficient rainfall for effective weed control since there was an interval of 8 days between treatment and first rainfall. This allowed weeds to emerge before herbicidal uptake.

Applications ranged from 23rd March to 9th May. Adverse weather conditions delayed early March drillings and the main proportion were in April with some continuing into May. Poor seed bed conditions due to difficulty of preparation were inclined to affect later drillings.

Weed Control

Results obtained throughout these trials were satisfactory. (Table 4). Survivors included certain resistant species and also affected weeds which showed reduced vigour and were likely to succumb.

TABLE 4

Summary of Weed Control with lenacil

Method of application	Rate of lenacil lb/a.i.	No.of sites	Average % weed control	Range of weed control %
Band sprayed	1.2	32	86.2	51-97
Band sprayed	1.6	6	81.0	67-88
Band sprayed	2.4	12	82.4	69-98
Overall sprayed	1.2	1	90.0	90.0
Overall sprayed	2.0	2	95.5	93-98

The general herbicidal effect appeared to last up to and beyond singling. Results compared favourably with other sugar beet herbicides. The control of individual species is shown in Table 5, which includes all weeds occurring in reasonable number in the controls at 2 or more sites. Less frequent weeds showing more than 85% control in these trials were Capsella bursa-pastoris, Myosotis arvensis, Papaver rhoeas, Chrysanthemum segetum, Sinapsis arvensis, Crepis biennis, Melandrium spp., Anagallis arvensis spp., and Geranium pratense. Urtica urens gave variable results depending on a range of conditions. Adequate rainfall after treatment was most important for the control of this species. Certain weeds were found to be relatively resistant to lenacil; these included Veronica hederifolia, Veronica persica, Veronica arvensis, Lamium amplexicaule, Reseda lutea, Euphorbia spp., Avena fatua and Galium aparine. Broad leaved perennial weeds were not controlled by lenacil except in the early seedling stage.

Table 5

Summary of control of certain weed species with lenacil

Weed species	No. of sites	Average % control	Range of control
Stellaria media	19	98.0	89-100
Polygonum aviculare	15	88.0	74-100
Matricaria spp	11	99.5	93-100
Chenopodium album	13	93.0	77-100
Poa annua	18	98.7	82-100
Veronica persica	17	58.8	0-100
Senecio vulgaris	5	98.5	93-100
Polygonum convolvulus	11	79.0	43-100
Urtica urens	4	77.5	55-100
Spergula arvensis	7	100	98-100
Ranunculus arvensis	2	96.0	92-100
Viola arvensis	12	58.0	0-99

Effect on sugar beet

At 61 sites it was possible to compare lenacil with untreated plots. Beet emergence counts showed that in 40 trials there was a slight increase, no difference at 2 sites, and at the remaining 19 sites decreases were of the following order: 13 up to 10%, 4 between 11% and 15%, and where a double rate of lenacil had been applied in error, the reduction was 20%.

Braird counts on lenacil plots corresponded favourably with the comparison herbicides. It has been suggested that a reduction of up to 15% emergence would still permit an optimum plant population providing the seed spacing is no greater than 3". This was borne out by the mid-season counts. 61 sites had seed spacings of 1-3 in., the remaining 7 varying from 5 to 11 in.

Depression in beet seedling vigour occurred in 12 trials but this was of a temporary nature and of the same order as that produced by comparison herbicides.

Mid-season counts showed no reduction in final plant population except in one trial where overdosing occurred due to a steep slope which affected the speed of band spraying.

The varieties encountered in the trials were Sharpe's Klein E and Klein-Poly, Battle's E, Hilleshog (E, N and Polyploid), Bush E, Triplex N, Johnson's E, Hilleshog Monogerm and Camkilt. There was no evidence of any varietal difference in response to lenacil.

Details were taken of the fertilizer programme used at the various trial sites. There was no discernible effect on the crop treated with lenacil where a range of

100 to 200 units of nitrogen had been applied.

There was no obvious difference in safety to sugar beet between the three overall farm applications compared to band spraying but more work would need to be carried out to confirm this. Field observations on these and small scale sites in the year following treatment have shown no adverse effects on winter wheat or barley at normal or double rates of lenacil.

IV. Supplementary Information - 1966

The main purpose of the 1966 trials was to gain more information for extended lenacil recommendations on coarse sands and loamy coarse sands. Three yield trials were laid down but results are not yet to hand. There were 14 farmer usage trials to compare rates of 0.8 lb and 1.2 lb per acre of lenacil either applied as a band application or overall. Reductions in stand occurred in 50% of the trials at the 1.2 lb rate. In one trial on a coarse sand where 3.3 in. of rain occurred in the 28 days after application, the beet stand was seriously reduced and re-drilling had to be carried out. At some sites where beet emergence was uneven, the smaller late emerging seedlings collapsed and died, whereas older seedlings in the same row were unaffected. It was the first time the authors had noticed these symptoms with lenacil. These symptoms could be related to high rainfall and adverse growing conditions followed by a sharp rise in temperature. Later drillings on similar soil types did not show this effect. The safety factor of lenacil on these sands could also be related to organic matter, but analyses are not yet available. Plant emergence on these soils is known to be disappointing even in the absence of herbicides and it would be extremely hazardous to drill beet to a stand or even at spacings over 3 in. Inconclusive results on sands over two seasons indicate that further work is required.

Seven incorporation trials were carried out on a range of soils at reduced rates. Weed control was good on 4 sites but not equal to normal pre-emergence application on other sites. More work is still required on suitable dosage rates and incorporation techniques before firm recommendations can be made.

Acknowledgments

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Research Summary

COMMERCIAL APPLICATION OF PROPHAM AND DIURON FOR WEED CONTROL IN SUGAR BEET

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INTRODUCTION

This note summarises our experience of certain physical and chemical properties of soils which bear upon the effectiveness and safety of the commercially available herbicide Dipro* which is formulated as a wettable powder to contain 40% of propham and 4% of diuron as the two active ingredients and which, in the United Kingdom, is applied pre-emergently for residual weed control in sugar beet.

Propham alone applied to or worked into the soil pre-emergently is not acutely phytotoxic to sugar beet, but it fails to control certain weeds frequently indigenous in sugar beet growing areas. Application of diuron with propham usefully extends the range of susceptible weeds so as to include *Atriplex patula*, *Capsella bursa-pastoris*, *Chenopodium album*, *Tripleurospermum maritimum* spp. *inodorum* etc. We have studied rates of application in relation to their adequacy for weed control and to their freedom from risk to the crop; furthermore, we have identified certain properties of soils which constitute a risk to the use of this mixture.

METHODS

For a given soil type in a particular season a field trial will fix the optimum application rate; the trial will also permit assessment of those other rates, usually smaller and greater respectively, at which weed control is just adequate and at which safety of the crop is not at risk. Such trials can be performed on various soil types and can be repeated annually under the influence of different kinds of weather. Experience with soils of different kinds shows that margins between rates that are just adequate for weed control and rates that are free from risk to the crop are usually wide enough for commercial use, although there are some soils for which this margin is too narrow, and a few for which no rate seems both adequate for weed control and free from risk to sugar beet.

During four successive growing seasons experience has convinced us that simple visual examination of soils does not as a rule permit estimation of the optimum rate, nor does this provide any certainty that the margin between a rate adequate for weed control and a rate harmful to the crop would be sufficient for practical farming. We have, therefore, developed methods of soil examination which afford greater reliability of this residual herbicide for commercial use.

By conducting field trials on a given type of soil in one season the field biologist determines the optimum application rate. Meanwhile the chemist determines the proportion of diuron adsorbed by a measured volume of the soil from a standard volume of diuron solution.

A sample of air-dried soil is crushed to pass a 2 mm mesh. 5.5 ml of prepared sample are brought to equilibrium by shaking for 15 minutes with 25 ml of diuron solution of initial concentration 40 ppm and containing 1,000 ppm aluminium ammonium sulphate. After centrifuging the mixture, the equilibrium concentration of diuron in solution is determined by absorption spectrophotometry at 2470 Å.

Such collaboration on a series of soil types reveals a smooth empirical interdependence of application rate and diuron adsorption. Consequently, in a later season diuron adsorption can be measured for soil on which no field trial has ever been performed; then by reference to the empirical relationship the chemist can recommend, subject to other tests mentioned below, what is likely to be a suitable

* Dipro is a trade mark registered in the name of Farm Protection Ltd.

rate. After several seasons with weather of different kinds we have found the locus of points to correlate optimum application rates (3-15 lb/ac overall) with diuron adsorption (20%-76%).

However, a single measurement of diuron adsorption can never guarantee a fool-proof recommendation, if only for the reason that two constants in the adsorption isotherm for each variety of soil cannot both be found at once. After the herbicide has been applied to the soil its availability, which largely governs the degree both of weed control and risk to the crop, is related to the application rate, to the numerical values of the adsorption constants, also to the rate of desorption of herbicide in the field which is too slow a process to be conveniently measured. Furthermore, availability changes with weather, growth of crop and weed roots, and with factors unknown at the time a recommendation must be given to a farmer. Therefore, to help us judge whether the herbicide will be suitable for use at all we refer to two other criteria as follows.

First, it is well-known that sugar beet grows best on soils of pH 6.2-7.5, though it can be grown successfully on slightly more acidic soils, especially those of high organic content. On mineral soils sprayed with propham and diuron sugar beet is much more sensitive to acidity, phytotoxicity rising steeply as pH falls below 6.2. Therefore, it is prudent not to accept the risk of treating with propham and diuron sugar beet to be grown on any mineral soil of pH less than 6.2.

Secondly, the various components of soils adsorb diuron in different degree. For example, 5 grams of coarse sand separated from a medium loam adsorb 6% of the diuron from 25 ml of solution of initial concentration 40 ppm, 5 grams of clay adsorb 22%, but 5 grams of any soil containing 5% of organic humus adsorb up to 80% of the diuron, whilst some highly organic soils adsorb virtually the whole. Thus, soils of vastly different compositions might adsorb the same proportion of diuron in the standard laboratory test, but their ability to retain diuron near the surface of a seed bed could vary widely during heavy rain. Our investigations show for diuron that the tenacity of adsorption is high on organic matter but low on fine sand, silt and clay. It is therefore an unacceptable risk to treat any seed bed in which a very appreciable proportion of the measured capacity for diuron adsorption is due to these mineral constituents.

Three grams of the prepared soil sample are moistened with 50% aqueous 2:3-butylene glycol to which a trace of surfactant has been added. By stirring this mixture to a paste the components of the soil are readily dispersed. A representative portion is transferred to a slide, then with a few drops of 2:3-butylene glycol the dispersion is spread in a thin film over 1-2 cm^2. By microscopical examination, the organic humus is identified as brown-black flocs whilst bi-refringence in polarised light reveals fine sand and silt. A small proportion of clay is difficult to identify, but appreciable amounts of very finely divided minerals are easily detected.

For most soils the practised eye is able to correlate this microscopical test for organic matter with the result of the diuron adsorption test. For other soils it becomes practicable to decide whether a very appreciable part of the measured adsorption is due to mineral constituents; wherever this is so it is probable that the safety margin would be too small for success in a season of heavy rainfall.

CONCLUSION

By making it a rule to examine soil samples in three ways, viz. for diuron adsorption, for pH, microscopically for balance between organic humus and finely divided mineral constituents, we are able to avoid the disappointments of earlier years, and can confidently recommend the use of propham-diuron for weed control on suitable seed beds.

Research Summary

RESULTS WITH LENACIL IN 50 SUGAR BEET EXPERIMENTS IN 1965

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INTRODUCTION

In 1965, 3-cyclohexyl-5,6-trimethyleneuracil (lenacil), a promising new pre-emergence herbicide for sugar beet discovered and described by E.I. Du Pont de Nemours & Co. (Inc.), was tested in 50 experiments in eastern England. The main purpose of these experiments was to study the performance of lenacil under a wide range of conditions and to attempt to find a relationship between the expected variability of performance and differences in soil type, weed population, spraying date or other conditions. Two yield experiments were also carried out to test the effect of lenacil on crops drilled at three different times.

DESCRIPTION OF EXPERIMENTS

All treatments were applied as overall sprays within a few days after drilling.

Standard experiments (2 replications): on 50 farm crops lenacil was applied logarithmically (dose: 8 lb - ½ lb a.i./ac) and at constant doses (1.2 lb and 1.6 lb a.i. on light soils; 1.6 lb and 2.4 lb on heavier soils) at a spray volume of 20 gal/ac. Soils: mainly loams and sands but some clays and organic soils were included. Spraying period: mid-March to early May. Weather: wet in the second half of March and second half of April; dry in the first half of April and for much of May.

Yield experiments (4 replications): on 2 sites beet drilled at three times (end March, mid-April, early May) was sprayed at 0.8, 1.6, 2.4 and 3.2 lb/ac lenacil.

Results of yield experiments and 45 standard experiments (5 discarded because of poor weed infestation), were assessed by visual scores of weed and crop growth just before singling. Beet plants were also counted on sample areas of constant-dose plots. On yield experiments, plots 3 drills x 14 yd were harvested and sugar analysis data were obtained on samples of roots.

RESULTS

In the majority of the experiments weed control was good or excellent at doses of lenacil which had little or no effect on the crop, though the level of activity varied and no one dose gave satisfactory results in all experiments. Results from the individual sites showed a fairly wide selectivity margin (difference between minimum effective dose and maximum dose tolerated).

The experiments were divided into 3 main groups: 71% of the trials gave good results at doses ranging from 1 - 2 lb/ac; in 11% of the trials (5 trials) activity was low and the common dose needed to give good weed control was too high for practical use; 18% (8 trials) showed serious crop damage at 1 lb/ac and although activity was also very high on weeds, a satisfactory selectivity margin could not be shown since the doses were so close to the lower limit of the logarithmic range.

An attempt was then made to define the conditions under which extreme results occurred and as far as possible to account for the variation in good results obtained with doses between 1 and 2 lb/ac. It was found that, as had been shown by other workers, much of this variation could be overcome by adjusting the dose in relation to soil type. Other causes of variation were the susceptibility of the weed species present and the time of spraying. Results relating to these aspects are outlined below.

Soil Types

a) Light soils: 8 experiments showed very high activity resulting in crop damage. All of these were on sandy soils and at 6 sites the soil contained a high proportion (60 - 75%) of coarse sand. There were only two other experiments on soils with this percentage of coarse sand; these did not show unusually high activity.

b) Heavy soils: although no definite conclusions could be drawn from the results of the few trials carried out on heavy soils, there were indications of poor weed control on such soils. Of the 5 'low activity' results, 2 were obtained on clay loams. The other 3 appeared to be due to other factors and are mentioned below.

Weed Susceptibility

Most of the common weeds of beet fields including annual grasses were readily controlled by lenacil but certain species (*Galium aparine*, *Veronica hederifolia*, *V. persica*, *Viola sp.* and *Avena fatua*) were found to be resistant to 1 - 2 lb or not reliably controlled at these doses. One of the 5 poor weed control results was obtained on a weed population composed mainly of resistant species.

Time of Spraying

Lenacil showed reduced activity when the application was made late in the season, followed by dry weather. On three drillings of beet on each of two sites, early April and mid-April applications gave over 90% weed control at all doses (0.8 - 3.2 lb/ac). However, on the latest drilling in early May, followed by dry weather, the average weed control was only 74% in one experiment and 56% in the other. 2 standard experiments which showed very poor weed control on light soils were sprayed in early May.

Effect of Lenacil on Beet

Counts of beet before singling showed that lenacil, at doses and on soils considered for usage recommendations, sometimes slightly reduced the stand of beet. Provided however that the plants were not too widely spaced at drilling, the population could be adjusted at singling, and the final stand was satisfactory.

In the yield experiments, 1.6 lb lenacil (a slightly higher dose than would be recommended on these sandy loam sites) gave about 20% reduction in plants on the average of the first two times of application but no reduction at the last (early May) application. The beet on these sites was drilled at 2 inch spacing, and yields were satisfactory as is shown in the table below.

Yield of Sugar as % of Control (Mean of 2 Experiments)

Time of drilling	Dose of lenacil in lb a.i. per acre			
	0.8	1.6	2.4	3.2
late March	99.3	99.8	101.6	93.9
mid-April	97.8	99.3	94.9	102.7
early May	97.8	102.4	99.9	98.9

Analysis of variance : differences not significant

Lenacil at the doses tested did not appear to affect the percentage of sugar and limited observations did not indicate any increase in bolting on treated plots.

Acknowledgment

The author wishes to thank Mr. N.B. Joy of Du Pont Company (U.K.) Ltd., for his advice and information on lenacil.

THE POST-SINGLING USE OF PYRAZON TO CONTROL WEEDS IN SUGAR BEET

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Summary The use of pyrazon with Citowett to control weeds germinating after the singling of sugar beet is described and the optimum stages of development of beet and weeds are defined. Because of difficulties in achieving the correct association of beet and weed stages this technique is to be considered only as an emergency measure.

INTRODUCTION

In the United Kingdom as in other countries pyrazon is a herbicide essentially applied to the soil surface before weed or crop emergence, usually immediately after sowing the beet seed, or, in special circumstances sprayed and incorporated into the soil before drilling.

Pyrazon does however exert a marked phytotoxic effect when applied to weeds after emergence at early stages of development and although it is not practicable under commercial conditions to use pyrazon at early stages of beet development the work of Hanf, Beinhauer and Fischer has shown that in cases where no pre-emergence treatment has been made, the weeds emerging after singling when cultivations are no longer practicable or economical, can be controlled by application of pyrazon preferably with added surface active agent.

A programme of trials was arranged to study the practicability of this technique in the United Kingdom and although this work is not yet complete it seemed worthwhile reporting the progress made to date.

MATERIALS AND METHODS

In this programme of 10 replicated detailed trials and 22 unreplicated user trials carried out in 1965-6 pyrazon was used in the form of the standard 80% dispersible powder marketed as Pyramin.

Pyrazon was applied on soil types ranging from very sandy to heavy clay at rates spanning the normal pre-emergence rates for the soil type, with and without a surface active agent. The wetter used in most of the trials was based on an alkyl aryl polyglycol ether in the form of Citowett. This is the wetter with which the work of Hanf et al[1, 2], has been carried out in Europe.

Applications were made at a series of beet and weed growth stages in order to study the selectivity of pyrazon used in this manner.

RESULTS

Certain facts have emerged clearly from the trials carried out to date.

1) The most satisfactory herbicidal effect occurred with applications made when weeds were at the cotyledon to first true leaf stage. It was found to be important for full emergence of weed to have taken place since climatic conditions at the time of the season when this technique is used do not favour pre-emergence weed control.

2) The four fully expanded true leaf stage is the earliest at which optimum crop safety has consistently occurred when using an adequate rate for weed control. Application of pyrazon to sugar beet at earlier growth stages has tended to cause crop damage with a degree of mortality depending on the actual stage of growth - the earlier the stage the more susceptible the crop.

3) Under the conditions laid down in 1) and 2 above, the optimum rate of pyrazon on medium loam soils where the pre-emergence rate of use is 2.8 lbs a.i. per acre and on heavy soils where the pre-emergence rate is 3.6 lbs a.i. per acre has been found to be 2.4 lbs and 2.8 lbs a.i. per acre respectively. In each case it has been found necessary for adequate weed control to add in the form of a spray tank mix, a quantity of the alkyl aryl polyglycol ether equivalent to ¾ pint per acre of Citowett.

On sandy soils which are more prevalent in the main sugar beet areas of the United Kingdom than probably in any country in continental Europe, the situation is less well defined at present. On these soil types there is a greater tendency for pyrazon used after singling at the optimum rate for weed control to cause crop injury at the four true leaf stage which is found to be safe on the other soil types referred to above. To delay application until a later sugar beet stage usually means that weeds will be too far advanced for satisfactory control. Increase in the amount of wetter has to date tended to cause phytotoxicity to a commercially unacceptable level. The investigation of alternative wetters is in progress.

The table summarises the response of weeds and sugar beet to post-singling application of pyrazon and wetter in 16 trials carried out in 1966 on different soil types. Only the ¾ pint rate of Citowett is included in this table as higher rates were excluded following the 1965 trials. The table also indicates differential weed susceptibility.

DISCUSSION

It is clear from work carried out to date in the United Kingdom that the post-singling use of pyrazon together with Citowett is a practical proposition on medium and heavy soil types to control weeds germinating after singling in circumstances where no pre-emergence treatment was used. There are also possibilities for this technique in late sown sugar beet, mangolds and fodder beet and also in steckling beds.

Success of the method depends on achieving the association of the appropriate weed and beet stages defined above and the probability of doing this is dependent on climatic conditions the effect of which can be summarised as follows:-

a) Rainfall can delay application until weeds are too far advanced to be controlled. Once weeds have developed beyond the susceptible stage increase in rate does not produce an economically worthwhile improvement in result whilst increase in rate of Citowett causes increased phytotoxicity.

b) Periods of high temperature during and/or shortly after application can cause phytotoxicity to the beet in the form of scorch irrespective of stage. The more advanced the beet at the time of application the more it is able to withstand these effects.

On light sandy soils it is not yet possible to recommend this use of pyrazon due to difficulty in achieving the necessary selectivity. Further work with other wetters may well be justified in an endeavour to improve this factor.

It is clear, for the reasons outlined, that the post-singling use of pyrazon cannot be considered as an alternative to pre-emergence use but this technique can fulfil a very useful purpose on medium and heavy soils as an emergency measure where application of pyrazon at the time of drilling was not made.

<u>Table of Results - 1966</u> (Summarised from 16 user trials)

CROP EFFECT AND PERCENTAGE WEED CONTROL

Rate of pyrazon per acre, soil type and number of trials ( )
(Citowett @ $\frac{3}{4}$ pint/acre included in all cases)

Crop & Weeds	Heavy soil 2.8 lbs (2)	Medium soil 2.4 lbs (5)	2.4 lbs (2)	2 lbs (3)	1.6 lbs (7)
Sugar beet	Nil	Nil	VS	Mod	Nil
Fathen	70	70	-	50	40
Speedwell	-	80	-	-	-
Redshank	70	75	90	70	70
Black bindweed	75	80	90	70	60
Knotgrass	20	60	60	20	20
Chickweed	40	80	60	40	40
Mayweed	-	20	40	10	0
Charlock	-	-	90	70	60
Groundsel	-	40	-	-	0

V.S. = very severe crop effect. Mod. = moderate crop effect

<u>Weed Susceptibility</u>

Susceptible: black bindweed, redshank, charlock
Moderately susceptible: chickweed, fathen
Moderately resistant: knotgrass, mayweed
Species appearing to be susceptible pending further data: speedwell spurrey, annual nettle, pansy.

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LENACIL, A NEW RESIDUAL HERBICIDE FOR THE CONTROL OF ANNUAL WEEDS IN SUGAR BEET

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Summary Experiments are described in which 6,cyclohexyl-2,3,4,5,6,7-hexahydro-5,7-dioxo-4,6-diazaindene was applied to sugar beet directly after drilling either as an overall or as a band spray on the soil surface and as an overall application incorporated into the soil. Trials were carried out on a wide range of soil types and weather conditions. The activity of the herbicide was found to be greatly influenced by soil type and was progressively inactivated with increasing clay content of the soil. Through the use of different rates according to soil type a high degree of selectivity was found on a wide range of soil types at doses consistent with satisfactory weed control, but where conditions were adverse to the growth of beet the emergence and vigour of the beet seedling were at times further reduced by lenacil. No advantage was found from incorporating the herbicide into the soil under the conditions in which the trials were carried out but band spraying appeared slightly safer to the crop than overall spraying.

INTRODUCTION

6,cyclohexyl-2,3,4,5,6,7-hexahydro-5,7-dioxo-4,6-diazaindene, proposed BSI common name lenacil, was introduced into the U.K. by Du Pont Co. (U.K.) Limited in 1962 under the code name 'Herbicide 634'. After investigations in 1962 and 1963 it was offered in 1964 for development as a selective herbicide for the control of annual seedling grasses and broadleaf weeds in sugar beet. Experience elsewhere had shown that the activity of this herbicide was greatly influenced by soil organic matter and clay content but its activity could be increased by incorporation into the soil. Two replicated trials were carried out in 1964 on widely different soil types. In these trials the herbicide was incorporated into the soil before drilling and applied to the soil surface immediately after drilling.

Following the 1964 work and work reported by Cussans (1964) it was considered that the activity of the herbicide was more influenced by the clay content than the organic matter normally found ($1\frac{1}{2}$ - 4%) in mineral soils. Accordingly a series of 12 replicated trials were laid down in 1965 covering a wide range of soil types, the dose range being arbitrarily selected to suit the soil type. In all these experiments surface and incorporated applications of the herbicide immediately after drilling were used. In addition to the replicated trials 19 farm strip trials were laid down to examine the performance of the material when applied through commercial spraying machinery.

From the 1965 work it was apparent that the dose range (1.2 - 2.4 lb/ac) tested on loamy sands was too high and five replicated trials were carried out on these soils in 1966 using a lower dose range. It was also thought that band spraying might be safer to the crop than overall spraying on these soils and these two methods of application were compared. A further 3 trials were also carried out in 1966 on clay loams.

METHOD AND MATERIALS

lenacil**	6,cyclohexyl-2,3,4,5,6,7-hexahydro-5,7-dioxo-4,6-diazaindene formulated as Du Pont Experimental Herbicide 634 and later 'Venzar*' lenacil weedkiller, an 80% wettable powder.
Standard (Std.)	A standard wettable powder commercially available.

** Proposed BSI common name. For convenience this name will be used throughout this paper.

In all experiments applications of herbicides were made with an Oxford Precision Sprayer in a total volume of 20 gal per acre (1965 and 1966 experiments) and 40 gal per acre (1964 experiments). A modification was made to the sprayer boom for application of the band sprayed plots in the 1966 trials. Soil incorporation was carried out using a heavy rake. Each plot was raked 3 times, the second and third rakings being at right angles to the previous one. The depth of incorporation was about 1 in. All treatments, including incorporated treatments, were applied as soon as possible after drilling except in 1964 when the incorporated treatments were applied prior to drilling. The raking after drilling did not disturb the beet drills.

Two types of trial were used, the first being small plot trials mainly for assessment of weed response and the second, larger plot trials for measurement of crop yields. In the 1965 weed control trials split plots were used to provide data on the same dose of lenacil applied to the surface and incorporated into the soil. The trials were of a randomised block type with 3 or 4 replicates.

In the 1964 trials the doses of lenacil were selected from the range of rates used in earlier European screening work. The results of which were available to one of the authors. Following the 1964 work, doses were selected according to the soil type for 1965 trials. In 1966 the dose rates were slightly altered so that they were in accordance with label recommendations. All doses are given as pounds of active ingredient per acre.

Weed control assessments were made on eight or more quadrat counts from each plot in the replicated trials about four weeks after the treatments were applied. In the 1964-1965 trials where overall applications only were used counts were made on foot square quadrats. With the inclusion of band sprayed treatments in the 1966 trials a quadrat measuring 36 in. x 4 in. was used and weed counts were made in a 7 in. band along the rows on all plots. In all replicated trials crop counts before singling were made on 4 x 6 ft row length from each plot and in the yield trials post-singling counts were made on 4 x 10 ft row lengths in each plot. Singling of trial plots was carried out by farm labour. Estimates of yield were obtained by lifting 4 x 5 yd of row from the middle of each plot. The beet lifted were weighed and from these beet 20 were taken at random and analysed for dirt tare and sugar content.

Soil samples were taken from all replicated trials in 1965 and 1966 for mechanical analysis to determine the soil types on the various trial sites. The soil types are described according to the NAAS classification which is based on the New Jersey scale.

In addition to replicated trials, nineteen unreplicated farm strip trials were carried out in 1965 to test the performance of lenacil when applied through commercial sprayers. These trials also gave further information on the performance of lenacil on a wide range of soil types. Weed and crop counts were made on all farm strips using an 18 in. x 4 in. quadrat laid along the row. 40 quadrats were taken at random throughout the area treated with lenacil and in an adjacent unsprayed area.

* Venzar is a Trade Mark of E.I.Du Pont de Nemours Co. (Inc.)

RESULTS

The results of the replicated trials are given in Table 1 and Figures 1 to 4. In the figures the results are expressed as means of trials on different soil types as indicated.

Results obtained from farm strip trials showed that lenacil gave good control of Polygonum convolvulus, Veronica persica, Sinapis arvensis, Stellaria media, Chenopodium album, Polygonum aviculare, Fumaria officinalis, Papaver rhoeas, Polygonum persicaria, Matricaria spp. (including Tripleurospermum sp.) and Poa annua. Veronica hederifolia, Viola arvensis and Avena fatua proved resistant to lenacil on all sites where they occurred.

DISCUSSION

The increasing labour shortage and the improvement of cultural techniques in sugar beet growing has created a need for both an effective and safe weedkiller for use on this crop. The results reported in this paper show that lenacil fulfills these requirements.

Effect on beet

Lenacil showed a high degree of selectivity and acceptable weed control at doses selected in relation to soil type, e.g. 0.8 lb/ac on loamy sands excluding loamy coarse sands, 1.2 lb/ac on sandy loams, 1.6 lb/ac on silts and silty loams and 2.0 lb per acre on loams. A reduction in the number of emerged beet occurred in a number of the trials described but where the reduction was small this did not affect the final plant population and even where the reductions were significant, differences in the final populations and yields were not. It is interesting to note that in some trials (Trials C, D and F 1965 Yield Trials) singling contributed more to the variation in final populations obtained than did the reduction in number of emerged plants and that in some cases the optimum population of 25-30,000 plants per acre was not achieved although there were adequate numbers of plants before singling.

The 1965 results on loamy coarse sands indicated that doses of 1.2 - 2.4 lb/ac were too high for these soil types (see Table 1, Sites A and B) and lower rates were tested in 1966 but it is considered that further work is required to establish safe dose rates for loamy coarse sands and sands. Although rates in the region of 2.0 lb per acre gave acceptable results on clay loams in these trials, further work under drier conditions is considered desirable to establish suitable dose rates for these soils.

Effect on weeds

The results of the 1965 Weed Control Trials and the data obtained from the farm strip trials show that lenacil used at doses tolerated by sugar beet gave good control of a number of important weed species occurring in sugar beet.

Species successfully controlled included P.convolvulus, P.aviculare, C.album, S.media and S.arvensis. Control of Poa annua was generally good and excellent control of Alopecurus myosuroides has been shown in commercial use during 1966. Variable control of V.persica and Urtica urens was obtained in the trials and this could not be correlated with soil type or inadequate rainfall. V.hederifolia and V.arvensis proved resistant in all the trials. Weed control persisted at least until singling in all trials.

Greenhouse trials carried out in 1966 to examine the effect of placing lenacil at different positions in relation to seeds of Brassica oleracea showed that where the lenacil was placed below the seed the number of emerged seedlings was less than when it was placed above the seed. Where surface irrigation was applied the degree of activity was similar to that shown by lenacil placed below the seed indicating that rainfall after application is necessary for optimum herbicidal activity.

Effect of Method of Application

Under the conditions of these trials soil incorporation of lenacil did not appear to increase its herbicidal activity to any extent. In the 1965 Yield Trials incorporated treatments at half the surface applied rates showed slightly better crop tolerance but poorer weed control than surface applied treatments. In the Weed Control Trials where incorporation and surface application were compared at equal dose rates, weed control was not improved by incorporation. In both 1965 and 1966 however all sites had considerable rainfall which moved the lenacil well into the soil. If lower rainfall conditions had existed it is thought that incorporation would have shown higher activity than surface application through moving the lenacil into the top layers of soil.

The 1966 trials showed that band spraying of lenacil tended to be slightly safer to the crop than overall spraying on all soil types. It is thought that application in a band allows the sugar beet roots to spread out to areas beyond the band which are free of herbicide. Dilution by lateral spread into untreated soil is considered unlikely since the weed control obtained was generally as good as that obtained by overall spraying. The poor weed control obtained by band spraying on Site A in 1966 was due to the occurrence of 'blow' which filled the furrows left by the drill press wheels with untreated soil from between the rows.

Effect of Soil Type and Weather

The relationship between soil type and the activity of lenacil is clearly shown in the results reported. With increasing clay content the herbicide is progressively inactivated by adsorption onto the colloidal fraction in the soil, thus necessitating the use of higher doses on those soils with a high clay content.

The 1966 trials were spread over a considerable period and it is particularly noticeable that the two early drillings, Site A and B , both suffered reduction in beet numbers. In the two weeks following drilling temperatures were unseasonally low and rainfall high and these unusual conditions had a deleterious effect on plant stand and vigour apart from the effect of lenacil.

The sensitivity of lenacil to soil moisture referred to by Cussans (1964) has not been demonstrated in these trials owing to the fact that adequate amounts of rain fell on all sites.

References

CUSSANS, G.W. (1964) Some experiments with 3,cyclohexyl-5, trimetylene uracil in sugar beet. Proc. 7th Brit. Weed Cont. Conf. 671-678.

Figure 1

1964 Trials - Seedling counts of weeds and sugar beet

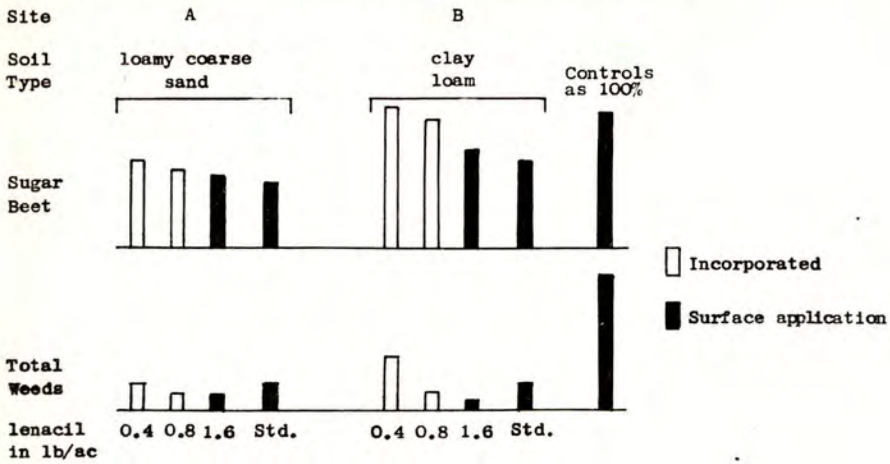


Table 1

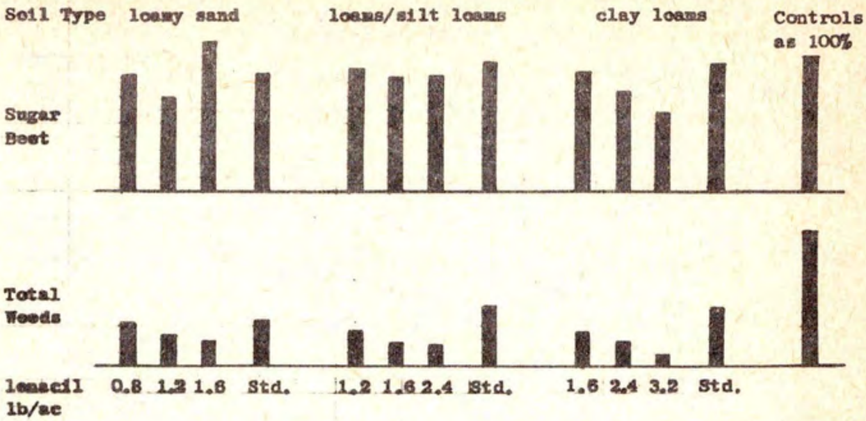
1965 Yield Trials - Results of Surface Applications

Site and soil type	lenacil lb/ac	% Emerged beet	% Weed survival	Final density 000 plants/ac treated	Final density 000 plants/ac untreated	Sugar yield cwt/ac treated	Sugar yield cwt/ac untreated
A L. coarse sand	1.2	67	3	26.4	28.7	51.7	59.7
	1.6	40*	3	21.1		42.3	
	2.4	51*	1	21.6		42.5	
	Std.	121	7	27.0		56.1	
B L. coarse sand	1.2	93	3	27.0	28.8	32.5	42.7
	1.6	87	2	28.2		38.1	
	2.4	61	2	19.5*		31.3	
	Std.	129	5	26.0		34.6	
C Sandy loam	1.2	102	21	20.5	20.0	61.6	70.1
	1.6	102	14	19.1		62.9	
	2.4	86	12	20.1		70.1	
	Std.	120	23	20.5		67.8	
D Silty loam	2.4	89	30	27.4	26.2	54.2	42.5
	3.6	93	31	25.7		48.6	
	4.8	89	40	26.6		54.0	
	Std.	98	36	25.7		53.8	
E Silty loam	2.4	119	20	27.7	27.7	50.2	52.3
	3.6	117	12	27.2		47.6	
	4.8	138	13	27.2		42.3	
	Std.	120	32	27.7		50.8	
F Clay loam	2.4	102	9	21.4	23.5	not taken	
	3.2	86*	14	24.0			
	4.8	61*	7	21.7			
	Std.	96	9	22.0			

* Denotes significant difference at P = 0.05

Figure 2

1965 Weed Control Trials - Seedling counts of sugar beet and weeds



Mean Percentage Survival of Main Weed Species

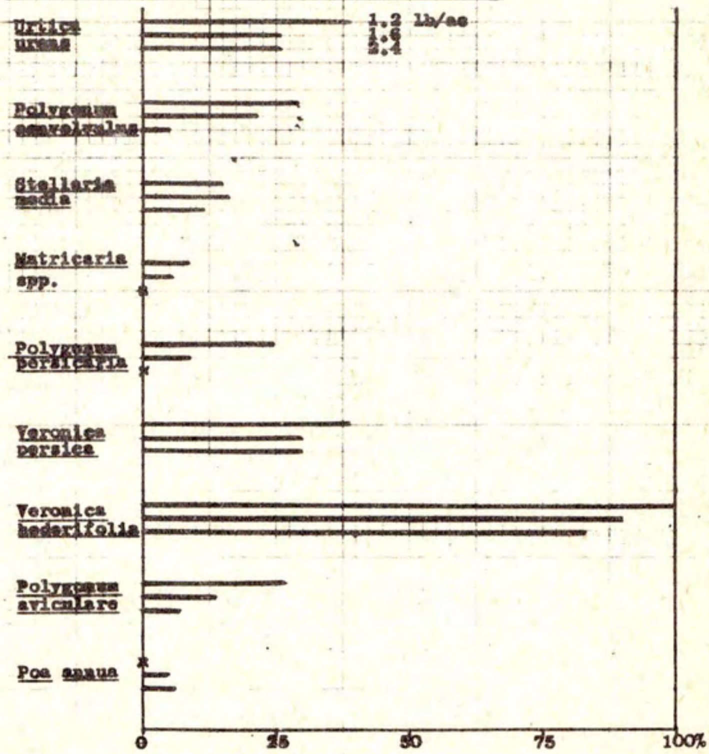


Figure 3

1965 - Comparison between surface and soil incorporated applications

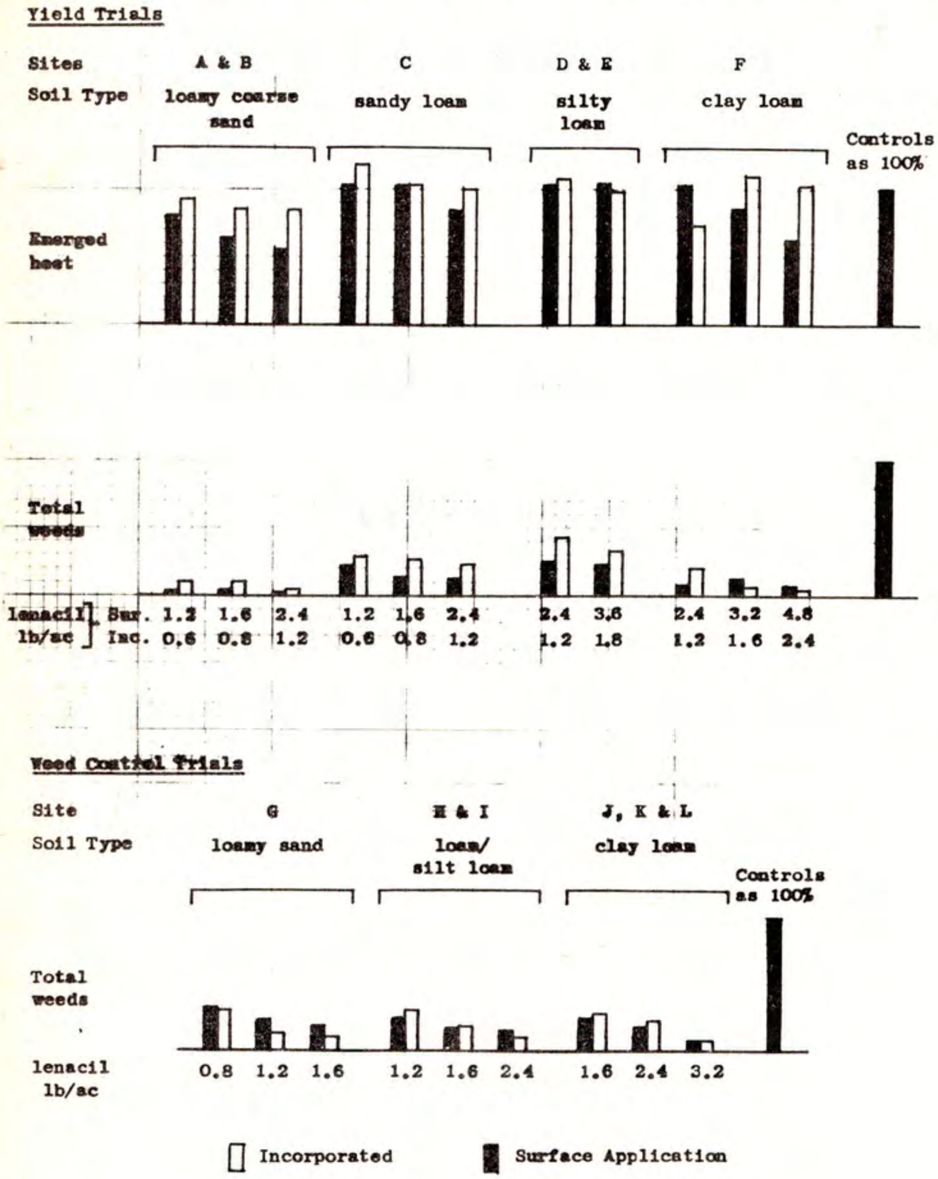
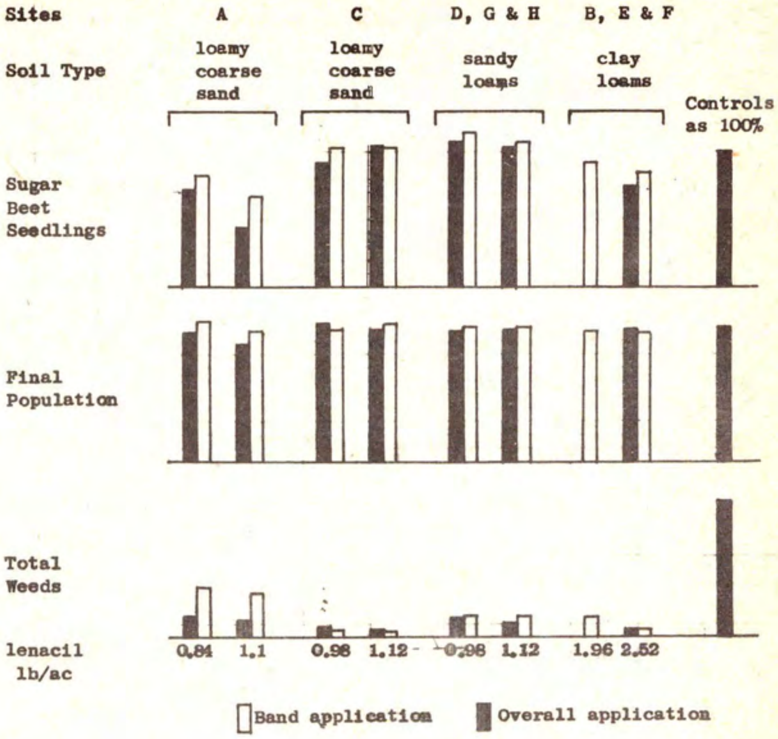
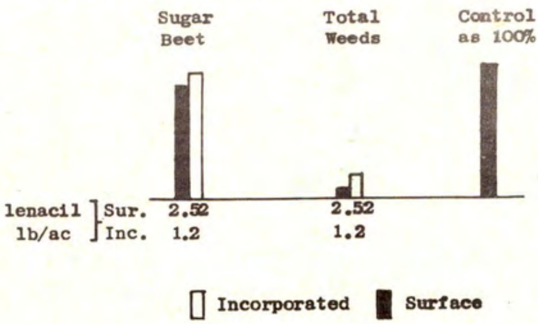


Figure 4

1966 - Results of overall and band applications



1966 - Comparison between surface and soil incorporated applications on clay loams



POST EMERGENCE WEED CONTROL IN SUGAR BEET WITH PYRAZON AND CHLORO-PYRAZON

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Summary Experiments carried out in England and Scotland during 1965 and 1966 are described in which pyrazon and chloro-pyrazon were applied in mixtures with different wetting agents at various dosage rates. Applications were made at the cotyledon, 2 leaf and 4-6 leaf stages of crop growth. The majority of annual weed species were controlled up to the early seedling stage but rapidly became resistant with age. The crop tolerated treatments applied from the 4 leaf stage onwards but phytotoxic effects sometimes occurred at the earlier stages of growth. Optimum results were obtained following pyrazon 2.8 lb/ac. and Citowett ¾ pt. applied shortly after hoeing and singling when a new flush of weeds was in the cotyledon to early seedling stages, but the degree of control varied according to the prevailing weather conditions and the treatment can only be regarded as useful in an emergency.

INTRODUCTION

Pre-emergence applications of pyrazon for residual weed control on light, medium and heavy textured soils have proved successful in sugar beet husbandry over a number of years but the technique suffers from the principal limitation that weeds are not satisfactorily controlled on clays and fen peats (Lush et al, 1964). Post-emergence treatments demonstrated the phytotoxicity of pyrazon to sugar beet sprayed in the cotyledon stage (van der Zweep, 1964) but limited success was obtained from treatments applied at the 2 leaf stage (Cussens, 1964; Langbein, 1964). Later, it was discovered that the addition of a wetting agent to pyrazon improved the herbicidal activity. Chloro-pyrazon was reported to have similar properties to pyrazon (Fischer, 1965) with a greater selectivity to the crop.

The aim of the current work was to investigate in detail the post-emergence use of pyrazon and chloro-pyrazon with various wetting agents.

METHODS AND MATERIALS

Field trials were carried out in four series during 1965 and 1966. In Series A, two randomized block experiments with three replicates were sprayed with an Oxford Precision Sprayer at the cotyledon stage of crop growth. In Series B, six trials with four replicates were sprayed with a tractor-mounted sprayer at the 2 leaf stage of the beet. Series C comprised five trials with three replicates sprayed at the 4-6 leaf stage after hand-hoeing and singling. Trials at ten sites in Series D consisted of single plots sprayed at various stages with an Oxford Precision Sprayer.

The equipment for the tractor sprayer was specially designed using separate polyethylene containers for each chemical treatment and a front-mounted spray boom. Treatments were applied as overall sprays, with the exception of trials in Series C which were applied as band sprays 7 ins. wide at crop height. The plot size in the replicated experiments was 1/100th ac. and in the unreplicated trials 1/240th ac. All trials were sprayed at a volume rate of 30 gal/ac at a pressure of 32 p.s.i.

Soil types varied from light sands to heavy clays and fen peats. Climatic conditions also differed greatly from eastern England to central Scotland (Series A).

Two formulations both containing 80% a.i., were used, 1-phenyl -4- amino-5-chloro-pyridazone- (6) (known commercially as Pyramin and hereafter referred to as pyrazon), and 1 -phenyl-4(α-hydroxyβ,β,β - trichloro-ethyl-amino)- 5-chloro-pyridazone-(6) (hereafter referred to as chloro-pyrazon). The surface active wetting agents used as additives were Citowett (nonionic wetter containing 100% a.i.) alkyl-arylpolyglycol-ether), Nonidet P.40 (nonionic wetter containing nominal 100% octyl-phenol/ethylene oxide condensate), Teepol (anionic wetter commercial grade) and Risella 917 (highly refined paraffinic white oil). Pyrazon, chloro-pyrazon and Citowett were supplied by Badische, Anilin & Soda Fabrik/A.G., Nonidet and Teepol by Shell Chemical Co. Ltd and Risella by Shell Mex and B.P. Ltd.

Weed control and effects upon the beet were recorded 1-2 weeks after spraying. There was seldom any reduction in the number of weeds and as a result assessments were based on growth vigour. Assessments were carried out by two operators scoring the plots independently; 0 indicating complete lack of vigour and 100 the most vigorous of the plots.

RESULTS

Details of soil type, stages of growth at application and weather conditions are given in Table 1.

Effects on weeds In Series A, sites I and II were assessed approximately 10 days after treatment and the results are shown in Table 2.

Table 2.

Series A.

WEED VIGOUR FOLLOWING TREATMENTS AT COTYLEDON STAGE
(Commercial acceptability = less than 30)

Treatment	I.	II.	Mean.
Control - untreated	100	100	100.0
pyrazon 2.4 lb/ac a.i. & Citowett 3/4 pt.	15	22	18.5
" 2.1 " " " " 3/4 "	19	22	20.5
" 2.1 " " " " 1½ "	7	8	7.5
" 1.2 " " " " 1½ "	10	15	12.5
Chloro-pyrazon			
2.4 " " " " 3/4 "	44	26	35.0
" 2.1 " " " " 3/4 "	49	29	39.0
" 2.1 " " " " 1½ "	33	25	29.0
" 1.2 " " " " 1½ "	22	37	29.5
Sig. diff. (P = 0.01)	29	10	

Table 1.

DETAILS OF TRIAL SITES

Soil Type	Stages of growth: Crop	Stages of growth: Weeds	Weather Conditions: At application	Weather Conditions: After application
Series A.				
I light loam	Cotyledon	Cotyledon	Warm	Dry and warm for 2 days
II light loam	Cotyledon	Cotyledon	Very Warm	Dry and warm for 1 day
Series B.				
III Light	2-leaf	Cotyledon to 4-leaf	Temp 21°C * R.H. 55%	Cool. Occasional Showers
IV Heavy loam	2-leaf	2-4 leaf	Temp. 16.5°C R.H. 81%	Continuous rain followed in 4 hours
V Clay	2-leaf	Cotyledon to 2-leaf	Temp. 24°C R.H. 30%	Dry and warm. Occasional light showers
VI Fen peat	2-leaf	2-4 leaf	Temp. 18°C R.H. 55%	Cool. Occasional Showers
VII Fen peat	2-leaf	Cotyledon to 4-leaf	Temp. 21°C R.H. 54%	Warm. Occasional Showers
VIII Fen peat	2-leaf	Cotyledon to 4-leaf	Temp. 18°C R.H. 56%	Showery and cool
Series C.				
IX Clay	4-6 leaf	Cotyledon to 6-leaf	Temp. 19°C	Light rain after 1 hour. Unsettled.
X Fen peat	6-leaf	Cotyledon to early flower-bud	Temp. 20°C R.H. 62%	Unsettled
XI Sandy loam	4-leaf	Cotyledon to 4-leaf	Temp. 23°C Dry	Very warm for 1 day
XII Light loam	4-leaf	Cotyledon to 4-leaf	Temp. 10°C Dry	Warm and dry
XIII Fen peat	4-leaf	Cotyledon to 6-leaf	Temp. 21°C Dry	Warm and dry

R.H. = Relative Humidity.

Excellent control of weeds was obtained at both sites with pyrazon which was markedly superior to chloro-pyrazon. The higher dosage rate of Citowett improved results.

Experiments in Series B were sprayed when the crop was in the 2-leaf stage. The stage of weed growth at the time of application was variable but in general corresponded to the atage of crop growth. Results are shown in Table 3.

Table 3.

Series B.

WEED VIGOUR FOLLOWING TREATMENTS AT THE 2 LEAF STAGE
(Commercial acceptability - less than 30)

Treatment	Sites						
	111	IV	V	VI	VII	VIII	Mean
Control - untreated	100	100	100	100	100	100	100
Pyrazon 4.2 lb/ac a.i. & Citowett 3/4 pt.	-	-	8	-	-	-	
" 2.8 " " " " 3/4 "	-	24	22	21	1	24	18
" 2.1 " " " " 1 "	57	24	27	28	46	28	35
" 2.1 " " " " 3/4 "	51	27	32	24	30	18	30
" 2.8 " " " " 1 "	-	-	42	-	-	-	-
Chloro-pyrazon							
3.6	67	73	-	63	57	53	63
" 2.1 " " " " 3/4	67	71	-	-	50	32	55
" 2.1 " " " " 1	65	67	-	[illegible]	34	50	53
Sig. diff: (P = 0.01)	N.S	33	24	20	33	N.S.	

The best treatment was pyrazon 4.2 lbs/ac and Citowett 3/4 pt. but this treatment was only applied at one site. The most consistent result which gave highly significant reductions in weed vigour was pyrazon 2.8 lbs/ac and Citowett 3/4 pt. Chloro-pyrazon was not as effective as pyrazon and failed to give satisfactory weed control.

Experiments in Series C were sprayed after hand-hoeing and singling when the crops were in the 4-6 leaf stage. The stages of weed growth varied in accordance with Table 1. The results are shown in Table 4.

As expected, the higher dosage rates gave improved weed control, but there was considerable variation due to weather conditions at the time of spraying. Rain falling within less than 24 hours reduced the effectiveness of the results. If the higher dosage rates of pyrazon are excluded due to economic considerations and the relatively advanced stage of weed growth at sites IX and X taken into consideration, satisfactory results appear to have been obtained from pyrazon 2.8 lb/ac and Citowett 3/4 pt.

Table 4.

Series C.

WEED VIGOUR FOLLOWING TREATMENTS APPLIED AFTER SINGLING
(Commercial acceptability = less than 30)

Treatment	IX	X	XI	Sites XII	XIII	Mean
Control - untreated	100	100	100	100	100	100.0
Pyrazon 4.0 lb/ac & Citowett 2 pt.					10	10.0
" 3.6 " " " 3/4"	28	20				24.0
" 3.2 " " " 2 "					20	20.0
" 2.8 " " " 1½ "			12	12		12.0
" 2.8 " " " 3/4"	42	55		16		37.7
" 2.4 " " " 1½ "	39	38				38.5
" 2.4 " " " 1 "	52	57				54.5
" 2.4 " & Nonidet 1 pt/ac	44	44				44.0
" 2.4 " & Risella 8 " "	20	27				23.5
" 1.6 " & Citowett 2 " "					40	40.0
" 1.4 " & " 1½" "				22		22.0
" 1.4 " & " 3/4 "			33	57		45.0
Sig. diff. (P = 0.01)	22	N.S	N.S	38	25	

Series D. consisted of ten unreplicated trials carried out in England and Scotland. Cultural and climatic conditions varied considerably and it is not possible to give details of treatments and results owing to limitations of space. In general, the results confirmed those of the replicated trials that treatments applied to the weeds at the cotyledon stage gave 55% better control than treatments applied at the 2 leaf stage. There was a linear response to increasing levels of pyrazon at constant rates of wetter. Comparisons between different wetting agents showed that Citowett and Nonidet were more effective than both Risella and Teepol. Generally, rates of pyrazon at less than 2.8 lb/ac a.i. plus Citowett or Nonidet at less than 3/4 pt. did not give satisfactory weed control.

There were no indications that different soil types affected the results. Weed control inspections at frequent intervals up to two months after spraying indicated that there was little or no residual activity and that the action was mainly by foliar penetration. Under conditions of rapid weed regeneration, such as occur on fen peats, effective control of weeds was of limited duration. During the two years under review, the rainfall pattern was irregular affecting weed germination and on the lighter soils, which were more subject to moisture stress, stages of weed development tended to be very uneven with the result that the more mature weeds were not well controlled.

The response of annual weed species to the more successful treatments varied greatly according to stage of development and local climatic conditions, but a summary of the results indicates the following degrees of susceptibility:-

SUSCEPTIBLE OR MODERATELY SUSCEPTIBLE SPECIES.

Polygonum convolvulus, *Chenopodium album*, *Urtica urens*, *Atriplex patula*, *Polygonum persicaria*, *Capsella bursa-pastoris*, *Senecio vulgaris*, *Sonchus oleraceus*, *Stellaria media* and *Sinapis arvensis* (rapid development of this weed frequently made control difficult).

Semi-resistant species. (well controlled in the cotyledon stage under optimum conditions). *Matricaria spp*, *Galeopsis tetrahit*, *Polygonum aviculare*, *Thlapsi arvense*, *Raphanus rephanistrum*, *Veronica spp*, *Viola arvensis*, *Galium aparine*, *Fumaria officinalis*.

Effects on crop. Experiments at sites XI, XII and XIII carried out in 1965 were harvested and crop yields were as follows:-

Table 5.

CROP YIELDS OF WASHED BEET (W.B.) AND SUGAR IN TONS PER ACRE

Treatment	Sites XI W.B.	XI Sugar	XII W.B.	XII Sugar	XIII W.B.
Pyrazon 1.4 lb/ac & Citowett 3/4 pt.	11.00	2.06	17.66	3.24	
" 2.8 " " " 1½ "	11.60	2.16	18.17	3.27	
" 1.4 " " " 1½ "			17.40	3.14	
" 2.8 " " " 3/4 "			18.70	3.47	
" 1.6 " " " 2 "					18.74
" 3.2 " " " 2 "					17.62
" 4.0 " " " 2 "					21.37
Control - untreated	7.35	1.34	13.23	2.39	13.98
Sig. diff. (P = 0.01)	1.60	0.88	N.S.	0.71	N.S.

All treatments gave large increases in yield of washed beet and sugar in comparison with the unweeded controls. Despite a slight initial check to crop growth at site XI, treatments did not reduce yields. The tolerance of beet to treatments applied at the 4-6 leaf stage was demonstrated by the increased yield obtained from the highest dosage rate at site XIII.

Trials carried out in England in 1966 have not yet been harvested, but observations of crop growth indicated that loss of vigour and some chlorosis of the cotyledons generally followed treatments applied at the cotyledon stage. Tolerance increased with age and at the 2 leaf stage only slight damage occurred at three sites in Series B; the crop appeared to recover quickly in good growing conditions, but it will not be known whether there is a permanent effect until these trials are harvested. Sugar beet showed a high degree of tolerance to treatments applied at the 4-6 leaf stage after singling. In Scotland, treatments applied at the earlier stages of beet development did not significantly affect crop vigour.

DISCUSSION

The experiments have shown that the effectiveness of post-emergence treatments depends upon critical timing of the spray application. The majority of weeds are controlled in the cotyledon and early seedling stages but rapidly become resistant with age. However, except in Scotland, the crop is seriously affected at the cotyledon stage and, under some conditions, can be slightly affected at the 2 leaf stage. Tolerance increases as the crop develops and treatments can be applied with safety at the 4 leaf stage.

The optimum time for treatment is therefore shortly after hoeing and singling when the crop has at least 4 leaves and the newly germinated weeds have not developed beyond the first true leaf stage.

A possible explanation for the greater tolerance of the crop in Scotland, is that the leaf cuticle is thicker and foliar intake reduced under the cooler slower growing conditions.

The optimum dosage rate is pyrazon 2.8 lb/ac and Citowett ¾ pt. However, Citowett is a viscous material and a promising alternative wetting agent with easier handling properties is Nonidet. It was found that Nonidet altered the spray pattern and further work is required before recommendations can be made.

As the mode of action is mainly contact with little or no residual activity, weather conditions prior to treatment, at the time of spraying and for about 24 hours afterwards are important. Crops which are not in active growth due to unfavourable weather conditions at the time of treatment, are more liable to damage and poor weed control is obtained when rain falling shortly after spraying washes the chemical from the leaves. Thus, results are inclined to be variable according to the prevailing environmental conditions.

Owing to the considerable variability in the results obtained, due primararily to the dependence on fine weather after spraying and to the short persistence of weed control, especially under conditions of rapid weed regeneration such as on fen peats, it would appear that post-singling treatments should only be applied in an emergency when spraying is the only convenient method of control.

Further work is necessary before this technique can be recommended for general use.

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