TRIALS WITH CHLORBROMURON AND METOBROMURON WITH WETTING AGENT FOR WEED CONTROL IN POTATOES

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Summary Trials are reported in which chlorbromuron and metobromuron were compared alone and with added wetter as residual herbicides for potatoes. The results show that when applied pre-crop emergence, both compounds controlled a wide range of important annual weeds when application was before the 3 leaf stage of the weed, without adverse effect on the crop. The weed control of metobromuron with wetter was superior to chlorbromuron alone but this was only marginal and both compounds would appear to be equally satisfactory as residual herbicides for potatoes.

INTRODUCTION

The field trials which led to the marketing of the potato herbicide metobromuron, were reported at the 8th British Weed Control Conference (Heim, Smith and Lewis 1966). The results presented showed that the herbicide was very safe to the crop, and gave good control of a wide range of annual weeds when applied before weed emergence, but did not give reliable control of germinated weeds.

The enhancement of contact activity of substituted urea herbicides by the addition of surfactants has been reported by Gossett and Reinhardt (1967) and Ilnicki *et al* (1965). In 1967 logarithmic trials were laid down to see if the addition of wetting agent enhanced the contact action of metobromuron. To corroborate this work a number of finite dose trials were laid down in 1967 and 1968 to compare the action of metobromuron and wetter with an established residual potato herbicide with a good contact action and chlorbromuron, a new residual potato herbicide which was reported by Green *et al* (1966) as having excellent contact activity to seedling weeds.

METHOD AND MATERIALS

The compounds used in the trials were as follows:

metobromuron	-	formulated as a 50% wettable powder
chlorbromuron	-	formulated as a 50% wettable powder
linuron	-	formulated as a 50% wettable powder
wetting agent	-	octylphenol-octaglycol ether

All herbicide doses are given as lb a.i./ac and the amount of wetter used is given as percentage of spray volume. The logarithmic trials were sprayed with a Chesterford Mini-log sprayer which gave a 1/12 dilution over a 20 yd plot with a 4.5 ft. swath width. Treatments were applied in 20 gal/ac at a pressure of 30 p.s.i. Assessments of weed and crop damage were made by noting the distances, and hence doses, at which crop damage and adequate control of various weed species occurred.

The finite dose trials were of randomised block design with 4 replicates and a plot size of 24 yd^2. The treatments were applied with a precision plot sprayer in a total volume of 25 or 50 gal/ac at a pressure of 30 p.s.i. As far as possible, applications were made after weed emergence but not later than 75% crop emergence. Weed control assessments were made on 4-8 1 yd^2 quadrat counts per plot and by using the European Weed Research Council scoring system. The latter method was also used to assess crop damage. Estimates of yield were obtained by harvesting 4 x 4 yd row from each plot where possible.

RESULTS

1967 logarithmic trials

Results of these trials are shown in Table 1.

Table 1

Comparative weed control results

Trial No.	Stage of weed at spraying	Minimum dose giving 95% weed control: Chlorbromuron 6.0 - 0.5 lb	Chlorbromuron 6.0 - 0.5 lb + 0.01% wetter	Metobromuron 6.0 - 0.5 lb	Metobromuron 6.0 - 0.5 lb + 0.01% wetter
1	Cotyledon-1 leaf	0.99	1.11	0.75	0.8
2	2 leaf	1.86	2.1	1.91	1.56
3	4 leaf	2.15	2.6	2.0	2.25

1967 randomised block trials

Results of the 1967 series of randomised block trials are shown in Table 2-4.

Trial 1

Location: Duxford, Cambridge. Stage of crop at spraying: 5% emerged.
Soil type: Medium loam. Stage of weed at spraying: 2 leaf.

Table 2

Comparative weed control and yield results

Herbicide and dose in lb/ac:	% weed control and crop score: Chlorbromuron 1.5	Chlorbromuron 2.0	Chlorbromuron 3.0	Metobromuron 1.0 + 0.01% wetter	Linuron 1.5	Weed Nos. Control
Avena fatua	61.8	64.9	77.6	76.1	73.5	490
Tripleurospermum maritimum ssp. *inodorum*	82.85	91.7	91.4	87.3	91.4	373
Polygonum aviculare	98.2	97.8	100	98.2	97.8	924
Sinapis arvensis	100	100	100	100	100	27
Stellaria media	100	96.4	100	100	100	550
Veronica persica	100	100	100	100	100	327
Total Weeds	91.3	92.85	95.1	94.0	94.4	2891
Crop Score	4	5	5	4	5	1
Yield tubers tons/ac	13.75	14.76	13.0	13.26*	14.5	9.2

Significant differences between yields at P = 0.05 = ± 3.39 tons/ac

* Equivalent replicate yield taken from 3 plots only owing to double spraying of third replicate.

Trial 2

Location: Snetterton, Norfolk. Stage of crop at spraying: 25% emerged.
Soil type: Loamy coarse sand. Stage of weed at spraying: 1 leaf.

Table 3

Comparative weed control results

Herbicide and dose in lb/ac:	Weed and crop score EWRC					
	Chlorbromuron 1.5	Chlorbromuron 2.0	Chlorbromuron 3.0	Metobromuron 1.5 + 0.01% wetter	Linuron 1.5	Control
Polygonum aviculare	1	1	1	1	1	6
Polygonum convolvulus	1	1	1	1	1	3
Senecio vulgaris	1	1	1	1	1	2
Veronica persica	1	1	1	1	1	6
Viola arvensis	1	1	1	1	1	3
Total Weeds	1	1	1	1	1	7
Crop Score	2	2	3	2	3	1

Trial 3

Location: Downham Market, Norfolk. Stage of crop at spraying: 75% emerged.
Soil type: Coarse sandy loam. Stage of weed at spraying: 1 leaf.

Table 4

Comparative weed control and yield results

Herbicide and dose in lb/ac:	Weed and crop score EWRC					
	Chlorbromuron 1.5	Chlorbromuron 2.0	Chlorbromuron 3.0	Metobromuron 1.5 + 0.01% wetter	Linuron 1.5	Control
Poa annua	1	1	1	1	1	5
Tripleurospermum maritimum ssp. *inodorum*	2	2	2	1	2	5
Polygonum persicaria	2	1	1	2	1	4
Urtica urens	1	1	1	1	1	4
Total Weeds	2	2	2	2	2	7
Crop Score	1	2	2	3	2	1
Yield tubers tons/ac	15.9	15.7	14.25	14.6	14.8	14.95

No significant differences between yields at $P = 0.05$.

1968 randomised block trials

Results of the 1968 series of randomised block trials are shown in Table 5-8.

Trial 4

Location: Duxford, Cambridge. Stage of crop at spraying: Pre-emergence.
Soil type: Coarse sandy loam. Stage of weed at spraying: Cotyledon.

Table 5

Comparative weed control and yield data

Herbicide and dose in lb/ac:	% weed control and crop score Chlorbromuron 1.25	1.5	2.5	Metobromuron 1.5 + 0.01% wetter	Linuron 1.25	Weed Nos. Control
Aethusa cynapium	28	0	6	78	0	32
Lolium perenne	31	69	77	38	77	13
Matricaria spp.	63	84	84	89	100	19
Polygonum aviculare	89	93	100	95	95	75
Stellaria media	100	100	100	100	100	119
Veronica hederifolia	80	89	62	72	95	80
Viola spp.	89	96	100	100	98	47
Others	26	86	77	83	89	35
Total Weeds	78	85	89	90	89	420
Crop Score	1	1	1	1	1	1
Yield tubers tons/ac	7.3	6.1	6.7	6.7	6.4	5.8

No significant differences between yields at P = 0.05.

Trial 5

Location: Kirton, Lincolnshire. Stage of crop at spraying: Pre-emergence.
Soil type: Clay loam. Stage of weed at spraying: None.

Table 6

Comparative weed control results

Herbicide and dose in lb/ac:	% weed control and crop score Chlorbromuron 1.75	2.0	2.5	Metobromuron 2.0 + 0.01% wetter	Linuron 1.75	Weed Nos. Control
Avena fatua	26	9	0	3	30	34
Galium aparine	67	93	96	93	99	
Matricaria spp.	80	59	92	94	92	254
Polygonum aviculare	77	73	93	77	83	222
Polygonum convolvulus	52	69	69	57	71	65
Polygonum persicaria	47	12	88	8	74	49
Stellaria media	97	97	100	100	100	31
Others	0	100	100	0	0	2
Total Weeds	66	60	82	72	82	657
Crop Score	1	1	1	1	1	1

Trial 6

Location: Duxford, Cambridge. Stage of crop at spraying: 1% emergence.
Soil type: Coarse sandy loam. Stage of weed at spraying: 2 leaf.

Table 7

Comparative weed control and yield results

Herbicide and dose in lb/ac:	% weed control and crop score					Weed Nos.
	Chlorbromuron 1.25	Chlorbromuron 1.5	Chlorbromuron 2.5	Metobromuron 1.5 + 0.01% wetter	Linuron 1.25	Control
Aethusa cynapium	16	11	73	87	85	75
Lolium perenne	92	88	97	96	92	32
Matricaria spp.	90	83	100	100	99	52
Polygonum aviculare	99	100	100	99	100	74
Stellaria media	100	100	100	97	100	33
Veronica hederifolia	89	76	95	96	94	96
Viola spp.	100	94	100	97	100	34
Others	100	100	98	89	95	19
Total Weeds	79	73	93	97	93	415
Crop Score	1	1	1	1	1	1
Yield tubers tons/ac	13.6	15.0	13.7	13.7	14.2	12.5

No significant differences between yields at P = 0.05.

Trial 7

Location: Snetterton, Norfolk. Stage of crop at spraying: Pre-emergence.
Soil type: Loamy coarse sand. Stage of weed at spraying: Cotyledon.

Table 8

Comparative weed control and yield results

Herbicide and dose in lb/ac:	% weed control and crop score					Weed Nos.
	Chlorbromuron 1.25	Chlorbromuron 1.5	Chlorbromuron 2.5	Metobromuron 1.5 + 0.01% wetter	Linuron 1.25	Control
Poa annua	100	100	100	100	100	51
Capsella bursa-pastoris	100	80	100	100	100	15
Chenopodium album	100	100	100	100	100	32
Polygonum aviculare	64	84	97	79	87	67
Stellaria media	100	100	100	100	100	28
Urtica urens	100	100	100	100	100	13
Veronica spp.	64	86	92	91	84	76
Others	58	81	100	86	86	21
Total Weeds	80	90	97	92	92	363
Crop Score	1	1	1	1	1	1
Yield tubers tons/ac	11.2	10.83	10.32	11.0	11.02	9.63

No significant differences between yields at P = 0.05.

DISCUSSION

The results of the logarithmic trials in 1967 show that the addition of a wetter to metobromuron improved the control of weeds at the 2 leaf stage, but had little effect when applied at cotyledon stage and actually reduced control at the 3-4 leaf stage. The dominant weed in these trials was Matricaria spp. however and the results of trials with a number of herbicides not reported here, have indicated that compared with many other weeds, Matricaria spp. show a poor response to the addition of wetter to herbicides. In these trials the addition of a wetter to chlorbromuron consistently reduced weed control and would appear to be of no value. The herbicidal activity of chlorbromuron alone was generally superior to metobromuron alone for the control of emerged weeds, but was slightly inferior when 0.01% wetter was added to the latter.

The results in Table 2 support this conclusion, the weed control of the 2.0 lb rate of chlorbromuron being equivalent to that of the 2.0 lb metobromuron + wetter treatment. Unfortunately, in the other trials of 1967 (Tables 3 and 4) all the chemical treatments gave exceptional weed control and no differences between treatments were apparent. The results of trials in 1968 (Table 5, 6, 7 and 8) confirmed the 1967 trials results with metobromuron + wetter being consistently, although only marginally, superior to the same rate of chlorbromuron for weed control. Compared with the standard herbicide, weed control and crop safety were generally satisfactory from both herbicides and no significant differences between treatment yields occurred.

The results of these trials therefore show that the addition of 0.01% wetting agent to metobromuron improves its contact action and should enable it to be used both pre- and post-weed emergence as is frequently desirable under practical farming conditions. Both compounds should, of course, be used pre-crop emergence. The new herbicide chlorbromuron performed well on different soil types applied both pre- and post-weed emergence and appears to be a very promising residual potato herbicide.

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HERBICIDE TRIALS ON EARLY POTATOES IN PEMBROKESHIRE AND CORNWALL

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Summary Six replicated trials were carried out in 1967 on early potatoes in Pembrokeshire and Cornwall comparing various triazines and mixtures. In each trial four of the replicates were irrigated to simulate the very wet conditions experienced there in April 1966. The remaining two replicates were not irrigated and hence could be regarded as relatively dry owing to the low rainfall for several weeks after spraying. Weed assessments were carried out throughout the season and yields were taken at harvest time. This was followed by sowing susceptible crops on the plots to ascertain whether any effect could be noticed from soil residues.

In these conditions some of the triazine mixtures gave better weed control than ametryne. The most suitable alternative was a prometryne/simazine mixture which gave reliable weed control as well as having no adverse effect on yields or on succeeding crops.

INTRODUCTION

In 1966 weed control was unsatisfactory in early potatoes following the use of ametryne in Pembrokeshire, Cornwall and S.W. Scotland. The cause was thought to be the cold weather delaying weed germination while heavy rainfall in April diluted and decomposed the chemical. When warmer weather brought on weed emergence the chemical remaining in the soil was insufficient to affect control. Moreover, due to the late weed emergence there was no contact action from the ametryne. Under these conditions it appeared that ametryne alone had insufficient residual activity to give the required residual weed control. It was decided therefore to lay down a series of trials to test various triazine mixtures on early potatoes in Pembrokeshire and Cornwall. Records showed that heavy rainfall could be expected one year in six and to simulate these conditions it was decided to use heavy irrigation.

In December 1966 the co-operation of five farmers in Pembrokeshire and one in Cornwall was obtained. Farmers were asked to plant the trial area with seed from one source and variety and with even-sized tubers. Cultivations and planting were to be just the same as for the commercial crop.

METHOD AND MATERIALS

Treatments and Design

Treatment 1 Ametryne 0.75 lb/trietazine 0.75 lb a.i./ac (A 0.75/T 0.75)

Treatment 2 Ametryne 0.75 lb/trietazine 0.5 lb a.i./ac (A 0.75/T 0.5)

Treatment 3 Ametryne 1.13 lb/trietazine 1.13 lb a.i./ac (A 1.13/T 1.13)

Treatment 4 Ametryne 1 lb/simazine 0.2 lb a.i./ac (A 1/S 0.2)

Treatments and Design (continued)

Treatment 5 Ametryne 1.5 lb/simazine 0.3 lb a.i./ac (A 1.5/S 0.3)

Treatment 6 Ametryne 1.3 lb a.i./ac (A 1.3)

Treatment 7 Prometryne 1.2 lb/simazine 0.3 lb a.i./ac (P 1.2/S 0.3)

Treatment 8 Linuron 0.75 lb a.i./ac (L 0.75)

Plots were 10 yd long by two drills with a guard row between each plot and one yd discard between plot ends. In addition, an unsprayed control was to be cultivated as under normal farm practice; this consisted of two drills running the length of one side of the trial.

Four replications	-	irrigated	complete randomized blocks
Two replications	-	under normal conditions	complete randomized blocks

Herbicide applications were made with a knapsack sprayer at 30 gpa and 20 psi.

Collection of Data

Weed control was assessed on a 0-10 basis (10 = complete control) in early May and early June. A score of 7 conforms with the limit of commercial acceptability. Plant counts and yields were taken on whole plots. Yields were taken when the farmer was harvesting the field, using the farm equipment and 6 or 8 of his picking gang to work the plots.

Rainfall

In Pembrokeshire and Cornwall 1966 and 1967 produced opposite extremes of rainfall during the first seven weeks after spraying. Most commercial crops were sprayed in the period 20th March-5th April in 1966 and 6-7 in of rain fell between 1st April and mid-May. Throughout these areas this was equal to 3.0 and 5.3 in of "leaching water" or water in excess of field capacity.

In 1967 in Pembrokeshire between spraying and 31st March, 0.34 in fell at Perkins', 0.64 in at Williams', 1.20 in at McNamara's. All sites received 0.75-1.0 in on 1st April. No rain of consequence fell again until 2nd May. Leaching water under normal conditions varied from 0-0.4 in in the 50 days following spraying in 1967. Hence during this period the natural conditions were relatively dry. After 2nd May 5-6 in of rain fell during May. In Cornwall $4\frac{1}{2}$-5 in rain fell during 50 days after spraying in 1967. Very cold winds prevailed until May and weed emergence was slow in both counties in 1967.

Irrigation

In the 50 days after spraying the rainfall in Pembrokeshire and Cornwall was considerably less than in 1966. Irrigation was therefore used to simulate the wet conditions of the previous year. This meant 3-5 irrigations of 0.5-1.0 in on each site giving a total of 2.75-4.66 in of leaching water. (At Noyes', 6.5 in of leaching water was given due to heavy rainfall.) On the five Pembroke trials irrigation was by means of sprinklers. The Cornish trial was irrigated by a Farrow rain gun.

Other Trial Details

Weather conditions in 1967 split the planting season into two separate spells; mid-February (the trials at Morgan's, Perkins' and Williams' were planted during this spell) and early March (the remaining trial sites). All herbicide spraying was carried out between 8th-12th March in Pembrokeshire and on 20th March in Cornwall.

Varieties were Home Guard (3 trials), Arran Pilot (1), Craigs Royal (1) and Craigs Alliance (1). All trial sites were on fine sandy loam soils. Planting depth was about 3 in and only at Perkins' were the drills pulled down before spraying.

Cultivation of the control plots was unsatisfactory. Farmers were asked to cultivate as they considered necessary. None cultivated before early May by which time the weather had turned wet and the effect of cultivating was barely observable. Either one or two cultivations were done in early-mid May.

Stellaria media was the main weed species throughout the trial series. Polygonum persicaria and P. lapathifolium were important at Morgan's (very high infestation), McNamara's and Williams', Urtica urens at Perkins and Noye and Spergula arvensis at McNamara's and Williams'. Other species frequently encountered were Senecio vulgaris and Sinapis arvensis.

Soil Residues and Following Crops

Possible effects from soil residues on following crops have been investigated. Succeeding crops of Italian ryegrass, swedes, broccoli, kale and oats were grown on the trial areas. Succeeding crops were examined on 21st-22nd September in Pembrokeshire and on 6th September in Cornwall.

RESULTS

Overall Weed Control in Early May

Differences in weed control were apparent in all trials except at Mathias' where too few weeds were present for assessment. With the exception of Morgan's, weed control was better on the irrigated plots. All treatments on the dry plots carried some large weeds which had probably germinated below the level of the chemical in the soil.

Overall Weed Control in Early June

Weed control was certainly better in the irrigated plots in Cornwall, and marginally better at Perkins and McNamara (Table 1). Notable was the lack of persistency from ametryne alone under "dry" conditions, but all treatments on the "dry" plots carried some large weeds which had probably germinated below the level of the chemical in the soil.

Table 1

Weed assessments in early June

Irrigated Plots

	Site	Treatments 1	2	3	4	5	6	7	8
	Morgan	7.75	7.75	8.4	8.0	8.5	7.25	8.2	6.5
	McNamara	8.5	8.0	9.25	8.25	8.9	8.0	8.75	7.5
	Perkins	7.2	7.2	8.75	7.7	9.0	6.8	8.0	8.75
	Mathias	Too few weeds for assessment							
P	Williams	Trial oversprayed by farmer							
	Mean	7.82	7.65	8.80	7.98	8.80	7.35	8.32	7.58
	Placing	5	6	1	4	1	8	3	7
C	Noye*	5.25	4.5	8.75	4.0	7.5	3.5	7.75	7.5

Non-Irrigated

	Site	1	2	3	4	5	6	7	8
	Morgan	7.75	8.0	8.25	8.0	8.5	7.25	8.0	6.5
	McNamara	8.25	7.7	8.0	7.5	8.8	7.5	8.6	7.25
	Perkins	6.0	6.25	8.75	7.5	8.75	2.0	8.0	8.0
	Mathias	Too few weeds for assessment							
P	Williams	Trial oversprayed by farmer							
	Mean	7.33	7.32	8.33	7.66	8.7	5.58	8.2	7.25
	Placing	5	6	2	4	1	8	3	7
C	Noye*	5.5	4.0	7.0	3.5	3.5	0.5	5.5	6.0

P = Pembrokeshire, C = Cornwall

*NB: 10 = complete control, 0 = limit of comm. acceptability and is equal to 7 on other trials.

Of the triazines, the three best were treatments 3 (A 1.13/T 1.13), 5 (A 1.5/S 0.3) and 7 (P 1.2/S 0.3), while the worst were treatments 2 (A 0.75/T 0.5) and 6 (A 1.3). This order of placing had been maintained since early May. The performance of linuron was poor where P. persicaria or P. lapathifolium were present.

Control of Individual Weeds

Stellaria media: Treatment 3 (A 1.13/T 1.13) and 5 (A 1.5/S 0.3) gave the best control of Stellaria media throughout the season. Closely following were treatments 7 (P 1.2/S 0.3) and 8 (L 0.75), the former having rather longer persistency. Poorest results obtained with treatments 6 (A 1.3) and 2 (A 0.75/T 0.5).

Polygonum sp. and Senecio vulgaris: Mixtures containing high doses of trietazine or simazine gave superior control of these species. Linuron was rather weak on both species.

Urtica urens: Treatments 8 (L 0.75), 7 (P 1.2/S 0.3) and 5 (A 1.5/S 0.3) gave good control.

Spergula arvensis: Well controlled by all treatments.

Brassica campestris: This weed was present on one site only; treatment 8 (L 0.75) gave very good control, closely followed by treatments 5 (A 1.5/S 0.3) and 7 (P 1.2/S 0.3).

Effect on the Crop

No visual chemical effects were noted on the crop and there were no treatment effects on plant number.

Yields

Four trials were yielded in Pembrokeshire and one in Cornwall. The fifth Pembroke trial (Williams) was accidentally oversprayed by the farmer. Only yield data for irrigated plots are given at Morgan's, the dry plots were not harvested satisfactorily.

Two analyses of variance were done on the yield data (Table 2 A & B), one involving the four irrigated replicates only and the other analysis was on both irrigated and non-irrigated replicates together.

Analysis of variance shows no significant difference between yields at the 0.05% level of significance with the exception of high ametryne/trietazine (A 1.13/ T 1.13) on irrigated treatments at McNamara's.

Although high ametryne/simazine (A 1.5/S 0.3) markedly reduced yield on non-irrigated plots at Mr. Noye's, Table 2 (B), this reduction has not proved significant when irrigated and non-irrigated treatments were analysed together.

Table 2

Potato yields as % of ametryne yields
(Yields have been corrected for plant numbers)

Farmer	Treatments 1	2	3	4	5	6	6 (Tons/ac)	7	8	LSD P = 0.05%
(A) Irrigated Treatments										
Morgan	98.1	97.3	107.4	109.9	105.7	100	(5.25)	106.8	93.0	25.4
McNamara	100.8	99.5	121.0	111.9	108.2	100	(7.3)	111.1	109.7	18.9
Perkins	85.5	96.3	97.4	105.7	120.5	100	(4.5)	114.6	101.6	33.5
Mathias	100.9	108.9	110.5	104.8	107.2	100	(6.4)	92.8	103.3	20.7
Noye	99.6	118.2	106.6	105.1	99.2	100	(3.9)	114.7	112.7	31.9
(B) Irrigated and Non-Irrigated										
Morgan				Not yielded satisfactorily						
McNamara	101.9	103.9	107.4	106.4	105.8	100	(6.56)	112.9	105.3	16.5
Perkins	86.5	105.0	101.3	102.7	116.1	100	(6.75)	119.6	99.0	25.1
Mathias	103.5	105.6	107.0	104.5	104.8	100	(8.6)	97.5	105.9	14.7
Noye	98.3	105.2	97.3	106.1	88.8	100	(5.4)	107.3	105.7	22.2

Soil Residues and Following Crops

No residual effects were noted on Italian ryegrass (4 sites), red clover (1), Condor oats (3), swedes (1) and kale (1) sown between 17 and 19 weeks after application of herbicide treatments, or Seale Hayne extra early broccoli (1) planted 17 weeks after herbicide treatment.

DISCUSSION

In Pembrokeshire and Cornwall, chitted seed are often planted in early February and this necessitates herbicide application about 20th March when the tops emerge and when very few weeds have germinated. In fact weeds generally germinate in mid-April which means that four weeks residual chemical activity has already been wasted. Thus, when the main flush of weeds comes in early May there must be sufficient chemical left to control them. Past commercial experience and this series of trials suggest that this is not the case with ametryne.

The reason is by no means clear. The theory that high rainfall leached the chemical in 1966 has certainly not been confirmed under high rates of irrigation in the present trial series. On the contrary, ametryne alone gave worse weed control and had a shorter active life under dry conditions than under irrigation. Reliability of weed control into May was only achieved with triazine mixtures if a high rate of trietazine or some simazine was included (Table 1). The apparent low reliability of linuron reflected the presence of *Polygonum spp*. on three sites.

A surprising result of the trials was the almost complete absence of yield effects from simazine mixtures under heavy irrigation. In only two out of 15 simazine treatments under irrigation was the crop yield below that of ametryne. On the other hand, under dry conditions, half the simazine treatments yielded below and half yielded above ametryne. Compared with simazine mixtures, ametryne/trietazine mixtures have given variable yield results, many of the treatments yielding rather below the ametryne plots. No chemical treatment effects are apparent on plant numbers relative to control plots.

Although treatments 3 (A 1.13/T 1.13) and 5 (A 1.5/S 0.3) gave the most reliable weed control, they are rather uneconomic and were included in the trials chiefly to show what effect such high doses would have on yields. In fact treatment 5 (A 1.5/S 0.3) caused a non-significant but rather disturbing yield loss on "dry" plots in Cornwall. On the other hand, treatment 7 (P 1.2/S 0.3) gave consistently reliable weed control with no adverse yield effects. A comparative treatment with ametryne (i.e. A 1.2/S 0.3) was not included in the trial series and its worth could not be ascertained.

When a similar prometryne/simazine mixture (P 1.2/S 0.3 for earlies; P 1.6/ S 0.4 for maincrop) was used commercially in 1964, it gave very satisfactory results but was withdrawn because of damage to succeeding crops in Eastern England following a dry summer. However, no adverse effects were seen on succeeding crops following commercial use in wetter regions of Britain and this has been fully borne out in the present series of trials.

In view of the reliability of weed control from treatment 7 (prometryne 1.2 lb/ simazine 0.3 lb a.i./ac) under both the wet and dry conditions of these trials, and the safety of the mixture to the crop and to succeeding crops, it was decided to replace ametryne (1.3 lb a.i./ac) with this mixture on commercial crops in the wetter, early potato regions of Britain in 1968.

Proc. 9th Brit. Weed Control Conf. (1968)

THE POST-EMERGENCE USE OF PROMETRYNE ON POTATOES

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Summary Four replicated trials were carried out in 1967 on early and maincrop potatoes to compare the pre-emergence use of ametryne with a low dose of prometryne applied after crop emergence. Although the prometryne treatment gave good initial weed control the length of the residual activity was insufficient for maincrop potatoes. Also there was a strong check to the crop which resulted in a yield depression in the three trials taken to yield.

INTRODUCTION

In South Lincolnshire during the past few years some farmers have used cultivation techniques for early weed control in potatoes, and have followed this by chemical weed control for late germinating weeds after the crop has emerged. For this purpose prometryne has been used commercially at 1-2 lb a.i./ac when the potato tops were 2-8 in above the soil.

In 1966 limited trials indicated that although weed control was excellent from a post-emergence spray of prometryne the yield of tubers could be reduced. Hence further trials were planned for the 1967 season.

METHOD AND MATERIALS

Four trials were carried out in South Lincolnshire, of which two trials were on early potatoes and two on maincrop. In each trial prometryne, at 1.25-1.5 lb a.i./ac applied when the haulm was 4-8 in high, was compared with ametryne at 1-2 lb a.i./ac applied before crop emergence. The sprays were applied at 40 gallons per acre and the treatments were replicated at least four times. The soil types were a sandy loam and a silt loam for the early crops, and a loamy fine sand and sandy loam for the maincrop. Visual assessments were carried out at intervals on both weeds and crop and yields were taken at normal harvest time.

RESULTS

Effect on weeds Ametryne applied before crop emergence gave good control of annual weeds except for a few surviving plants of *Galium aparine*, *Polygonum aviculare* and *Senecio vulgaris*. In the early crops the weed control was still satisfactory when the crops were harvested in July, while in the maincrops the weeds were still controlled satisfactorily in August after the haulm covered most of the ground. Prometryne applied post-emergence gave good initial control or check to most annuals but 4-6 weeks after spraying the control achieved was not as good as ametryne for *Tripleurospermum maritimum* ssp. *inodorum*, *Galium aparine* and *Polygonum aviculare*.

Effect on crop Ametryne applied before crop emergence caused some yellowing of the haulm on one of the early and on one of the maincrop sites. This was partly due to heavy rain shortly after spraying and partly because planting was poorly executed in one trial where the seed tubers were near the soil surface. On some plants where the symptoms were severe, yellowing persisted for 2-3 weeks.

On all the trials post-emergence prometryne caused yellowing of the haulm. This was more severe on the two maincrop trials which were sprayed when the potatoes were 8 in high. The vigour and height of the haulm was reduced on all trials for most of the season.

Yields Yields were taken at normal harvest time on three of the trials as shown in Table 1.

Table 1

Potato yields comparing pre-emergence ametryne with post-emergence prometryne

Trial No.	Treatment (lb/ac)	Date applied	Crop emergence when sprayed	Yield (tons/ac)
1. Earlies	Ametryne 1 lb	14th April	None	6.7
	Prometryne 1.25 lb	10th May	Up to 4 in	6.1
2. Maincrop	Ametryne 2 lb	19th May	Up to 50%	18.6
	Prometryne 1.25 lb	2nd June	Up to 8 in	16.6
3. Maincrop	Ametryne 1.5 lb	24th May	Up to 10%	17.7
	Prometryne 1.25 lb	12th June	Up to 8 in	14.1

This table shows that the yield was lower in all trials from the prometryne treatment. In one maincrop trial it was reduced by 2 tons (11%), while in another it was reduced by 3.6 tons/ac (20%) when compared with ametryne applied before crop emergence.

DISCUSSION

Although weed control from prometryne applied post-emergence was good initially the residual effect from the low dose used (1-1.25 lb a.i./ac) was not long enough. Ametryne applied pre-emergence at 1-2 lb a.i./ac gave better initial weed control and at 2 lb a.i./ac the residual effect lasted longer.

In the three trials which were taken to yield, post-emergence prometryne treatments yielded less than pre-emergence ametryne. In one early trial the yield reduction was 9%, while in the two maincrop trials the reduction was 10-20%. Farmers who have been applying prometryne post-emergence at their own risk may not have noticed any effect on yield on a field scale. However, the yield indications from trials in 1966 have now been confirmed from the 1967 trials reported above and the practice should, therefore, be discouraged.

Proc. 9th Brit. Weed Control Conf. 1968

THE EFFECT OF TIME OF PARAQUAT APPLICATION ON WEED CONTROL AND THE GROWTH OF POTATOES

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Summary The influence of the time at which paraquat was applied to crops of Arran Pilot and Majestic potatoes was studied in the field in 1967. In a weed-free environment damage to emerged potato shoots was greater the later that paraquat was applied. Spraying early post-emergence caused no obvious delay in foliage development, and the yields, even from a very early harvest, were not affected. The delay in haulm growth from sprays applied at complete emergence or later was reflected in lower yields early in the season although final yields were not significantly reduced. Majestic was less affected by late spraying than was Arran Pilot. In the presence of a natural weed flora early post-emergence application of paraquat gave markedly higher yields than a pre-emergence spray, due to more efficient weed control. Spraying later was reflected in significant final yield reductions in the case of Arran Pilot but not in Majestic which was more strongly competitive to weeds following recovery from chemical damage.

INTRODUCTION

A recent survey of weedkiller usage in the potato crop by the Potato Marketing Board (1966) indicates that the bipyridylium herbicides, particularly paraquat, are used on about half of the sprayed acreage. Due to the non-selective foliar action of these herbicides their use was initially restricted to application before emergence of the crop. However their lack of residual activity with the consequent need to ensure maximum weed germination has led to the widespread practice of delaying application until a certain degree of crop emergence.

Despite this there has been little critical work to evaluate the influence of time of spraying. Taylor (1967) in New Zealand recorded a reduction in yield compared with hand-weeded controls which was only just significant when potatoes five inches in height were sprayed with paraquat. An experiment at S.H.R.I. Mylnefield (Anon., 1966) also showed a reduced yield from paraquat sprayed at 50-70% emergence compared with pre-emergence application, but only at a very early harvest.

In experiments of this type it is not possible to estimate the simple effect of herbicide damage on the crop itself due to the interaction with weed control efficiency. A part of the present investigation was therefore conducted in a weed-free environment to determine the direct effect of paraquat application onto emerged potato shoots. The additional effect of weed competition was examined by a parallel series of treatments in which paraquat was sprayed at similar times onto the same crop with its natural weed association.

METHODS AND MATERIALS

Well chitted Grade A seed of Arran Pilot early and Majestic maincrop potatoes was planted on the 3rd April and 18th April respectively one day after ridging. The tubers, average weight 3 oz, were planted to a depth of 7 in. and had a single apical sprout about 1 in. in length. This was achieved by removing other buds during storage with the object of producing a more uniform emergence and a standard shoot number in the field. In the event the mean winter temperature of 50°F during glass-house storage induced axillary branching on the main sprout which resulted in the normal condition of staggered emergence and multiple stems per hill in the field. The soil type was a sandy clay loam at Jealott's Hill and the spacing of plants 18 in. with 28 in. rows. The varieties were arranged in adjacent randomized blocks with 5 replicates per treatment. Plots comprised 2 rows each with 8 experimental plants divided into 4 sub-plots for successive harvests with guard plants between the plots and sub-plots.

Paraquat with 0·05% wetting agent was sprayed at 0·75 lb (equivalent to 3 pints Gramoxone W) in 40 gal/ac with an Oxford precision sprayer onto plots which had either a natural weed flora or which were maintained in a weed-free condition. The latter was achieved by an overall application of paraquat before emergence followed by shielded inter-row spraying and hand weeding after emergence.

The growth stages at which paraquat was applied in the experiment are shown in Table 1.

TABLE 1.

Times of paraquat application in relation to crop emergence

Growth Stage			Arran Pilot		Majestic	
Number	Emergence	Mean plant height (in.)	Date	Days from 50% emergence	Date	Days from 50% emergence
G1	pre-	0	26.4	-14	8.5	-14
G2	50%	2	10.5	0	22.5	0
G3	100%	4	24.5	+14	29.5	+7
G4	100%	8	31.5	+21	5.6	+14

Shoots were assessed for herbicide damage and the crop harvested 4 times at monthly intervals commencing 6 weeks after 50% emergence. The number and dry weight of weeds from 4 quadrats (each 6 in. x 18 in.) per plot were obtained at the times of spraying and thereafter at the times of crop harvests.

RESULTS

1. Effects on the crop in a weed-free environment

Visual damage to the emerged shoots (Table 2), which took the form of leaf scorch and chlorosis, increased the later that spraying occurred.

TABLE 2

Percentage foliage damage at weekly intervals after spraying

Growth stage	Arran Pilot				Majestic			
	1	2	3	4	1	2	3	4
G2	38*	7	4	1	21*	7	0	0
G3	46	21	14	13	35	17	12	2
G4	66	40	34	-	65	44	12	-

* Damage to emerged shoots at time of spraying only

Application of paraquat at 50% emergence (G2) gave only marginal leaf scorch from which there was rapid recovery; also further shoots emerged soon after spraying. The growth of the haulm as measured by fresh weights taken at the times of crop harvests was not affected. When spraying was carried out at complete emergence (G3) leaf scorch was more extensive but the unexpanded apical leaves grew away healthily after an initial delay. This delay gave a lower haulm weight at the first harvest for Arran Pilot and senescence of the foliage was slightly retarded. The haulm weights of Majestic were not affected. Spraying at the final growth stage (G4) when plants were on average 8 in. in height caused severe damage to the main stems with recovery growth, after a marked delay, occurring from axillary shoots near the stem base giving plants a bushy appearance. This caused reduced haulm weights at the first harvest for both varieties and a noticeable delay in the senescence of the foliage at the end of the season.

The difference in visible damage between the two varieties sprayed at comparable growth stages was not large although there was a tendency for initial scorch to be greater and to persist longer with Arran Pilot than with Majestic. The measurements of haulm weight, particularly following spraying at the intermediate growth stage showed an appreciably quicker recovery with Majestic than with Arran Pilot.

These differences between varieties and times of spraying in the response of the tops to paraquat were reflected in the growth of the tubers (Fig.1).

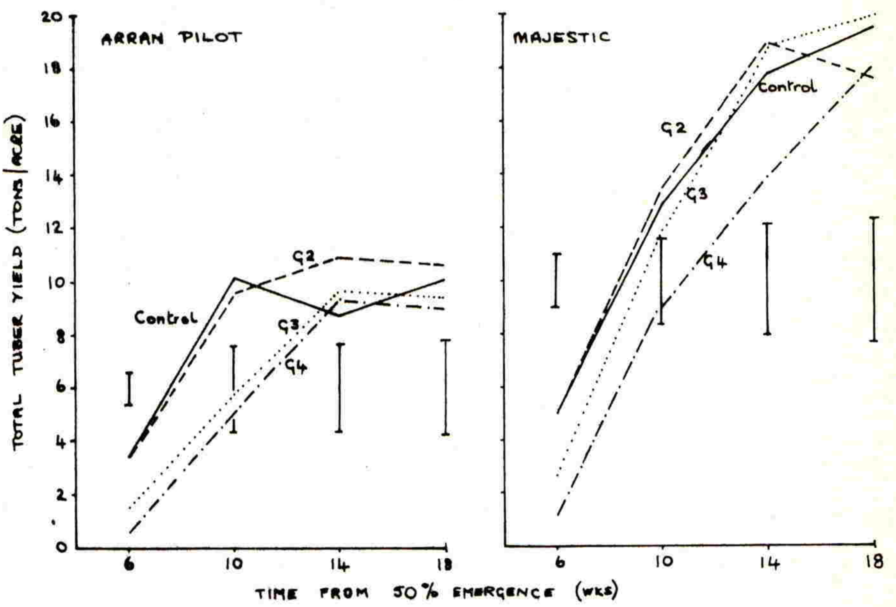

Fig. 1 The change with time in tuber yield in the absence of weeds (unsprayed control ______, paraquat sprayed at growth stages G2 ---, G3 ..... and G4 -.-.-. LSD (P=0·05) indicated by vertical lines at times shown)

Paraquat sprayed at 50% emergence had no effect on the growth of tubers of either variety. Sprays applied after this time caused yield reductions at the early harvests but final yields were similar to those of the unsprayed controls. Majestic was less affected by spraying at the intermediate post emergence than was Arran Pilot. Apparent times of tuber initiation may be deduced by extrapolating the curves to the time axis (Borah and Milthorpe, 1959). This indicates that spraying at G3 delayed tuber initiation by about 1 week and at G4 by about 2 weeks. Neither of these treatments had any obvious effect on the relative rate of tuber growth.

2. The influence of weed competition

The plots left to develop a natural weed flora had a fairly uniform infestation of *Agropyron repens* (couch) with predominantly *Poa annua* (annual meadow grass), *Sinapis arvensis* (charlock), *Polygonum convolvulus* (black bindweed) and *Polygonum aviculare* (knotgrass) in the spring flush of annual weeds.

Although weed species were recorded individually, for the sake of simplicity only the total values are presented (Table 3).

TABLE 3.

Total dry weight (g) and numbers of viable weeds ( ) per 3 ft^2 at times of spraying (S) and harvests (H1-H4) shown

Variety	Growth stage	S	H1	H2	H3	H4
Arran Pilot	G1	0·080(28)	15·1	102·6	97·0	52·2
	G2	0·472(44)	6·8	45·4	46·5	28·1
	G3	4·89(114)	24·6	89·4	80·9	27·2
	G4	14·3 (135)	20·1	76·8	56·0	22·5
	Control	-	90·5	170·9	96·9	70·9
Majestic	G1	0·060(25)	17·4	45·8	65·8	44·3
	G2	0·894(49)	6·3	30·5	25·7	26·9
	G3	2·80 (80)	3·6	10·1	8·2	9·1
	G4	8·17(103)	6·4	22·7	19·0	16·7
	Control	-	71·9	112·6	110·0	64·7

At the first time of spraying (G1) immediately before the crop had appeared weed cover was sparse and comprised mainly the young shoots of *Agropyron repens* and *Sinapis arvensis* at the cotyledon stage. At 50% crop emergence (G2) there was a general cover of all weed species at the cotyledon to young seedling stage. The increase in the number of weeds beyond this time was due to further shoot production by *Agropyron repens* and to the extended germination of *Poa annua* and *Polygonum aviculare*. The data of dry weights of weeds collected at the various times of crop harvests clearly show for both varieties the poor control achieved by spraying before crop emergence. This was due to the rapid regeneration of *Agropyron repens* and to the germination of further annual weeds before the establishment of a crop canopy.

For Arran Pilot best weed control was obtained by spraying at 50% emergence (G2). Sprays applied after this time gave poorer control of *Sinapis arvensis* and *Polygonum aviculare* which were then well developed; their regeneration together with that of *Agropyron repens* was aided by the reduction in crop vigour caused by spray damage. In the case of Majestic, best weed control was achieved by spraying at complete emergence (G3). The resistance of *Sinapis arvensis* and *Polygonum aviculare* at this time was more than offset by the increased numbers of weeds controlled and by the greater recuperative ability (and hence competitive influence) of the variety.

The tuber yields depicted graphically in Fig. 2 show a good correlation with weed control.

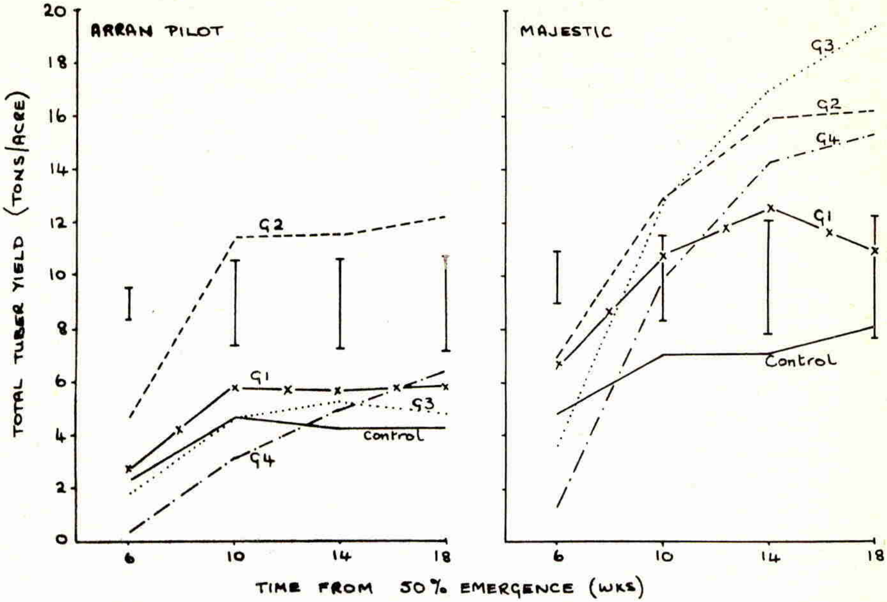

Fig. 2 The change with time in tuber yield in the presence of weeds (unsprayed control ______, paraquat sprayed at growth stages G1 x ______x, G2 ---, G3 ...... and G4 -.-.-. LSD (P=0·05) indicated by vertical lines at times shown.)

The yield from unsprayed plots, where weed infestation was very heavy, was only 40% of that from controls in the weed-free environment (Fig. 1).

For Arran Pilot these was a very clear advantage of spraying at 50% emergence in terms of tuber yields at all harvests. For Majestic the optimum time was less clearly defined since all post emergence applications gave yields which were eventually greater than that from pre-emergence spraying but were not significantly different between themselves. However there was a trend towards maximum yield from spraying at the intermediate post emergence stage (G3).

DISCUSSION

In contrast to crops grown from true seed the potato has a large supply of food reserves which make a significant contribution to growth for some time after emergence (Headford, 1962). It is to be expected therefore that recovery from early contact damage will be rapid provided growth is not impeded by adverse temperature or water supply.

Thus in the absence of weeds when paraquat was sprayed at 50% emergence with emerged shoots on average 2 in. in height there was no deleterious effect on crop development. Even the retardation in early haulm growth by spraying well after this time was compensated by delayed senescence of the tops at the end of the season leading to a prolonged period of tuber growth and similar terminal yields. The lower early yields were the consequence of a delay in tuber initiation rather than to a lower rate of bulking. This indicates that the effect of paraquat is simply that of physically removing a part of the leaf area, i.e. reducing photosynthetic capacity, rather than having a more deep-seated effect on photosynthetic efficiency.

When sprays were applied in the presence of weeds crop yields reflected a complex interaction between the direct effects of paraquat on the weeds and on the crop and the indirect effect of damage to the crop reducing its competitive ability. In the present investigation paraquat was clearly more effective sprayed after rather than before emergence of the crop. However, the optimum time of post-emergence application differed between the two varieties.

For Arran Pilot best weed control and crop yields were obtained by spraying at 50% emergence since there was no significant set back to crop development and there was a good emergence of weeds at a susceptible stage of growth. Although more weeds were available for control by paraquat after this time the sprays were less effective due to the retardation of crop growth and to the partial resistance of certain weeds which were then well established. These factors combined to allow more weed development and gave lower yields. For Majestic best weed control and highest final yields were obtained by spraying somewhat later, at 100% emergence. The data suggest that the greater power of recovery from spray damage of the variety was a major contributory factor. More extensive work on the comparative susceptibility of potato varieties to herbicides in progress at the N.I.A.B. may reveal further differences capable of practical exploitation.

It must be emphasized that the foregoing results were obtained using well sprouted seed which produced a crop emerging in advance of the main flush of weeds. With unchitted seed it may frequently be unnecessary to delay spraying until after emergence to obtain optimum weed control and yields. A further point which must be stressed is that large healthy seed was used and the herbicide sprays were applied during a period of abundant moisture. In addition the haulm was kept healthy for as long as possible with regular fungicide sprays against blight. Under these conditions there was the minimum impedence to crop recovery following spray damage and the maximum opportunity for a long period of bulking. In practise these conditions will not always apply. Moreover the results show clearly that where maximum early yields are required late spraying should be avoided. In view of all these factors it is obviously necessary for the practical recommendations to contain a reasonable margin of safety and it is advised that paraquat be applied not later than 10% emergence on early varieties or 40% emergence on maincrops.

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A GRANULAR FORMULATION OF EPTC FOR THE CONTROL OF PERENNIAL GRASSES AND OTHER WEEDS IN POTATOES

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Summary EPTC applied as a granule treatment gave a consistent but small (4%) increase in the control of couch grass over EPTC applied as a spray treatment. The use of 5% granule at 80 lb/ac product at one site gave improved control of couch and broad leaved weeds over the 10% granules at 40 lb/ac product. This was probably due to more efficient distribution. The improvement of annual weed control by the granule treatment over the spray treatment was 12% at the late season assessment indicating increased persistence by the granular formulation.

INTRODUCTION

Following successful trial results in 1966 (Bartlett and Marks 1966) EPTC was introduced commercially in 1967 for the control of perennial grasses in potatoes. Commercial results in the Netherlands in 1967 showed that a granular formulation could be used satisfactorily in potatoes.

In the U.K. one of the main disadvantages of a sprayed application of EPTC is the need to incorporate the EPTC into the soil within 15 minutes of application, to avoid vapour loss. Gray and Weierich (1965) have compared the vapour loss of different formulations of EPTC from soils of varying wetness by steam distilling the remaining EPTC from the soil samples and analysing the distillates. By extrapolation from their graphs the approximate figures for a comparison of EPTC sprayed and granular application can be seen in Table 1.

Table 1.

Comparison of vapour loss of EPTC spray and granule application on soils of different moisture

Soil Moisture	Vapour loss as % of original 3lb/ac a.i. at various times after appln.							
	15 min		1 hour		2 hour		24 hour	
	spray	granule	spray	granule	spray	granule	spray	granule
dry	20	0	22	0	23	1	24	10
moist	27	9	46	22	47	28	58	41
wet	44	16	67	25	73	45	85	79

The possibility of less vapour loss before incorporation and greater persistence in the soil by a granular application of EPTC prompted The Murphy Chemical Company Limited to carry out a series of trials to compare liquid and granular applications of EPTC in potatoes.

METHODS AND MATERIALS

EPTC: s-ethyl NN dipropylthiolcarbamate - (used as Eptam) an e.c. containing 72% a.i. w/v, at 4 lb/ac a.i., and as 5% and 10% a.i. granular formulations based on Fullers Earth SYK 22/44 at 4 lb/ac a.i., the 5% g. was only applied at site 5.

The 10% granules were grower applied at sites where EPTC e.c. was going to be applied commercially. The granule treated area was one acre in size, while the sprayed area varied in size from one to twenty acres; counts were only taken from the acre adjacent to the granule treatment.

Site details appear in Table 2.

Assessments of couch and annual weed control were made soon after full crop emergence and again just before harvest. Assessments were made by taking 10 quadrats of 10 x 20 in. on top of the potato row, in each treatment. Annual weed assessments were made only at sites where no herbicide other than EPTC was applied.

Table 2.

Site details

Site No.	Location	Applcn. date	Planting date	Soil type	Organic matter % w/w	Method of granule application	Method of incorporation
1	Suffolk	25.3.68.	30.3.68.	sandy loam	1.6	Vicon Vari-spreader	reciprocating harrow
2	Norfolk	8.4.68.	26.4.68.	fine sandy loam	2.3	International fertiliser spinner	rotavator
3	Worcs.	9.4.68.	13.4.68.	sandy clay loam	2.5	Vicon Vari-spreader	rotavator
4	Essex	11.4.68.	13.4.68.	sandy clay loam	2.9	Horstine Farmery air-flow	disc harrows
5	Herts.	16.4.68.	16.4.68.	loam	4.0	Vicon Vari-spreader	spring tines + rotavator
6	Yorks.	25.4.68.	29.4.68.	loamy sand	3.7	Vicon Vari-spreader	disc harrows + rotavator
7	Herefs.	30.4.68.	30.4.68.	loam	2.5	fertiliser fiddle	disc harrows + planter
8	Herts.	2.5.68.	1.4.68.	sandy clay loam	3.7	Vicon Vari-spreader	re-worked ridges

Table 3.

% couch and annual weed control from any early and late assessment

Site No.	Dominant couch sp.	Assessment at crop emergence: % annual weed control, spray	granule	% couch control, spray	granule	Assessment pre-harvest: % annual weed control, spray	granule	% couch control, spray	granule
1.	A. repens	-	-	82.7	88.9	-	-	-	-
2.	A. repens	100.0	100.0	100.0	100.0	100.0	100.0	96.2	98.7
3.	A. repens	88.2	94.9	100.0	99.4	80.4	98.0	100.0	100.0
4.	A. repens	-	-	90.4	98.5	58.7	88.7	84.2	99.2
5.	A. gigantea/ A. repens	89.9	94.9 (98.3)	85.5	90.4 (98.8)	85.2	94.4 (99.1)	91.9	94.1 (100.0)
6.	Agrostis tenius	100.0	93.7	94.7	97.5	61.3	67.7	89.6	91.6
7.	A. repens	92.3	92.9	89.0	95.0	-	-	-	-
8.	A. gigantea	-	-	91.0	95.8	-	-	94.8	97.9
	average values	94.1	95.3	91.7	95.7	77.1	89.8	92.8	96.6

Figures in brackets () at site 5 represent % weed control by 5% granules applied at 4 lb/ac a.i.

DISCUSSION

Control of A. repens at site 1 was slightly lower than average which may have been due to the rather shallow incorporation achieved by the reciprocating harrows. No second assessment was possible because the potatoes var. Desirée were burnt off and harvested early for seed. Yields were - untreated 6.48 ton/ac, spray 8.04 ton/ac and granules 7.26 ton/ac. This is the only site which has been harvested to date.

At site 2. both the EPTC treatments were rotavated to a depth of 12 in. but still gave 100% control of A. repens and of Avena fatua which was the only other weed present.

The second assessment at site 3. showed that the granules gave control of A. repens equal to the sprayed treatment, but gave an 18% improvement in annual weed control. The control of the two dominant weeds - Stellaria media and Polygonum aviculare was only slightly improved whereas that of Poa annua and Chenopodium album was improved by over 50%. A similar result was found at site 4. where the granule improved the control of P. convolvulus by 46%. C. album, S. media and Sinapis arvensis were well controlled by both treatments.

At site 5. an application of 5% granules at 4 lb/ac a.i. was also included and gave a noticeably superior control of S. arvensis and P. convolvulus over the 10% granules. Both treatments gave an improved control of these weeds and of P. aviculare over the spray treatment. All treatments gave good control of Fumaria officinalis, Galium aparine, S. media and Tripleurospermum maritimum ssp. inodorum.

Agrostis tenuis occurred only at site 6. where the control by both formulations was slightly below average for the second assessment, but there was no sign that the regrowth was by stolons as has been noticed elsewhere.

The granule application at site 7. was by a fertiliser fiddle, incorporation was by one-way discing and cross planting. In spite of any doubts about application and incorporation the control of *A. repens* and annual weeds including *P. persicaria*, *C. album*, *P. aviculare* and *T. maritimum ssp. inodorum*, was satisfactory. No second assessment was possible because the grower cultivated through the untreated and sprayed plots.

At site 8. both spray and granule treatment were applied post planting and an application of paraquat was made over the untreated area at potato emergence. In spite of this the control of *A. gigantea* was very good at both assessments, the granule being slightly superior. One portion of the sprayed plot received an additional application of granules, there was no visible effect on the crop.

Grower assurances, from all sites, have been received that application was made on to dry or slightly damp soils and that incorporation took place within 15 minutes. An interesting technique was used at site 5. where a very rapid shallow incorporation was first made using spring tine harrows, later followed by a deeper more thorough incorporation with a rotavator.

Granule application generally proved satisfactory. The most suitable machine was found to be the Horstine Farmery Airflow applicator which with a 30 ft swathe gave very even distribution. The Vicon Vari-spreader, which had to be modified by the addition of two blanking-off discs in the feeding mechanism, and the International fertiliser spinner, were barely able to apply a rate as low as 40 lb/ac, particularly with the small quantities supplied for the trials. At site 5. the application of 5% granules at 80 lb/ac by the Vari-spreader enabled a more even distribution which almost certainly was responsible for the improved control of couch and annual weeds at this site.

The EPTC 10% granules gave a consistent 4% increase of couch control at both assessments and of annual weed control at the first assessment, the increase of annual weed control at the second assessment was 13%. It is not known whether the improved couch control by the granules was due to reduced vapour loss before incorporation or increased soil persistence, but the 13% improvement of annual weed control by the granules at the second assessment compared with the 4% improvement at the first assessment was most likely due to increased persistence of the granules.

Acknowledgements

The authors wish to thank the growers who carried out the trials.

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Proc. 9th Brit. Weed Control Conf. (1968)

HERBICIDE USAGE ON MAINCROP POTATOES IN GREAT BRITAIN

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Summary The Maincrop Survey conducted in 1963 by the Potato Marketing Board indicated that the control of weeds was almost entirely by traditional cultivations: approximately 1% of the potato crop was treated with pre-emergence herbicides based on diquat salts, another 1% was treated with dinoseb and MCPA.

Total maincrop application of herbicides in England and Wales in 1965, 1966 and 1967 was 16%, 22% and 33% respectively (50% bipyridyl compounds, 10% triazines, 25% urea compounds). In Scotland herbicide usage for the same period was 7%, 19% and 37% respectively (50% bipyridyl compounds, 10% urea compounds). 30% of the total acreage checked in Scotland received applications of both a contact and a residual herbicide, compared with a figure of 3% in England and Wales.

Herbicide usage is discussed in relation to varieties and different factors of production.

The Maincrop Survey conducted in 1963 by the Potato Marketing Board in collaboration with the Survey Section of the N.I.A.E. and the Statistical Department of Rothamsted Experimental Station recorded information from 905 farms in England, Scotland and Wales on potato husbandry practices up to and including planting.

The Survey (Potato Marketing Board 1963) indicated that weed control was almost entirely by traditional post-planting mechanical cultivations and that the picture was

Table 1.

	Average number of post planting operations 1963	1958
Harrowing	1.3	2.0
Ridging	1.7	1.6
Other cultivations	2.5	2.3

(P.M.B. Maincrop Survey 1963)

more or less the same as for the previous Survey five years earlier (Table 1). In 1963 approximately 1% of the potato crop was treated with pre-emergence herbicides based on diquat salts and another 1% was treated with dinoseb and MCPA.

The main purpose of the crop check weighing survey as carried out by the Potato Marketing Board is to estimate the national yield. Farms are selected so that as far as possible there will be a fair proportional representation of soils, varieties and production acreages.

For the period 1965 to 1967 the total acreage included in the crop check weighing survey and the percentages of this acreage treated with herbicides are shown in Table 2.

Table 2.

Percentage of acreage treated with herbicides - Crop Check Weighing

	England and Wales			Scotland		
	1965	1966	1967	1965	1966	1967
Total Acreage checked	17,745	14,741	15,202	7,783	7,065	7,631
% of acreage treated with herbicides	16.0	22.0	33.0	7.0	19.0	37.0

Overall use of herbicides in England and Wales has doubled over this period to the present value of 33% of total acreage treated; the corresponding level of herbicide treatment in Scotland has increased by approximately five times over the same three year period to the level of 37%.

Table 3.

Percentage of total acreage sprayed with various herbicides

Herbicides	England and Wales			Scotland		
	1965	1966	1967	1965	1966	1967
Bipyridyls	41.5	39.4	53.5	31.2	41.0	48.8
Dalapon	0.7	0.6	0.3	3.7	-*	-
MCPA	5.7	6.2	2.6	9.2	-	-
Dinoseb	12.4	10.3	3.0	8.2	8.0	2.8
Triazines	7.9	9.0	10.7	-	0.7	2.8
Ureas	28.9	27.9	25.1	17.1	9.1	11.5
Contact + Resid. Mixt.	2.0	5.9	3.5	29.8	34.4	32.6

-* : nil acreage

In the United Kingdom as a whole the contact acting herbicides, the bipyridyls - paraquat, diquat plus paraquat, constitute half of the total herbicide application. The triazine compounds (ametryne and prometryne) are approximately 10% of the total usage in England and Wales but are used to a much smaller extent in Scotland. Approximately 25% of the total application in England and Wales is made up of the urea compounds (linuron, monolinuron, linuron plus monolinuron). In Scotland the figures for the use of residual acting herbicides by themselves are somewhat less than in England and Wales, but here there is a much greater use of mixtures of contact and residual herbicides, mainly monolinuron and paraquat, which are not yet commercially available in the rest of the country (Evans, S. 1968).

Although it might be predicted or recommended that varieties with a less spreading haulm growth, for example Pentland Dell, might receive more treatment with herbicides than a variety such as Majestic, which exhibits greater haulm spread across the drills, there is no evidence from the Board's survey to show that this is in fact the case. The treatment of maincrop varieties with herbicides shows no bias towards any variety. It would seem therefore that potato producers have no experience of a specific reaction of a variety to a herbicide that might in turn have influenced the choice of herbicide that was applied.

Table 4a.

England and Wales - % of total acreage of varieties treated with herbicides 1965-1967

Majestic			King Edward			Record			Redskin			Pent.Crown			Pent.Dell			Others		
'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
14	21	32	17	23	36	24	30	41	16	17	20	23	23	40	14	21	34	33	39	36

Table 4b.

England and Wales - % of total acreage of each variety sprayed with various herbicides

Variety	Bipyridyls			MCPA			Dinoseb			Triazines			Ureas			Contact + Resid.		
	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67	'65	'66	'67
Majestic	40	33	55	5	11	1	12	8	4	15	11	10	26	34	25	-	2	2
King Edward	39	47	50	8	1	1	15	13	1	8	7	14	37	22	29	1	7	6
Record	38	17	59	-	-	-	10	15	4	-	-	4	52	27	19	-	35	14
Redskin	34	77	77	-	-	-	-	-	-	-	-	-	40	23	23	26	-	-
Pentland Crown	38	41	46	11	8	15	29	-	11	3	12	7	24	38	21	-	-	1
Pentland Dell	38	47	56	-	8	2	31	18	3	-	-	11	31	26	23	-	-	4
Others	69	50	72	-	-	10	-	19	-	6	22	6	7	9	12	-	-	-

Pot and field trials at the N.I.A.B. support the thesis that no yield reductions will be caused and varietal differences will tend to disappear if herbicides are correctly applied, before emergence of the potato and with the seed covered by an adequate depth of soil. 4" appear to be enough in the pots though field trials at Terrington in 1966 showed that 7" was needed in the field.

Table 5.

Regional use of herbicides (England and Wales)
(% of total checked acreage on which herbicides used)

Year	West & Wales	South East (& London)	Midlands & NW.	East	North
1965	41	29	18	10	12
1966	44	35	27	15	19
1967	63	46	37	25	34

The Board surveys indicated that 63% of the potato acreage in the West of England and Wales region received herbicide applications in 1967 (Table 5) which is significantly higher than the national average of 33% sprayed in 1967, and quite considerably higher than the figure of 25% for the Eastern region which includes the important maincrop potato producing areas of Lincolnshire, Ely, Peterborough and Cambridgeshire.

The results of the survey, however, also suggest that herbicides are used by the bigger acreage producers than the smaller acreage producer (Table 6). There are more bigger acreage producers in the Eastern region than in the West but their actual numbers are, of course, relatively few and this might well account for the apparent anomaly that more herbicides are used in the West and also more by the bigger acreage producers, the majority of which are in the Eastern region.

Table 6.

England and Wales - distribution of potato acreage planted by registered producers by acreage size-group

Acreage Size-Group	1965 a*	1965 b*	1966 a	1966 b	1967 a	1967 b
0-10	1	19	1	18	1	17
10-20	5	18	5	18	6	18
20-30	9	13	7	13	9	13
30-40	11	10	11	9	10	9
40-60	16	12	18	12	15	13
60-75	9	6	10	6	10	7
75-200	24	17	31	17	33	17
200+	25	6	16	6	17	6
Total	100	100	100	100	100	100

*a: % acreage using herbicides, by acreage size groups
*b: % National acreage, by acreage size group

Table 7.

Regional use of herbicides in England and Wales (% of total use in each region)

Herbicide	West & Wales '65	'66	'67	Scotland '65	'66	'67	Midlands & NW '65	'66	'67	East '65	'66	'67	North '65	'66	'67
Bipyridyls	63	59	75	40	41	55	33	38	48	28	31	44	68	47	67
MCPA	-	-	-	3	5	-	12	8	6	11	9	3	-	4	5
Dinoseb	16	8	5	9	7	3	5	10	5	17	17	2	15	6	1
Triazines	11	16	8	16	12	7	5	7	7	3	11	18	-	-	-
Ureas	10	17	11	28	26	29	45	20	24	35	31	29	16	39	19
Others	-	-	2	1	11	6	-	18	10	5	2	2	2	4	1

The contact acting herbicides are used to a greater extent in the Western region and Wales, the North of England (Table 7) and Scotland (Table 3), namely where the rainfall is normally higher than the rest of the country, and there is correspondingly less use of the herbicides with a mainly residual action. The Eastern region which normally experiences a drier growing season (the 1968 weather being regarded as somewhat abnormal) shows less use of these contact herbicides and a greater usage of urea compounds. It would seem that in wetter parts of the country it is an advantage to use a contact herbicide and thus reduce any danger of a residual acting herbicide being washed down into the soil and affecting the tubers.

There may be several reasons for the variation in overall use of herbicides over the country. Firstly in the West country, Wales and Scotland and the normally higher rainfall and hence greater weed growth combined with land of varying contours (Anderson 1967) can make conditions difficult for cultivations. Producers in the West and Wales might be more likely to be in the habit of using herbicides on their crop of early potatoes and may thus tend to treat the maincrop in the same way.

The Potato Marketing Board Maincrop and Early Survey of 1968 should supply even more information on the growth and distribution of herbicide usage in Great Britain.

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FURTHER WEST OF SCOTLAND TRIALS WITH POTATO HERBICIDES

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Summary 1965 trials suggested that differences in weed growth stages at spraying might account for variation in weed control by herbicides. Trials in 1966 and 1967 did not confirm this, but again showed that application of soil-acting herbicides within 10 days of planting was too early for best results. On the other hand, post-emergence treatments with linuron or paraquat in 1967 gave excellent control of weeds up to the young plant stage, but as in 1966 there appeared to be a risk of reduced potato yields from paraquat used post-emergence on maincrop varieties. Post-emergence spraying with linuron gave a smaller mean reduction in yield. For practical purposes spraying at about the time of first potato shoot emergence was a sound recommendation.

INTRODUCTION

The trials covered by this paper continued those reported to the Seventh British Weed Control Conference (Waterson, 1964) which showed that herbicides could substitute for cleaning cultivations in the potato crop under relatively high rainfall conditions. There was, however, variation in the control of some species even by the most successful treatments and in these later trials, factors affecting the reliability of herbicides under field conditions were considered.

Seven trials in 1965 studied low and high rates of three soil-acting herbicides, the low doses used in conjunction with paraquat, and paraquat alone. Two trials in 1966 compared planting-time sprays of three soil-acting herbicides with spraying at first potato shoot emergence; also emergence and post-emergence applications of paraquat. Three trials in 1967 included three spray timings of linuron and two of paraquat. All trials included additional evaluation treatments of newer herbicides which are not reported here.

METHODS AND MATERIALS

The methods used were those described for the earlier trials (loc. cit.) except that fixed quadrats (randomly located within the plots) were adopted for weed counts. The monolinuron used 1965-6 was a 50 per cent w.p. supplied by Messrs. Hoechst Chemicals Ltd., other materials were the same as in the first trial series. Trial sites are identified in the tables by the county in which they were located.

RESULTS AND DISCUSSION

1965 Trials

Table 1 gives the 1965 herbicidal treatments and mean weed control scores from seven trials. Also, whether satisfactory control was obtained of weed species present at more than one centre, and mean tuber yields from the three trials weighed.

Table 1.

1965 Trials. Weed control and tuber yields

Treatment. oz. a.i. per acre (emergence spraying)	Mean tuber yield tons per acre (3 centres) Centres: A R W	Mean weed control score scale 1-10 (7 centres)	*Galeopsis tetrahit* S_2	S_1	C	P	*Polygonum persicaria* A	C	R	S_1	*Spergula arvensis* P	S_2	C	*Stellaria media* A	R
Linuron 16	14.4	8	+	0	0	0	+	0	0	0	+	+	0	0	+
Linuron 32	14.8	9	+	0	0	0	+	0	+	0	+	+	0	+	+
Monolinuron 16	14.9	8	+	0	0	+	+	0	0	0	+	+	0	+	+
Monolinuron 32	14.0	9	+	0	0	+	+	0	0	0	+	+	0	+	+
Prometryne 16	13.1	7	+	0	0	0	0	0	0	0	+	+	0	+	+
Prometryne 32	12.9	8	+	0	0	0	+	0	0	0	+	+	0	+	+
Linuron 16 + paraquat 12	15.0	8	+	0	0	0	+	0	0	0	0	+	0	+	+
Monolinuron 16 + paraquat 12	14.4	9	+	0	0	0	+	0	0	0	+	+	0	+	+
Prometryne 16 + paraquat 12	13.1	8	+	0	0	0	0	0	0	0	+	+	0	+	+
Paraquat 12	12.7 ± 1.8	6	+	0	0	0	+	0	0	0	0	+	0	+	0
Weed growth stage (at spraying)			C	1	2	2	C	1	1	1	C	1	3	C	4

Growth stages - 1, 2, 3, 4 leaves
C = cotyledon

Centres - A Ayrshire
C Cowal, Argyllshire
P Perthshire
R Renfrewshire
S Stirlingshire
W Wigtownshire

\+ - > 80% control
0 - < 80% control

Table 2.

1966 Trials. Species and overall weed control; tuber yields

Treatment, oz. a.i. per acre and timing			Tubers over $1\frac{1}{4}$", tons per acre	Weed Control score, scale 1-10 10/6	Weed Control score, scale 1-10 13/7	*Chenopodium album*		*Galeopsis tetrahit*	*Polygonum aviculare*	*Polygonum persicaria*	*Stellaria media*	
Centres:			A	A	L	A	L	L	L	A	A	L
Linuron	24	(planting)	19.0	9	3	0	+	+	0	0	0	+
Linuron	24	(emergence)	18.3	10	7	+	+	+	+	+	+	+
Monolinuron	24	(planting)	17.3	7	6	0	+	+	0	0	0	+
Monolinuron	24	(emergence)	19.0	9	5	+	+	+	+	0	+	+
Linuron + Monolinuron	24	(planting)	17.5	9	6	0	+	+	+	0	0	+
		(emergence)	17.9	10	7	+	+	+	+	+	+	+
Ametryne	24	(planting)	16.8	7	3	0	+	0	+	0	0	+
Ametryne	24	(emergence)	18.1	10	6	0	+	+	+	+	+	+
Paraquat	16	(emergence)	16.7	9	7	+	+	+	+	0	0	+
		(post-emergence)	13.8	10	8	0	+	+	+	+	+	+
Leaves at emergence spray *						2	2	2	2	1	4	2

* No weeds present at planting spray
Weeds flowering at post-emergence spray

Centres - A Ayrshire
L . Lanarkshire

\+ - >80% control
0 - <80% control

Yield differences between treatments were small, but prometryne and paraquat gave somewhat lower yields than the remainder and the scores show poorer weed control from these treatments. The higher rates of the residual herbicides gave slightly improved weed control without yield advantage.

Control of Stellaria media was, in general, satisfactory, but control of Galeopsis tetrahit, Polygonum persicaria and Spergula arvensis was less dependable. Doubling the dose of the soil-acting herbicides, or adding paraquat to the lower doses, did little to improve control of these species once they were beyond the cotyledon (Spergula arvensis - 1 leaf) stage and it appeared that spray timing and weed growth stage at spraying were likely causes of variable weed control.

Trials 1966-1967 studied the effects of differences in spray timing on weed control, using widely spaced times because of the difficulty in spraying exactly when intended due to weather conditions.

1966 Trials

In view of the 1965 results, soil-acting herbicides were applied within 10 days of planting the crop and at crop emergence; paraquat was applied at emergence and when 30-50 per cent of plants were through the soil. Results from two centres are summarised in Table 2.

Spraying within 10 days of planting reduced weed control by the residual herbicides, the apparent exception for monolinuron at the Lanarkshire centre being due to late-germinating Galeopsis tetrahit in one of the emergence timed plots. Post-emergence spraying of paraquat had spectacular results on both weeds and potatoes, a check from which the crop never recovered completely.

Only two species were well distributed at both centres. Chenopodium album was at the 2 leaf stage at emergence spraying in both trials, but even so was not controlled by ametryne at the Ayr centre. The difference in control of this weed between the two centres from the planting-time spray may have been due to soil and climatic differences between the centres; lighter soil and heavier rainfall at Lanark.

Failure of the post-emergence paraquat spray to control 80 per cent Chenopodium album plants at the Ayr centre was due to sheltering by the potato haulm.

The situation in respect of Stellaria media was essentially the same as for Chenopodium album, and the more advanced development of the plants at the Ayrshire centre at emergence spraying did not affect the results.

1967 Trials

The 1967 treatment timings were within 10 days of planting, at emergence, and post-emergence (50 per cent shoot emergence); linuron was applied at all three times and paraquat only at the last two. Table 3 shows the application rates used for maincrop and early potatoes. Planting-time application of linuron was again less effective than spraying at emergence; the variable yield effects of this treatment presumably reflect the differences in

Table 3.

1967 Trials. Weed control and tuber yields

Treatment, oz. a.i. per acre and timing	Tubers over $1\frac{1}{4}$", tons per acre			Overall weed control scale 1-10			Polygonum aviculare		Spergula arvensis			Stellaria media		
				30/6	14/8	4/7								
Centres:	A	P	W	A	P	W	A	P	W	P	A	W	P	A
Linuron 24 planting	15.5	12.6	5.3	5	7	6	0	0	0	0	+	0	0	+
(W 16) emergence	13.7	13.7	8.1	9	8	9	+	0	+	+	+	+	+	+
post-emergence	13.9	11.7	7.6	9	9	9	+	+	+	+	+	+	+	+
Paraquat 16 emergence	13.6	14.2	6.2	9	8	6	+	0	0	+	0	0	+	+
(W 12) post-emergence	11.9	11.4	7.9	8	9	7	+	+	0	+	+	+	+	+
	±1.7	±1.5	±1.0											
Growth stage emergence							2	2	C	4	YP	C	4	4
post-emergence							4	YP	1	YP	YP	2	YP	YP

Centres - A Ayrshire - variety - Kerr's Pink
P Perthshire - variety - King Edward
W Wigtownshire - variety - Epicure

Growth stages - 1, 2, 3, 4 leaves
C - cotyledon
YP - young plant

+ - control >80%
0 - control <80%

smothering ability of the three potato varieties concerned. The planting-time application of linuron gave good control of four weed species at the Ayrshire centre but allowed a dense stand of Polygonum aviculare to develop which accounted for the low overall weed control score recorded. At the other centres this treatment was less effective against Spergula arvensis and Stellaria media. Spraying linuron at potato shoot emergence gave satisfactory overall weed control at all three centres, although control of Polygonum aviculare at Perth was inexplicably poor. Linuron applied at 50 per cent potato shoot emergence gave excellent weed control but reduced yields compared with the emergence spray at two of the three centres.

Post-emergence spraying with paraquat again gave spectacular damage to the potato haulm with a minor improvement in weed control. Yields at both maincrop centres were lower with this late spraying than with spraying at first shoot emergence, but the early potatoes (Epicure) made a complete recovery and gave a higher yield than those sprayed at emergence.

General

Although the overall level of weed control obtained from herbicides in 1965 was satisfactory, some weed species were not controlled consistently. A possible cause was spray timing in relation to development of the weed seedlings; accordingly and also because farmers were spraying both before and after crop emergence, the 1966 and 1967 trials concerned spray timing.

Early spraying of a soil-acting herbicide reduced its efficiency, in some cases seriously. Spraying linuron at about 50 per cent potato shoot emergence, on the other hand, did not reduce its weed control efficiency but crop yields were lower than from the emergence spray at two out of three centres. Delay beyond emergence for linuron spraying should therefore be minimal. The 1967 trials also suggested that paraquat could be sprayed on to early potatoes (variety Epicure) at 50 per cent emergence without lasting harm, but that maincrops suffered a greater check from such treatment.

A sound practical recommendation with a reasonable safety margin is to spray at or shortly after first potato shoot emergence. Weed growth stage may sometimes be important, but so also may weather conditions at spraying, rainfall, soil type, and sprayer efficiency.

Reference

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Proc. 9th Brit. Weed Control Conf. (1968)

WEED CONTROL IN SUGAR BEET WITH PHENMEDIPHAM

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Summary Field and greenhouse experiments were carried out with phenmedipham (3-methoxycarbonylaminophenyl-N-(3[1]-methylphenyl)-carbamate) for the control of annual weeds in sugar beet during 1967 and '68. Two formulations of phenmedipham, Sch 4072 and Sch 4075H were compared. Susceptible weeds (8 pints Sch 4072/ac, 5 pints Sch 4075H/ac) included *Atriplex patula*, *Chenopodium album*, *Capsella bursa-pastoris*, *Galeopsis tetrahit*, *Sinapis arvensis*, *Spergula arvensis*, *Stellaria media*. All species were best controlled when sprayed at the cotyledon, first and second true leaf stages. Control of *Polygonum aviculare*, *Matricaria inodora* and to a lesser extent *P. persicaria*, *P. lapathifolium*, *Fumaria officinalis* and *Galium aparine* was inadequate.

Sch 4072 and Sch 4075H retarded the growth of young sugar beet plants in greenhouse experiments. Some morphological changes were observed in leaves of treated sugar beet in field and greenhouse experiments but these may not have been caused directly by phenmedipham. Data on the 1967 experiments showed that phenmedipham did not affect yields of roots, sugar content and beet purity.

INTRODUCTION

Pre-emergence soil acting herbicides are widely used for the control of annual weeds in sugar beet. These herbicides often give inadequate control of weeds in heavy (clay loam) and organic type soils and when rainfall is limited following spraying (Cussans, 1964; Lush et al, 1967). Crop phytotoxicity is also sometimes obtained, especially on light soils (Beinhauer et al, 1964; Holmes, 1966). These limitations are not generally associated with foliar acting herbicides and thus there is considerable interest in the latter for use in sugar beet. Pyrazon has limited foliar activity and is not recommended for the control of established weeds (Beinhauer, 1967). The selective herbicidal properties of phenmedipham (3-methoxycarbonylaminophenyl-N-(3[1]-methlphenyl) carbamate) for post emergence use in sugar beet was announced by Arndt et al. (1967). Subsequent reports (Kötter and Arndt, 1968; van Oorschoot, 1968) confirmed the earlier findings and showed that phenmedipham interferes with CO_2 assimilation in plants.

This paper describes some field and greenhouse experiments carried out with phenmedipham in 1967 and '68.

METHODS AND MATERIALS

Field Experiments.

Three field experiments were carried out in 1967 with two formulations of phenmedipham, [1]Sch 4072 and [2]Sch 4075H.

[1]Emulsifiable concentrate 20% w/w
[2]Emulsifiable concentrate 16.7% w/w, containing surfactant.

Experiment 1.

This experiment was carried out to determine the effect of phenmedipham on the growth, yield and sugar percent of sugar beet.

The sugar beet, variety Irish Polyploid Commercial, was sown on a medium loam soil. The experiment was of randomised block design with six replications. Each plot consisted of three rows (inter row 22 in.) of sugar beet, 30 feet long. One row was left untreated between adjacent plots and an untreated area 3 feet wide was left between individual blocks. The herbicide was applied with an Oxford Precision Sprayer in 35 gallons water per acre. Crop vigour was assessed two days before singling and again one week before harvest. At harvest an area of 15.12 square yards was taken for yield determination, plant population counts and chemical analysis.

Experiment II.

This experiment was carried out on a weed infested crop on a free draining sandy loam soil. Methods and materials were the same as in Experiment 1. Weed control assessments were carried out 3 days before crop singling.

Experiment III.

The phytotoxicity of two formulations of phenmedipham (Sch 4072 and Sch 4075H) was compared on weeds in the absence of a sugar beet crop. Experimental design and method of herbicide application were the same as in Experiments I and II. Visual assessments, counts and weight of weeds were determined 17 days after spraying.

1968 Experiments.

Replicated field experiments were carried out in 1968 with Sch 4075H. These consisted of small (1968 A) and large (1968 B) plot experiments, the latter being carried out under the supervision of the staff of the Irish Sugar Co. The large plot experiments were sprayed at a volume rate of 30 gals water per acre with a tractor mounted sprayer. Data on yield and sugar percent are not available at the time of writing.

Greenhouse Experiments.

The effect of Sch 4072 and Sch 4075H on sugar beet was investigated in pot experiments. Sugar beet seeds were sown in trays containing a loam soil mixed with sand and horticultural moss peat. After emergence, the sugar beet seedlings were thinned to 20 plants per tray. The herbicides were applied in approximately 30 gals water per acre using a pressurised sprayer with a fan type nozzle. Each treatment was replicated 6 or 8 times. Visual observations, including vigour scores, were carried out on the beet plants at frequent intervals. The beet plants were harvested when they had 3 pairs of leaves. At harvest plants were washed free of adhering soil, towel dried and their fresh weights determined.

RESULTS

Effect on Weeds.

The control of annual dicotyledonous weeds obtained with Sch 4072 and Sch 4075H in the 1967 experiments is shown in Table 1 and 2. Results are expressed as a percentage of the counts in the control (untreated) plot. Plants which were only partially killed were included in the counts.

Excellent control of Atriplex patula, Capsella bursa-pastoris, Chenopodium album, Sinapis arvensis, Spergula arvensis and Stellaria media, was obtained with Sch 4072 (8 pints/acre) when sprayed before the weeds had more than two pairs of leaves. Polygonum aviculare, Polygonum persicaria and Matricaria spp. were not controlled to any appreciable extent after the cotyledon stage, although increasing the dosage rate from 8 to 12 pints/ac did give more effective, yet inadequate control. No control of grass weeds, including Poa annua, was obtained.

The stage of weed development at the time of spraying influenced the degree of control. This was particularly true for the 8 pints dosage rate when 84 and 44 % control was obtained following the first and second times of spraying respectively (Table 1 and 2).

A comparison of equal volume doses of Sch 4072 and Sch 4075H (Table 2) showed that the latter was more phytotoxic to weeds. This was particularly evident when weeds had 3 to 4 pairs of leaves at the time of spraying.

Table 1.

Effect of Sch 4072 on weeds (Experiment 2, 1967)

Treatment	Weed Control %	Growth stage of weeds	Prevalent Weeds
Sch 4072, 8 pints/ac, 1st leaf of beet $\frac{1}{3}$ in.	84.0	1st-2nd	Chenopodium album
" " 12 " " " " "	85.8	true	Matricaria spp.
" " 16 " " " " "	89.1	leaves	Polygonum aviculare
			Senecio vulgaris
Sch 4072 8 pints/ac, 1st leaf of beet $\frac{1}{3}$ in.	43.9	3rd-4th	Sinapis arvensis
" " 12 " " " " "	63.3	true	Spergula arvensis
" " 16 " " " " "	74.1	leaves	Stellaria media
Control (Untreated)	0.0		

Table 2.

Effect of Sch 4072 and Sch 4075H on weeds (Experiment 3, 1967)

Treatment	Weed Control %	Growth stage of weeds	Prevalent Weeds
Sch 4072, 8 pints/ac	100.0	1st-2nd	Capsella bursa-pastoris
" " 12 "	100.0	true	
Sch 4075H 8 pints/ac	100.0	leaves	Chenopodium album
" " 12 "	100.0		Polygonum persicaria
			Sinapis arvensis
Sch 4072, 8 pints/ac	74.4	3rd-4th	
" " 12 "	80.1	true	
Sch 4075H 8 pints/ac	77.0	leaves	
" " 12 "	92.6		
Control (Untreated)	0.0		

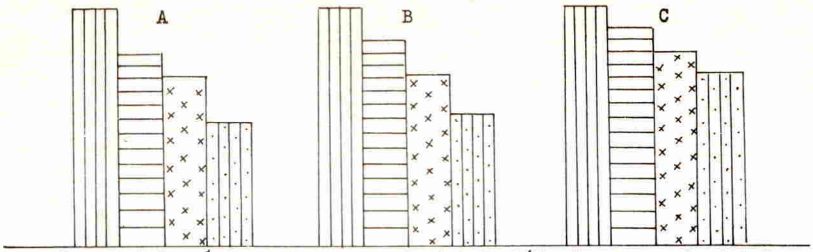
Table 3 Effect of Sch 4075H on weeds and beet seedlings (1968B)

Experimental centre	*Weed Control %				[2]Vigour of Beet Seedlings%				Growth stage of weeds at spraying		Weeds present
	5 pints/acre		8 pints/acre		5 pints/acre		8 pints/acre		Time 1	Time 2	
	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2	Time 1	Time 2			
1	90	40	90	50	100	100	100	95	Late cotyledon	1st leaves	Fumaria officinalis, Galium aparine, Galeopsis tetrahit, P. aviculare, P. persicaria, Stellaria media.
2	80	60	100	90	100	100	90	80	Early cotyledon	1st leaves	Chenopodium album, Lamium purpureum, P. aviculare, P. persicaria, Sinapis arvensis
3	90	50	90	50	100	100	80	100	cotyledon	2nd leaves	Anagallis arvensis, Chenopodium album, G. aparine, S. media, Veronica spp.
4	85	70	90	80	100	100	95	95	cotyledon 1st leaves	1st leaves 2nd leaves	C. album, P. convolvulus, P. lapathiolium, P. persicaria
5	95	40	95	50	100	100	95	95	cotyledon	2nd leaves	C. album, P. convolvulus, P. persicaria, S. media.
6	76	60	30	46	95	100	100	100	cotyledon 1st leaves	2nd leaves	P. aviculare, P. persicaria, Galeopsis tetrahit, Stellaria media.
7	67	55	20	17	93	100	100	97	cotyledon 1st leaves	2nd leaves	P. lapathifolium, S. media, P. persicaria

* Expressed as % of control plot (visual assessment)

2. " " % of " " (visual assessment)

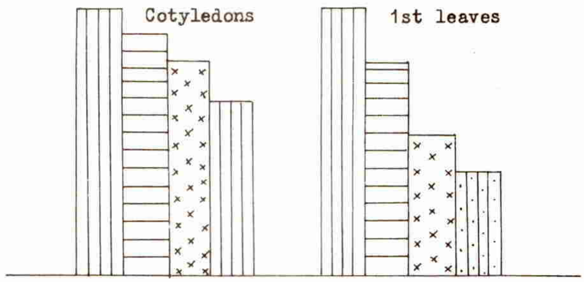
Table 5. Effect of Sch 4075 on early growth (fresh weight) of sugar beet



A = sprayed, cotyledon $\frac{1}{2}$ in. B = sprayed, 1st leaf $\frac{1}{8}$ in. C = sprayed, 1st leaf $\frac{1}{2}$ in.

Control as 100%   5 pints/ac   10 pints/ac   15 pints/ac

Table 6. Effect of Sch 4075 on the length of cotyledons and 1st leaves of sugar beet



Control as 100%   5 pints/ac   10 pints/ac   15 pints/ac

DISCUSSION

The most significant result obtained in the experiments reported here was the consistent performance of phenmedipham against a wide range of annual weeds. The poor control of Poa annua and Matricaria spp. is not of great significance at the present time in Ireland although both species, especially the latter, would appear to be on the increase. The degree of control varied considerably with the stage of development of the weeds at the time of spraying. This was particularly true for Polygonum spp. which were relatively resistant to phenmedipham after development of the first pair of true leaves. It is of interest to note that recovery of P. aviculare occurred even when the cotyledons were apparently dead and marginal necrosis of the first leaves was evident.

The inadequate control of P. aviculare and P. persicaria by phenmedipham is of considerable practical significance. Spraying of phenmedipham at the cotyledon stage of growth may overcome the problem, but this is not always feasible due to wet weather conditions. Furthermore weeds germinating subsequent to early spraying may be a problem at crop singling. In some of the 1968 experiments emergence of weeds after early applications of phenmedipham was noted. This is in agreement with some previous investigations when an emergence of annual weeds occurred five weeks after seed bed preparation, and in the absence of soil disturbance (Leonard 1966).

Elimination of weeds resistant to phenmedipham with a pre-emergence soil acting herbicide may be of practical value. The relatively inexpensive herbicides propham and chloropropham are suggested as suitable treatments where Polygonum spp. and Poa annua are likely to be a problem.

In the 1968 experiments Sch 4075H, 5 pints/ac gave good control of a wide range of weeds (Table 3). Poor control of P. aviculare, P. persicaria, Fumaria officinalis and Galium aparine was obtained. Increased doses generally gave improved results but inadequate control was obtained even with 10 pints/ac after development of the second true leaves. Necrosis and sometimes death of the cotyledons of P. aviculare was evident 7 to 9 days after spraying but the affected plants recovered.

Effect on Beet.

(a) Field Experiments. Phenmedipham (Sch 4072 and Sch 4075H) did not reduce pre-singling beet plant populations in the field experiments.

In the 1967 experiments a slight reduction in crop vigour was noted before crop singling following treatment with 12 and 16 pints Sch 4072/ac. Marginal necrosis of the cotyledons was also noted in some plants when spraying was carried out at the late cotyledon to 1st leaf stage of growth. Visual assessments of the crop during the growing season showed there was no retardation of crop growth. Final yield, sugar content and beet quality were not influenced by any treatment (Table 4).

Table 4. Effect of phenmedipham Sch (4072) on beet (Experiment 1, 1967)

Treatments, rate per acre	Yield tons/acre	Sugar percent
4072, 8 pints, late cotyledon stage	14.68	16.52
" 12 " " " "	15.82	16.50
" 16 " " " "	15.21	16.43
" 8 " 1st leaf ½ in. long	15.04	16.84
" 12 " " " " "	15.11	16.83
" 16 " 2nd " " "	15.43	16.89
" 8 " " " ½ in. long	15.50	16.80
" 12 " " " " "	15.61	16.79
" 16 " " " " "	15.71	16.96
Control	14.93	16.52
F Test	N.S.	N.S.
S.E. ±	0.47	0.15

In the 1968 experiments a reduction in crop vigour was obtained when beet was treated with Sch 4075H (7.5 and 10.0 pints/acre) at the cotyledon and 1st leaf growth stages. Morphological changes in some leaves were observed especially at the 10 pints/ac rate. However, the affected beet plants recovered fully and later developing leaves did not show any injury symptoms.

(b) Greenhouse Experiments. Some crop phytotoxicity was observed in greenhouse experiments with the high dosage rates of phenmedipham. A reduction in crop growth was detected within 72 hours after spray application and this was manifest at the time the immature plants were harvested, (Table 5). The degree of growth retardation of the cotyledons and first leaves of treated plants recorded is shown in Table 6.

Morphological changes in some leaves of treated plants was also noted. This was observed following treatment with Sch 4072 and Sch 4075H.

Seedling mortality was obtained following application of 15 pints Sch 4075H per acre at the cotyledon and first true leaf stages. The degree of mortality varied in repeated experiments but did not exceed 15 percent.

Sugar beet showed a high degree of tolerance to phenmedipham especially in the field experiments. The suppression of growth obtained in the greenhouse experiments is of interest. This may have been due to a greater penetration of herbicide into the greenhouse plants. It is also suggested that retardation of growth was more evident in the greenhouse experiments because of the relatively rapid growth of the untreated control plants. Ardnt (1965) has shown that CO_2 assimilation is inhibited in the cotyledons and leaves of sugar beet for 48 and 72 hours respectively, after treatment with phenmedipham (6 l./ha.). This could account for the suppression of growth noted in the experiments reported here. However, the degree of suppression and the rate of growth recovery following applications of 10 and 15 pints Sch 4072/ac indicate that CO_2 assimilation of other physiological process(es) may have been affected for periods in excess of those noted by Arndt (1967). The apparent recovery of sugar beet plants suggests that phenmedipham may be metabolised into non phytotoxic products in sugar beet as indicated for pyrazon (Fischer 1967).

The morphological changes of sugar beet leaves obtained in the field and greenhouse experiments is difficult to explain, as similar symptoms were observed in some untreated plants. However, an increase of 10% to 20% of affected plants in treated plots suggests that phenmedipham did not cause the observed effects directly, but rather conditioned the beet plants for some other casual agent.

Field observations carried out during the growing season indicated that affected plants recovered fully and it is unlikely that final yields of roots or leaves will be adversely affected.

ACKNOWLEDGEMENTS

Thanks are due to the Irish Sugar Co. who helped finance these studies. The author is also indebted to Mr. J. Burke for technical assistance. The phenmedipham was kindly supplied by Scheering Ag., Berlin and Fisons Pest Control Limited.

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Proc. 9th Brit. Weed Control Conf. (1968)

EXPERIMENTS ON THE FIELD PERFORMANCE OF PHENMEDIPHAM

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Summary Forty two development trials were carried out in 1967 with formulation 4072 of phenmedipham on sugar beet, mangolds and red beet. In these trials 2 lb a.i./ac gave good control of most annual broad-leaved weeds in the very young stages, while 3 and 4 lb a.i./ac generally gave only slightly improved control. This chemical had an excellent safety margin to the beet even when two sprays were applied at an interval of about two weeks.

A further 12 development trials were carried out in August 1967 comparing formulation 4072 with formulation 4075. On the annual weeds present formulation 4075 at 1 lb a.i./ac gave equally good weed control or better than formulation 4072 at 2 lb a.i./ac.

In 1968 combined sprays of phenmedipham with barban, manganese sulphate, borax, dimethoate or DDT showed that any of these mixtures could be used without any adverse effects from either constituent in the mixture.

Volume trials at 10, 20, 30 and 40 gallons per acre indicated that 20 gpa gave marginally quicker and better weed control than the other volumes used.

INTRODUCTION

In 1966 research trials by Holmes (1968) with phenmedipham showed very promising weed control from post-emergence use on beet. To obtain additional information and experience of this chemical, 42 development trials were carried out in 1967 using formulation 4072 mainly on organic soils. While these development trials were in progress, research trials by Holmes (1968) showed that formulation 4075 was more active and hence a further 12 development trials were laid down in August. The latter trials were on fallow land, or red beet or brassicas and were intended mainly to compare the relative activities of formulations 4072 and 4075 against weeds.

In 1968 six development trials were carried out using phenmedipham as formulation 4075 combined with either barban, manganese sulphate, borax, dimethoate or DDT. Four other trials were also carried out comparing volumes of 10, 20, 30 and 40 gallons per acre.

METHOD AND MATERIALS

Two formulations were used as follows :

4072 containing 20% w/w phenmedipham - used in 1967
4075 containing 16.7% w/w phenmedipham - used in 1967 and 1968.

1967 Trials

Thirty two replicated trials and ten farmer trials were carried out with formulation 4072 mainly on sugar beet, but a few of these trials were on mangolds and red beet. Phenmedipham was applied at 2 and 4 lb a.i./ac in the replicated trials and at 2 and 3 lb a.i./ac in the farmer trials. The volume of application was 20 or 40 gpa. The beet varied from the cotyledon to the 8 leaf stage and mangolds from cotyledon to the 2 leaf stage. In six of the replicated trials on organic soil a second spray was applied to half of the plots following a second germination of weeds. Visual assessments were carried out at intervals till July.

In August a further 12 replicated trials were laid down comparing formulations 4072 and 4075 at 1 lb and 2 lb a.i./ac. Some of these trials were on fallow land, others on red beet, kale or other brassicas. Volume of application was 30 or 40 gpa.

1968 Trials

In five replicated trials phenmedipham at 1 lb a.i./ac was applied to sugar beet as a combined spray with 4 lb manganese sulphate, 5 lb borax, 0.3 lb dimethoate, 0.3 lb barban or 1 lb DDT. The combined sprays were applied at 20 gpa when the beet and weeds were in the early seedling stage.

A further four replicated trials were carried out on sugar beet comparing 1 lb a.i./ac at 10, 20, 30 and 40 gpa at 25-40 lb psi with 20 gpa as a coarse spray obtained at a pressure of 10 lb psi. The sprays were applied when the beet were in the cotyledon to 2 leaf stage.

RESULTS

1967 Trials

Effect on weeds The range of weeds controlled was wide when application was made in the early stages of growth. In most trials the control of annual weeds by formulation 4072 at 4 lb a.i./ac was only slightly better than at 2 lb a.i./ac except on moderately resistant weeds where the higher dose gave much improved control. In the trials comparing different formulations 4075 at 1 lb a.i./ac in most cases gave equal weed control to 4072 at 2 lb a.i./ac. There were indications that 4072 at 2 lb a.i./ac was slightly more active than 4075 at 1 lb a.i./ac on *Urtica urens*, while the reverse was the case for *Atriplex patula*, *Lamium purpureum*, *Stellaria media*, *Polygonum convolvulus* and *Solanum nigrum*. Table 1 shows the susceptibility of the major weeds to 1 lb phenmedipham as formulation 4075.

Table 1

Weed susceptibility to 1 lb phenmedipham 4075 a.i./ac

Weed species	Stage controlled
Sinapis arvensis	Killed up to 4 leaves sometimes 6 leaves
Raphanus raphanistrum	" " " " " " " "
Galeopsis tetrahit	" " " " " " " "
Chenopodium album	" " " " " " " "
Urtica urens	" " " " " " " "
Lycopsis arvensis	" " " 2 " " 4 "
Veronica agrestis	" " " " " " " "
Veronica hederifolia	" " " " "

Table 1 (continued)

Weed susceptibility to 1 lb phenmedipham 4075 a.i./ac

Weed species	Stage controlled
Atriplex patula	Killed up to 4 leaves
Senecio vulgaris	" " " " "
Viola spp.	" " " " "
Lamium purpureum	" " " " "
Fumaria officinalis	" " " " "
Thlaspi arvense	" " " " "
Anagallis arvensis	Severely checked or killed up to 2 leaves
Papaver rhoeas	Killed to $1\frac{1}{2}$ in diameter
Stellaria media	Killed to $1\frac{1}{2}$ in diameter or height
Spergula arvensis	Killed to $1\frac{1}{2}$ in high
Capsella bursa-pastoris	Severely checked or killed to 1 in diameter
Polygonum convolvulus	Killed up to 1 leaf
Polygonum persicaria	Killed at cotyledon stage
Polygonum lapathifolium	" " " "
Tripleurospermum maritimum ssp. inodorum	Checked or killed to $\frac{1}{2}$ in diameter - variable
Anthemis cotula	" " " " " " "
Solanum nigrum	Slight check at cotyledon stage
Galium aparine	" " " " "
Polygonum aviculare	Checked or killed at cotyledon stage
Poa annua	Slight check up to 2 leaves
Sonchus arvensis *Trifolium spp.* *Lithospermum arvense* *Avena fatua* Most perennial spp.	Resistant

Effect on Crop

1967 Trials

Phenmedipham at 4 lb a.i./ac and to a lesser extent at 2 lb a.i./ac as 4072 caused slight effects on four sugar beet trials. In two trials there was a slight check possibly associated with physical damage from blowing soil. In the third trial the leaves became slightly yellow while in the fourth trial they rolled inward. In all these instances the plants recovered and looked normal after 2-3 weeks. In the remaining trials the beet was unaffected by 2 or 4 lb a.i./ac nor was there any effect noticed on any of the crops from the second application.

On mangolds 2 lb a.i./ac as 4072 in one trial checked the vigour of the crop and caused a slight reduction in plant numbers, but in the remaining three trials the crop was unaffected.

On globe red beet in one trial there was a slight check by 1 lb a.i./ac as 4075 and a severe check by 2 lb a.i./ac. In the other two trials there was no effect on the crop from 1 or 2 lb a.i./ac. A second spray was applied on one trial and caused no effect on the red beet.

The formulation comparisons on red beet, kale and other brassicas indicated that 4075 at 1 lb a.i./ac was not quite as selective as 4072 at 2 lb a.i./ac.

1968 Trials

When phenmedipham at 1 lb a.i./ac as 4075 was applied to sugar beet as a combined spray with 4 lb manganese sulphate, 5 lb borax, 0.3 lb dimethoate, 0.3 lb barban, or 1 lb DDT there was no difference in the effect of any mixture on the weeds or crop compared with 1 lb a.i. phenmedipham/ac.

In the volume trials 20 gpa as a fine spray at 25-40 lb psi gave the quickest and best weed control. This was followed by 10 gpa as a fine spray, then by the remaining treatments - 30 and 40 gpa as a fine spray and 20 gpa as a coarse spray - each of which gave similar weed control. The 40 gpa as a fine spray and the 20 gpa as a coarse spray tended to be slower than other treatments in controlling weeds.

DISCUSSION

In 1967 the majority of the development trials on sugar beet, mangolds and red beet were planned and executed comparing formulation 4072 at 2 and 4 lb a.i./ac. These trials showed that phenmedipham was very selective to sugar beet and perhaps slightly less selective, though adequately so, to mangolds and globe red beet. Most of the common annual weeds in beet were controlled in the seedling stage by 2 lb a.i./ac except annual grasses, mayweeds (Tripleurospermum spp., A. cotula) and knotgrass (Polygonum aviculare).

By July 1967 Holmes (1968) had convincing evidence that formulation 4075 was considerably more active than 4072. Hence development trials were laid down in August 1967 to obtain further information on both formulations. As the sugar beet spraying season had passed these comparative trials were carried out on other crops such as red beet, kale, other brassicas or even fallow land. These trials confirmed that 1 lb phenmedipham as 4075 gave similar weed control to 2 lb a.i. from formulation 4072. They also showed that the 4075 formulation was very selective to red beet though possibly the margin of safety was not as great as with formulation 4072. The weed susceptibilities were as shown in Table 1 and these agreed with the commercial results obtained in the 1968 season.

The 1968 trials with mixtures showed that the effect of phenmedipham on weeds or on beet is not affected by mixing with manganese sulphate, borax, dimethoate, barban or DDT.

In the volume trials a fine spray was shown to give better weed control than a coarse spray and the optimum volume appears to be 20 gpa.

As phenmedipham is a post-emergence spray it can be used on all soil types. It will be particularly useful for organic soils where the herbicides at present available to the grower are limited. It will also be useful for beet grown on very light or on very heavy clay soils where the residual herbicides have limitations. As its use is independent of soil moisture it can be used in dry conditions where the residual herbicides give poor weed control. Hence it will be useful for late drilled sugar beet or for red beet. The high safety margin to the beet crop will allow drilling "to a stand" which is becoming more popular as labour difficulties become more acute.

Acknowledgements

The author wishes to thank his colleagues Messrs. W. Griffiths, C.I. Mantle, G.J. Fielder, J.G. Swalwell, F.P. Cattle and R.L. Lake for carrying out these trials, and also the British Sugar Corporation staff and farmers who willingly co-operated in this work.

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Proc. 9th Brit. Weed Control Conf. (1968)

PHENMEDIPHAM - ACTIVITY AND SELECTIVITY UNDER U.K. CONDITIONS

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Summary In experiments carried out in 1966 to 1968, phenmedipham gave good post-emergence control of most important annual broadleaved weeds of beet crops in Britain with the exception of Polygonum aviculare. The recommended dose did not affect crop stand, yield of roots or sugar content. Formulation 4075 was twice as active as 4072.

INTRODUCTION

The herbicidal properties of phenmedipham were discovered by research workers of Schering A.G. Berlin who showed that this compound had great promise as a post-emergence herbicide for sugar beet (Arndt et al, 1967). After small exploratory trials in Britain in 1966 a new formulation, known under the code number 4075, was introduced and tested in 1967. Schering had found 4075 to be about twice as active as the earlier formulation, coded 4072. Similar results were obtained in this country and 4075 was therefore the formulation chosen for development in Britain. This paper briefly describes the results of experiments carried out in 1966 to 1968.

MATERIAL AND METHODS

Experiments on Crop Response : 3 yield experiments each with 6 replications with plot size of $1\frac{1}{2}$ x 12 yd comparing two formulations. Beet counts and visual assessments made on observational trials with 2 - 4 replications.

Experiments on Weed Control : information on weed spectrum is reported from 12 experiments carried out over three years and including logarithmic and constant-dose treatments. Comparisons of the two formulations were made on mixed weed populations in 1967. Sites were on both mineral and high organic soils with the associated weed flora.

Formulations : 4072 - 20% w/w phenmedipham - used 1966 and 1967
4075 - 16.7% w/w phenmedipham - used 1967 and 1968

Application Details : all experiments were sprayed at a volume of 20 gal/ac using knapsack sprayers giving either constant or logarithmic doses.

RESULTS

1. Crop Response

Crop response assessments were of three types: counts of beet plants before singling, visual assessments of stand and vigour made two to three weeks after spraying, and yield assessments.

In 1967 and 1968 plant counts were made on a number of experiments and the results expressed as percentages of control are shown in Table 1. The number and size of sample areas used for each mean figure is given in the last column. The counts were made before singling on all experiments except 32/67 where singling was carried out very early. The seed spacing varied from one experiment to another but on no site was it more than 3 in.

Table 1

Percentage of beet plants present after treatment on 6 experiments

Expt. No.	4072 - lb/ac a.i. 1	2	4	8	4075 - lb lb/ac a.i. 0.5	1	2	4	Number and size of samples
19/67	103	106	95	100	97	94	93	105	8 x 6 ft of row
32/67	100	98	101	87	100	112	94	81	6 x 36 ft of row
30/67	-	100	92	90	-	101	98	96	36 x 6 ft of row
21/67	-	102	97	101	-	103	102	89	36 x 6 ft of row
Means	101	101	96	94	98	102	97	93	
23/67	-	-	-	-	-	98	101	101	10 x 4 ft of row
41/68	-	-	-	-	-	104	98	93	60 x 6 ft of row
Means	-	-	-	-	-	101	99	97	

On average 2 lb phenmedipham as 4072 or 1 lb as 4075 was safe to the crop and even at 4 times these rates the mean reduction in stand was less than 10%.

Experiment 32/67 showed an appreciable reduction in plant numbers at the highest dose and this reduction was all the more significant since counts on this site were not made until after singling. Visual assessments indicated a reduction in the size of plants as well as the number. This experiment is of particular interest as it was on a high organic fen soil on a crop which developed symptoms of manganese deficiency soon after the application of the phenmedipham. A manganese spray was applied later. Reports have since been received of other manganese deficient crops which have shown lower than normal tolerance towards phenmedipham. The yield results for Experiment 32/67 are given in Table 2.

In some experiments a slight visual check to growth was recorded about two weeks after spraying. This was usually only a temporary effect, particularly at the standard dose of phenmedipham, and later observations showed that the plants were normal in size and vigour.

A number of experiments were carried out comparing applications at different growth stages of the beet from emergence to the 3-leaf stage but though there were indications that spraying very early, immediately after emergence of the beet, was somewhat less safe than a later treatment, evidence on this point was not conclusive.

Three yield experiments were carried out in 1967 and the yields of sugar are given in Table 2. The figures show that in Experiments 20 and 21/67 yields were not reduced even at the highest phenmedipham doses tested. In the manganese deficient crop on Experiment 32/67, however, yields were low after treatment with the two highest doses of each formulation, though at the lowest dose (the recommended rate) yields were not significantly different from untreated.

Although untreated plots were hoed, it was not possible to keep them completely clean throughout the season. Late re-infestation of the controls probably accounts for the significant yield increases shown in Experiment 20/67.

The two formulations gave very similar results when 4075 was used at half the dose a.i. of 4072.

Table 2

Yield of sugar in cwt per acre in 3 experiments

Expt. No.	Spraying date	Formulation	Dose of phenmedipham in lb/ac 4072: 0 / 4075: 0	4072: 2 / 4075: 1	4072: 3 / 4075: 1.5	4072: 4 / 4075: 2	4072: 6 / 4075: 3	4072: 8 / 4075: 4		Sig.* diff. P .05
20/67	11.5.67	4072	35.8	38.8	39.9	39.5	38.5	36.7	40.0	
	18.5.67		35.9	41.3	41.2	43.7	44.1	44.4		
	11.5.67	4075	36.6	39.6	41.2	40.3	40.8	40.2	41.0	
	18.5.67		36.9	43.6	42.0	41.7	44.2	42.8		
Means			36.3	40.8	41.1	41.3	41.9	41.0		1.90
21/67	9.5.67	4072	63.8	60.9	64.6	58.3	57.5	63.6	60.8	
	18.5.67		62.4	59.5	59.8	55.9	60.3	62.5		
	9.5.67	4075	58.5	56.5	61.6	63.6	63.7	60.5	60.8	
	18.5.67		61.3	62.0	56.6	62.3	62.2	61.0		
Means			61.5	59.7	60.6	60.0	60.9	61.9		N.S.
32/67	16.6.67	4072	45.4	43.1	-	41.7	-	39.6	42.4	
	16.6.67	4075	42.7	43.6	-	40.7	-	34.1	40.3	
Means			44.0	43.3	-	41.2	-	36.8		2.11

*Significant differences between mean doses (P .05)

2. Weed Control

Weed Susceptibility

The susceptibility of a range of common weeds to the standard dose of phenmedipham is described in another paper (Edwards, 1968). The results on only a few of the more important species are therefore given below.

In 1966 counts of weeds were made on 5 small-plot experiments two to three weeks after applying phenmedipham in the formulation 4072. In Table 3, showing the percentage kill of 6 species, the results of several experiments have been combined and the number of experiments contributing to the means is shown in the last column. The total area assessed for each treatment in any one experiment was 3 samples of 1 or 2 ft^2.

Table 3

Percentage reduction of 6 weed species sprayed at an early development stage

Species	Dose of 4072 in lb/ac a.i. 0.5	1	2	4	8	No. of expt.
Stellaria media	31	57	91	99	100	3
Veronica persica	77	90	95	98	100	3
Polygonum aviculare	0	0	0	0	47	2
P. convolvulus	74	81	87	94	100	1
Chenopodium album	92	95	99	99	99	2
Urtica urens	45	64	64	97	99	1

Although these weeds were not all sprayed at the optimum growth stage the table shows results which have since been confirmed in a number of other experiments: the striking difference in susceptibility between the two Polygonum species, the very high susceptibility of Chenopodium album and the moderately high susceptibility of the other species.

Polygonum aviculare was the most resistant of the common broad-leaved species tested; another weed which was not always easy to control was Tripleurospermum maritimum ssp. inodorum (Scentless mayweed).

Time of Application

Phenmedipham is known to be most effective on very young weeds and the timing of the application is particularly important on the less susceptible species. This is shown in Table 4 and Figure 1. Table 4 gives the control of two species sprayed at two different dates at two doses. Results for the two formulations have been combined, the dose described as 'standard' being 2 lb a.i. as 4072 and 1 lb a.i. as 4075. Each figure in the table is based on counts of plants on 24 sample areas each of 0.8 yd^2. Growth stages at each date are given below the table.

Table 4

Percentage reduction of Polygonum aviculare and Tripleurospermum maritimum ssp. inodorum at 2 spraying dates means of 2 formulations

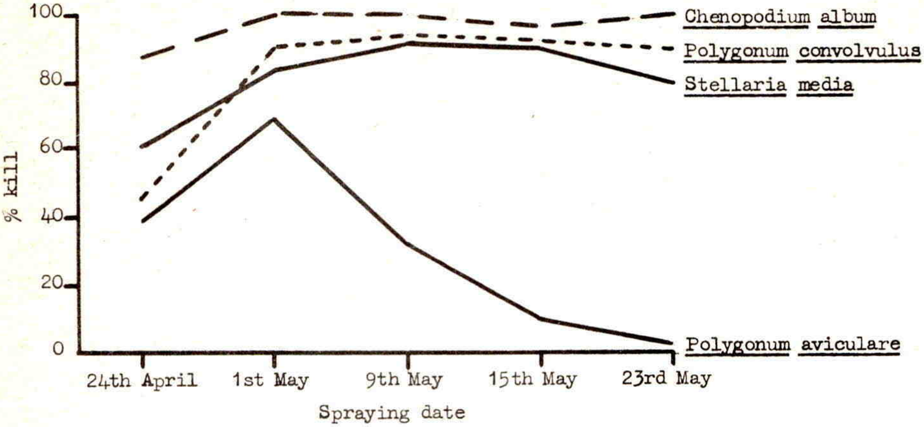
Spraying date	Dose Means of 4072 and 4075	Polygonum aviculare	Tripleurospermum maritimum inodorum
1. 11th May	Standard	52	85
	Standard x $1\frac{1}{2}$	70	89
2. 18th May	Standard	0	57
	Standard x $1\frac{1}{2}$	15	86
Growth stages	Spray 1	1 leaf	cots. to 2 leaves
	Spray 2	2-3 leaves	2-4 leaves

T. maritimum was fairly susceptible at the earlier date but P. aviculare was moderately resistant at the first date and extremely resistant later. Similar results were obtained in an experiment in which phenmedipham was applied at 5 different dates, at weekly intervals. Weed counts were made on sample areas of 2.5 yd^2 per plot. There were 4 replications. Figure 1 shows the control of 4 species obtained with the lowest dose tested (1 lb/ac phenmedipham as 4075). Two higher doses gave a similar picture though, because of the high level of control, differences between the species were smaller. Growth stages are shown below the figure.

In this experiment three of the species showed a high degree of susceptibility over a period of at least two weeks. With Polygonum aviculare however there was only one time of spraying which gave even a moderate degree of control.

Figure 1

Percentage reduction of 4 species sprayed at 5 dates with 1 lb/ac phenmedipham (4075)



Growth stages and weed density of species shown in Figure 1

Spraying date	*P. aviculare*	*P. convolvulus*	*S. media*	*C. album*
24th April	cots - ½ leaf	cotyledons	cots - 2 leaves	cotyledons
1st May	1 - 2 leaves	cots - 1 leaf	2 - 4 leaves	cotyledons
9th May	1 - 3 leaves	cots - 2 leaves	2 - 6 leaves	cots - 2 leaves
15th May	2 - 4 leaves	1 - 2 leaves	4 - 6 leaves	2 - 4 leaves
23rd May	over 3 leaves	1 - 3 leaves	well branched	4 - 6 leaves
Density per yd^2 (untreated)	18.7	6.9	7.4	1.7

Formulations

Experiments in 1967 comparing the two formulations of phenmedipham were carried out on mixed weed populations and the percentage reduction of the whole population was assessed visually. The results of 5 experiments are shown in Table 5.

Table 5

Percentage reduction in weed growth in 5 experiments means of 2 replications

Experiment number	Dose of 4072 in lb/ac a.i. 1	2	4	8	Dose of 4075 in lb/ac a.i. 0.5	1	2	4
19a/67	91	93	95	96	88	93	95	96
19b/67	75	90	96	96	78	92	96	96
23a/67	85	89	95	98	78	89	95	98
23b/67	38	50	88	-	40	75	95	-
26/67	80	97	98	99	95	98	98	99
Means	74	84	95	97	76	89	96	97

The figures indicate that 4075 was twice as active as 4072. Observations on individual species, some of which were the more resistant weeds, did not suggest any marked difference in the specificity of the two formulations.

DISCUSSION

Experiments carried out in Europe and those described in this paper showed that changing the formulation of phenmedipham doubled the activity without loss of selectivity. The use of 4075 (at half the dose of 4072) did not however give any marked improvement in the control of the more resistant weeds, for instance, Polygonum aviculare which has been found the most resistant of the important broad-leaved weeds of sugar beet in this country. Where there is a heavy infestation of this species, the recovery of plants surviving the treatment and their subsequent rapid growth in the absence of competition from other species can give rise to a serious weed problem later in the season. The results of spraying at different times suggest that P. aviculare is susceptible if sprayed at the right growth stage, probably at about the cotyledon to 1 leaf stage. The susceptible period however appears to be very short and since there will be a spread of growth stages in the population it follows that a high percentage kill is unlikely to be achieved.

Other weed species are also more easily controlled at early growth stages but their susceptibility extends over a longer period. A high degree of control can therefore be achieved without very critical timing of the application and in spite of variation in growth stage both within species and between species.

An outstanding feature of the work on phenmedipham has been the degree of selectivity of this herbicide. Control of weeds other than resistant species is normally very good at 1 lb/ac a.i. in formulation 4075. On the crop, 4 lb/ac has sometimes given a small reduction in the stand of beet but in two experiments on singled beet 4 lb did not affect the yield except insofar as the crop responded to improved weed control. This resulted in an increased yield of roots; no differences were found in the sugar content of treated as compared with untreated roots. In a third yield experiment the crop developed symptoms of manganese deficiency which though later corrected may have influenced beet growth at the time of spraying. This is a possible reason for the higher sensitivity of the crop on this field.

In general, observations on a considerable number of experiments indicate that 1 lb/ac phenmedipham as 4075 is safe to the crop and that the risk of appreciable damage from overdosing is very small.

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CHEMICAL HERBICIDES IN SUGAR BEET PRODUCTION AT HARPER ADAMS, 1965-68

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Summary Results from field experiments in 1965-67, on light to medium sandy loam soils in the West Midlands, showed that competition from weeds prior to singling sugar beet at the 4-true leaf stage of growth might reduce the final harvest root yield.

Under moist soil conditions prior to singling, residual soil-acting herbicides controlled 80-95% of annual weeds in sugar beet. But, under dry conditions prior to singling, residual soil-acting herbicides controlled less than 50% of annual weeds in sugar beet. In 1967, pyrazon applied pre-emergence, followed by phenmedipham applied post-emergence, resulted in practically complete control of annual weeds in sugar beet. It was, therefore, technically possible to establish and to grow beet in a weed-free environment without resort to cultural weed control.

Compared with narrow seed-spacing (i.e. 1-2 in. apart), precision drilling of either multigerm, or of monogerm sugar beet seed at wider spacing (i.e. 3-6 in. apart) led to useful savings in manhours and in the cost of spring work.

Further data is presented from experiments in 1968 on the use of chemical herbicides in sugar beet production and practical implications of the work are discussed. There was evidence that under certain soil conditions the mixture of chlorpropham/propham/fenuron might reduce sugar beet yield.

INTRODUCTION

The progressive increase in the cost of manual work, and also, in some areas, the scarcity or the absence of beet singlers, have become limiting factors for profitable sugar beet production. Consequently, methods of reducing manpower requirements for spring work have become matters of paramount importance in sugar beet culture.

Chemical herbicides have already made a significant contribution to weed control (Bray, 1968) and to the reduction of manpower requirements in sugar beet production. It was clear, however, from our recent review (Eddowes and Caldwell, 1968) that more developmental research work was needed before an ultimate objective of drilling sugar beet to a regularly spaced stand of single plants in a weed-free environment, with the elimination of post-planting manual work, could be achieved in commercial practice.

In Britain, average yields of washed sugar beet are now 13-14 ton per acre. Since costs of sugar beet production are currently about £70-£75 per acre, an average gross return of £85-£90 per acre leaves a relatively small profit margin for the grower. Hence the need to examine the cost of spring work in sugar beet.

From 1965-68, at Harper Adams College, developmental research work was carried out on the use of chemical herbicides in sugar beet, in a series of co-ordinated field experiments. All the experiments were carried out on light to medium sandy loam soils which had the following average percentage composition by weight: organic matter 2-3, coarse and fine sand 70, silt and clay 28. The pH level was between 6 and 7. The studies were organized in three parts as follows:-

(a) The effect, in a weed-free environment, of competition among sugar beet plants prior to the singling stage.
(b) The effect, in relation to application rate and to soil moisture, of different contact and residual herbicides on weed control and on growth of sugar beet.
(c) The use of chemical herbicides in commercial sugar beet production.

The results of the work from 1965-67 were fully reported and discussed by Eddowes and Caldwell (1968) and only the main conclusions are summarized in the present paper.

MAIN CONCLUSIONS FROM EXPERIMENTS IN 1965-67

(1) Under conditions of adequate fertiliser and water supply, and in the absence of weeds, competition among sugar beet plants for nutrients, water, and light, up to the 6-true leaf stage of growth did not reduce the final harvest root yield of sugar beet. Competition from weeds prior to singling beet at the 4-true leaf stage of growth might reduce the final harvest root yield (see Table 2). Hence the need for effective weed control in sugar beet before singling.

(2) In 1965 and in 1966, under moist soil conditions prior to sugar beet singling, high rates of pyrazon and of lenacil, applied pre-emergence, controlled only 5-15 per cent more annual weeds than low application rates of pyrazon and lenacil applied pre-emergence, as shown in Table 1.

Table 1

Effect of application rate of residual pre-emergence herbicides on the control of annual weeds in sugar beet

Year	Herbicide	Dose rate (lb a.i./ac)	% weed control
1965 and 1966	pyrazon	1.6-2.2	80 - 85
1965 and 1966	pyrazon	2.8-3.2	90 - 95
1966	lenacil	1.2	90
1966	lenacil	1.6	95

In 1967, under dry conditions prior to sugar beet singling, pyrazon and lenacil each controlled less than 50 per cent of annual weeds.

(3) In 1967, pyrazon applied pre-emergence, followed by phenmedipham applied post-emergence, resulted in practically complete control of annual weeds in sugar beet as shown in Table 2. It was therefore, technically possible to establish and to grow sugar beet in a weed-free environment without resort to cultural weed control.

Table 2

Effect of pre-emergence residual and post-emergence contact herbicides on annual weed control and yield in sugar beet

Treatment	Dose rate lb. a.i./ac	Average no. of weeds/yd^2 8/5	26/5	Yield ton/ac.
1. Control (unsprayed)	-	362	563	21.1
2. Pyrazon	2	227	318	21.8
3. Phenmedipham	1	*(318)	63	25.3
4. Pyrazon +	2	*(212)	15	26.5
Phenmedipham	1			
5. Lenacil	0.8	216	100	26.0
S.E.		29.2	28.4	0.82

* Phenmedipham not yet applied

(4) When multigerm seed was spaced 1.5 and 3 in. apart, 80 per cent and 66.7 per cent, respectively, of the established beet plants were removed, on average, at singling. When monogerm seed was spaced 3 in. apart, 50 per cent of the established beet plants were removed at singling. Plants from monogerm seed spaced 5 - 6 in. apart were not singled. It followed therefore, that, compared with narrow seed-spacing (i.e. 1 - 2 in. apart), precision drilling of either multigerm, or of monogerm sugar beet seed at wider spacing (i.e. 3 - 6 in. apart) would lead to useful savings in manhours and in costs of spring work in sugar beet production.

Further work in 1968, reported in this paper, continued and extended the previous investigations.

METHODS AND MATERIALS

Experiment 1 (planted 27/3) A 6 x 6 latin square. Plot size 5 rows x 5 yd. Overall application by knapsack sprayer fitted with an Oxford precision lance. Volume rate 27 gal/ac. The residual (soil-acting) herbicide treatments (lenacil, and pyrazon) were applied on 28/3, and the contact herbicide treatment (phenmedipham) on 13/5 when the sugar beet was at the 2-true leaf stage. Weeds were assessed by recording the number per unit area on 13/5, 10/6 and 10/7. Plots were side-hoed on 14/6, and the sugar beet was harvested (5 yd^2/plot) on 16/9.

Observation plots In an area adjacent to experiment 1, monogerm sugar beet was precision drilled at 3½ in., 5 in., and 7 in. spacing in 20 in. wide rows and sprayed overall with pyrazon at 2 lb a.i. in 40 gal/ac.

Rainfall	Period	Rainfall (in.)	Period	Rainfall (in.)
	April 1 - 15	0.31	May 1 - 15	1.50
	16 - 30	1.89	16 - 31	1.90

Thus, more than 1.5 in. of rain was recorded within one month, and more than 5.5 in. within 9 weeks of applying the residual herbicides.

Weeds present in order of frequency were: Poa spp. (meadow grass), Veronica spp. (speedwell), Chenopodium album (fathen), Viola spp. (field pansy), Stellaria media (chickweed), Polygonum spp. (black bindweed, knotgrass, redshank), Matricaria spp. (mayweeds), Galium aparine (cleavers) and Fumaria officinalis (fumitory).

Experiment 2 (planted 27/3) A 3 x 3 x 4 random block with plot size 5 rows x 5 yd. Overall herbicide application by knapsacksprayer fitted with an Oxford precision lance on 29/3. Volume rate 81 gal/ac. Three residual herbicides, pyrazon, lenacil, and chlorpropham/propham/fenuron, were each applied at three different rates. Weeds and beet plants were assessed by recording the number per unit area on 7/5 and 14/6. The plots were side-hoed on 14/6 and harvested (5 yd^2/plot) on 16/9.

Weeds present in order of frequency were similar to those recorded in experiment 1, but C. album (fathen) was more prevalent than Veronica spp.

RESULTS

Experiment 1

The results are summarized in Table 3.

Table 3

Effect of herbicide treatments on annual weeds and on beet plants

Treatment	Dose lb a.i./ac.	Mean no. of weeds/yd^2 13/5	10/6	10/7	Beet plants/ 15 yd row 20/6	Yield ton/ac.
1. Control (unsprayed)		96.7	149.8	9.9	74	13.8
2. Lenacil	0.8	12.3	12.6	4.8	75	15.0
3. Pyrazon	2	10.2	8.6	4.8	79	16.7
4. Lenacil + phenmedipham	0.8 1	*10	2.3	2.4	73	15.3
5. Pyrazon + Phenmedipham	2 1	*12.8	2.2	2.4	77	14.9
6. Phenmedipham	1	*(105.2)	29.3+(25.2)	5.9	80	15.4
S.E.		4.9	4.6	n.s.	n.s.	0.71

*Phenmedipham not yet applied + including 25.2 grass weeds

The results in Table 3 showed that on 13 May, compared with the unsprayed control, lenacil and pyrazon each gave highly significant control of annual weeds (about 90 per cent control). By 10 June, all the herbicide treatments had given very significant control of annual weeds. The degree of annual weed control ranged from 92 - 94 per cent for the residual herbicide treatments (2 and 3) to 98.5 per cent for the residual and contact herbicide treatments (4 and 5). Phenmedipham alone (treatment 6) controlled about 97 per cent of the annual broad-leafed weeds, but only about 80 per cent of the total annual weeds, because annual grass weeds were resistant.

The results showed (Table 3) that none of the treatments affected the establishment and growth of the sugar beet plants and differences between treatments in final harvest yield were not significant.

Results from the series of observation plots showed that 2 lb. a.i./ac of pyrazon, applied pre-emergence, gave adequate control of annual weeds. The numbers of established sugar beet plants on 28 June from precision drilling at 3.5, 5 and 7 in., spacings were 61,000, 44,000, and 26,500 per acre, respectively.

Experiment 2

The results are summarized in Table 4.

Table 4

Effect of herbicide treatments on annual weeds and on beet

Treatment	Dose lb. a.i./ac.	Mean no. of weeds/ft^2 7/5	14/6	Beet plants/ 40 ft. row 7/5	Yield ton/ac.
1. Pyrazon	1.2	2.63	1.25	74	16.3
2. Pyrazon	2.4	1.05	0.25	82	17.2
3. Pyrazon	3.6	0.9	0.35	76	15.6
4. Lenacil	0.8	2.4	1.1	72	15.6
5. Lenacil	1.6	1.25	0.2	82	15.9
6. Lenacil	2.4	1.0	0.33	58	15.9
7. Chlorpropham/ propham/fenuron	4 pts product	1.9	2.12	76	14.4
8. Chlorpropham/ propham/fenuron	8 pts product	0.95	0.95	96	13.7
9. Chlorpropham/ propham/fenuron	12 pts product	1.65	0.72	62	14.2
S.E.		0.40	0.34	2.5	0.55

The results showed (Table 4), that, compared with adjacent unsprayed control areas, the range of annual weed control was from 80% to 99% on 7/5 and from 87% to 99% on 14/6. Increasing the dose rate of pyrazon from 1.2 to 2.4 lb. a.i./ac. significantly increased annual weed control, but no further improvement of weed control was obtained at the highest application rate (3.6 lb. a.i./ac). Similar trends in relation to application rate were apparent with lenacil and with chlorpropham/propham/fenuron.

The highest dose rates of lenacil (2.4 lb. a.i./ac) and of chlorpropham/propham/fenuron (12 pts product) reduced the number of established beet plants.

The final harvest yield results showed (Table 4) that differences in dose rates had no significant effect on yield of beet, but that compared with pyrazon and with lenacil, chlorpropham/propham/fenuron significantly reduced yield of beet.

The choice of chemical herbicide for weed control in sugar beet must be carefully related to its potential for controlling the most frequently occurring weed species. In the present study, the following were the main annual weeds which tolerated (a) lenacil, (b) pyrazon, (c) chlorpropham/propham/fenuron, (d) Phenmedipham.

(a) Lenacil *Viola spp.* (pansy), *P. aviculare* (knotgrass), *Veronica spp.* (speedwell) and *G. aparine* (cleavers)

(b) Pyrazon *Viola spp.*, *P. Aviculare.*, *F. officinalis* (fumitory), and *G. aparine*.

(c) Chlorpropham/propham/fenuron *Viola spp.*, *Veronica spp.*, *F. officinalis* and *G. aparine*

(d) Phenmedipham *Poa spp.* (meadow grass), *P. aviculare*, *Matricaria spp.* (mayweed) and *Atriplex patula* (orache).

CONCLUSION

The results of developmental research work carried out on light to medium sandy loam soils at Harper Adams College from 1965 - 68 on the use of chemical herbicides in sugar beet have shown that new cultural systems of sugar beet production based on chemical weed control can result in significant savings in manhours and in costs of spring work. The results in 1968 supported the previous conclusions which were summarized at the beginning of the paper. In 1968, phenmedipham gave a very high degree of control of annual broad-leafed weeds without showing phytotoxicity to beet; pyrazon appeared to be the least phytotoxic to beet of the residual herbicides tested; and it was apparent that under certain soil conditions the mixture of chlorpropham/propham/fenuron might reduce beet yield.

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Proc. 9th Brit. Weed Control Conf. (1968)

PRELIMINARY REPORT ON FIELD TRIALS WITH A PROXIMPHAM MIXTURE IN SUGAR BEET

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Summary In small scale trials over the past two years a mixture of proximpham, diuron and propham, coded RH.5 has shown promise as a selective herbicide in sugar beet. The weeds shown to be effectively controlled included *Polygonum spp.*, *Stellaria media* and *Poa annua*. Further trial work is planned with RH.5 and related formulations.

INTRODUCTION

In 1967 a wettable powder formulation of proximpham, propham and diuron (code number RH.5) was made available, and has been evaluated in field trials over the past two years. The trials were designed to obtain data on weed control and crop response at various dosage levels. Trial work will continue in 1969 with RH.5 and other related formulations containing proximpham.

METHOD AND MATERIALS

In 1967 trials were carried out at four sites and in 1968 at six sites. Plots 1/400th or 1/200th acre were laid down in randomised blocks with two or three replications. Spraying was carried out at a total volume of 50 gallon/acre with an Oxford Precision Sprayer.

Weed control was assessed by either counting weeds in random quadrats or by visual assessment; crop tolerance by recording the number of plants in random 100" row lengths, or by visual assessment.

Yield data for two of the 1968 trials has been recorded up to the present. This was carried out by harvesting the centre two rows from each plot.

RESULTS

The % weed control and % crop stand reduction figures for 1967 and 1968 are given in Tables 1 and 2. The yield data for 1968 is given in Table 3, the yields for each treatment being expressed as a percentage of the untreated hand-weeded control.

Table 1

% weed control and % crop stand reduction - 1967

Treatment	Dosage lb/ac	% Weed Control				% Crop Stand Reduction			
		Sandy Loam		Clay Loam		Sandy Loam		Clay Loam	
		Site 1	2	Site 3	4	Site 1	2	Site 3	4
RH.5	6.0	98	85	-	-	4	-	-	-
	8.0	98	90	95	85	18	-	2.5	0.0
	10.0	99	90	95	85	26	-	2.5	2.5
	12.0	-	-	95	90	-	-	5.0	5.0

Table 2

% weed control and % crop stand reduction - 1968

Treatment	Dosage lb/ac	% Weed Control						% Crop Stand Reduction					
		Loamy Sand	Sandy Loam		Clay Loam		Peat	Loamy Sand	Sandy Loam		Clay Loam		Peat
		Site 1	Site 2	3	Site 4	5	Site 6	Site 1	Site 2	3	Site 4	5	Site 6
RH.5	4.5	89	51	65	-	63	-	46	0.6	27	-	-	-
	6.0	94	54	83	-	70	-	49	0.0	42	-	-	-
	7.5	96	70	89	88	70	-	69	11.6	48	5	-	-
	9.0	-	-	-	-	85	-	-	-	-	-	-	-
	10.0	-	-	-	88	-	-	-	-	-	5	-	-
	10.5	-	-	-	-	-	2.5	-	-	-	-	-	4
	12.0	-	-	-	-	85	-	-	-	-	-	-	-
	12.5	-	-	-	90	-	-	-	-	-	7.5	-	-
	14.0	-	-	-	-	-	17.5	-	-	-	-	-	14
	17.5	-	-	-	-	-	22.5	-	-	-	-	-	0

Table 3

yield of roots expressed as % of untreated control - 1968

Treatment	Dosage lb/ac.	Yield of roots as a % of untreated control	
		Site 2	Site 3
Control	-	100.0	100.0
RH.5	4.5	106.8	90.8
"	6.0	95.2	90.8
"	7.5	100.5	85.8

A number of annual weeds were encountered in the trials, and may be grouped according to susceptibility as follows:

Susceptible

Polygonum persicaria, *P. convolvulus*, *P. aviculare*, *Stellaria media*, *Tripleurospermum meritimum ssp. inodorum*, *Capsella bursa-pastoris*, *Spergula arvensis*, *Poa annua*.

Moderately Susceptible

Chenopodium albam, *Viola arvensis*, *Veronica spp.*, *Senecio vulgaris*, *Galium aparine*, *Galeopsis tetrahit*.

DISCUSSION

1967 Results

Results in 1967 demonstrated that RH.5 was able to control a range of annual weeds and selectivity to the crop was generally within the limits of commercial acceptance.

On lighter soils the higher dosage levels did not improve weed control significantly, and crop selectivity was reduced. Consequently in 1968 it was decided to test a lower dosage to determine if acceptable weed control could be obtained coupled with greater crop safety.

1968 Results

Weed control results were satisfactory in 1968. At Site 2 a lower level of control was due to the predominance of *Chenopodium album* (37% of population), which was found to be only moderately susceptible to RH.5; the level of control at 4.5 lb/acre being approximately 25% and at 7.5 lb/acre approximately 50%.

The results on the peat souls were disappointing and further trials will be carried out with modified formulations.

The tolerance of sugar beet to RH.5 on the lighter soils was rather variable in 1968, being related to the rainfall after application. At Sites 1 and 3 excessive precipitation occurred for several days after application, causing a severe reduction in crop stand and vigour of the crop. The plants apparently recovered during the growing period and no visual differences could be observed between treatments and control. Yield data does indicate that where the crop is seriously affected, as at Site 3, there can be some yield depression. On the heavier clay and peat soils there was good crop tolerance at high dosage levels. Yield data will be obtained from the remaining trials.

These results have been confirmed by similar trials carried out in Holland by; Verdugt's Industrie and Handelsonderneming N.V.

RH.5 and modified formulations will be tested in 1969 to further investigate weed control and crop selectivity.

Acknowledgment

RH.5 was made available from VEB Fahlberg List, East Germany, through their licensees;

Verdugt's Industric and Handelsonderneming N.V., Holland.

Proc. 9th Brit. Weed Control Conf. (1968)

THE USE OF TRIFLURALIN FOR PERSISTENT WEED CONTROL IN SUGAR BEET AFTER CROP EMERGENCE

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Summary Following successful use of trifluralin in the U.S.A. to control weeds in sugar beet up to the time of harvest, trials were carried out in the U.K. in 1967 and 1968. A modified Triple K harrow was used to incorporate the trifluralin, and Sinna Weeder blades were used to move treated soil into the sugar beet rows which were at the 4 - 12 true leaf stage at the time of application. A rate of 1lb/ac. a.i. was found to give effective control of *Chenopodium album*, *Stellaria media*, *Veronica spp.*, *Polygonum aviculare*, *P. persicaria* and *P. convolvulus*, until time of harvest.

INTRODUCTION

The pre-emergence herbicides at present used in sugar beet do not claim to give weed control beyond time of singling. In many seasons weed emergence, particularly that of *Chenopodium album* and *Polygonum aviculare*, can continue into July and August. The removal of these late emerging weeds often necessitates the use of hand labour which is against the present trend of minimal usage of such labour in sugar beet growing.

Field evaluation in the U.K. from 1963-66 (Tyson and Smith, 1966) had shown trifluralin to be an efficient soil incorporated herbicide, to which many transplanted and established crops were tolerant. Trifluralin was introduced commercially in 1967 for the control of certain weeds in transplanted brassica crops.

One of the advantages of the incorporation of trifluralin is that shallow cultivations can be carried out between the rows without reducing herbicidal efficiency. This gives the compromise asked for by growers who want overall weed control until harvest but who still want to cultivate to maintain a loose soil tilth. Another advantage of the incorporation of trifluralin is its non-dependence on any particular weather conditions for its efficiency.

In the U.S.A. several thousand acres of sugar beet were treated with trifluralin in 1966/67. The application was made soon after singling and weed control persisted up to time of harvest. Two preliminary trials in 1967 in Nottinghamshire gave encouraging results. A larger programme of trials was carried out in 1968 to determine the possibility of using trifluralin for late season weed control in the U.K.

METHODS AND MATERIALS

Trifluralin was used as(Treflan) an e.c. containing 4.8lb a.i./Imp.gal.

Sprays of trifluralin are non phytotoxic to emerged sugar beet. The application can therefore be overall, when the beet are at least at the 4 true leaf stage and when there are no emerged weeds. The trifluralin must then be incorporated into the soil between the rows and some of the treated soil moved into the rows among the plants.

In the U.S.A. a wide variety of suitable machinery for the application and incorporation of trifluralin is available, including the Lilliston rolling cultivator. As only a few of these machines were available in the U.K. it was decided that the trial machine would have to be composed of equipment already in general farm use.

The machine used comprised a Dorman band sprayer mounted on the frame of a Kongskilde Triple K spring tine harrow, with a 7 ft boom with nine nozzles on the front frame member. The harrows with $1\frac{3}{8}$ in. reversible tines were placed 2 - 1 - 2 on the centre three members in between the rows, and were regulated to penetrate to 2-3 in. by depth wheels. On the rear member were attached curved sprung steel Sinna Weeder blades - one on either side of each beet row - to move treated soil into the beet rows.

Three complete rows and two half rows were treated with each run of the machine; travelling at $4\frac{1}{2}$ m.p.h., applying 30 gal/ac at 10 p.s.i. Considerable attention was paid to getting the Sinna blades adjusted to avoid undue burying of the beet, which varied at different sites from 4 - 12 true leaves.

Trifluralin at 1lb/ac a.i. was applied at all sites and in certain instances also at 0.75lb and/or 0.5lb/ac a.i. depending on the soil type. A total of nineteen trials plus two farmer trials were put down to cover as many areas and soil types as possible, with emphasis on areas and sites where late season weed emergence was usually a problem. Plots were approximately half-acre, each trial being one to two acres in size.

The two farmer trials were carried out in Norfolk, both sites were sprayed overall, site no. 14 was incorporated using Triple K harrows, and site no. 15 using normal sugar beet inter-row hoe of "A" and "L" blades.

Assessments of weed control were made approximately two and four months after application by taking 10 quadrats of 960 in.^{2} in between the rows, per treatment. The untreated counts were taken from areas where blank runs of the machine had been made except at sites 1 and 10 where the untreated was taken from adjacent plots that were unhoed.

Site details are given on Table 1.

Table 1.

Site details

Site No.	Location	Date of application	Leaf No. at appln.	Soil analysis as % Coarse sand	Fine sand	Silt/clay	Organic matter w/w
1.	Cambs.	23.5.68.	4 - 6	31.6	28.8	39.6	2.3
2.	W.Suffolk	27.5.68.	6 - 8	41.8	48.0	10.2	2.0
3.	W.Suffolk	29.5.68.	6 - 8	43.8	31.2	25.0	1.6
4.	W.Suffolk	28.5.68.	6 - 8	41.8	43.2	15.0	1.3
5.	E.Norfolk	30.5.68.	6 - 8	50.6	33.8	15.6	2.1
6.	W.Norfolk	6.6.68.	6 - 8	52.2	30.6	17.2	3.6
7.	W.Norfolk	5.6.68.	6 - 8	48.2	32.2	19.6	3.6
8.	Lincs.	10.6.68.	8 - 10	1.8	64.8	33.4	2.9
9.	Lincs.	11.6.68.	8 - 10	0.8	59.8	39.4	3.9
10.	Essex	14.6.68.	10 - 12	26.4	36.6	37.0	1.9
11.	E.Norfolk	30.5.68.	10 - 12	47.4	27.9	25.6	2.1
12.	Notts.	11.6.68.	10 - 12	41.0	27.6	31.4	1.5
13.	Yorks.	12.6.68.	10 - 12	40.0	48.0	12.0	3.9

RESULTS

Results were obtained from thirteen of the nineteen trials carried out, the trials lost were due to (a) lack of weed emergence at three sites, (b) grower removal of the weeds at one site, (c) loss of trial marking pegs at one site and (d) presence of a large number of emerged weeds at time of application which made assessment impossible at one site.

The % weed control and dominant weeds present at each site are given in Table 2 and the average % weed control from comparable sites in Table 3.

Table 2.

% Weed control as assessed (a) 2 months and (b) 4 months after application

Site No.		Weeds in descending order of dominance: First	Second	Third	% Weed control: 0.5lb/ac	0.75lb/ac	1lb/ac
1	a)	Veronica spp.	Atriplex patula	Viola arvensis	-	-	71.4
	b)	Polygonum convolvulus	P. aviculare	A. patula	-	-	60.0
2	a)	V. arvensis	Chenopodium album	Urtica urens	58.1	-	87.2
	b)	V. arvensis	U. urens	Veronica spp.	60.3	-	97.3
3	a)	C. album	-	-	86.7	-	86.7
	b)	Stellaria media	-	-	17.1	-	68.6
4	a)	Veronica spp.	S. media	-	79.0	84.0	75.5
	b)	Veronica spp.	S. media	-	57.3	64.0	74.2
5	a)	V. arvensis	Veronica spp.	-	47.6	50.0	73.2
	b)	Veronica spp.	V. arvensis	C. album	64.4	62.5	86.5
6	a)	Agrostis gigantea	C. album	S. media	14.4	48.1	42.7
	b)	A. gigantea	S. media		46.8	75.0	88.1
7	a)	Senecio vulgaris	P. aviculare	-	-	27.9	37.2
	b)	C. album	-	-	-	86.7	86.7
8	a)	S. media	U. urens	Veronica spp.	75.7	-	70.3
	b)	U. urens	Veronica spp.	S. media	36.4	-	89.9
9	a)	Veronica spp.	G. aparine	-	-	53.8	48.4
	b)	Agropyron repens	G. aparine	S. media	-	55.3	73.7
10	a)	Veronica spp.	C. album	-	-	-	63.5
	b)	S. media	P. aviculare	Alopecurus	-	-	96.2
11	a)	C. album	-	-	-	87.1	90.0
	b)	C. album	-	-	-	84.2	84.2
12	a)	-	-	-	-	-	-
	b)	Veronica spp.	-	-	52.4	71.4	71.4
13	a)	-	-	-	-	-	-
	b)	Mentha sp.	A. gigantea	Poa annua	58.8	64.9	84.5
		Average % weed control from totals of all sites		(a)	60.3	58.5	67.8
				(b)	49.2	70.5	81.6

Table 3.

Average % weed control from comparable sites

	(i)	0.5lb and	1 lb	(ii)	0.75lb and	1 lb	(iii)	0.5lb	0.75lb and	1 lb
(a)	(6)	60.3	72.6	(6)	58.5	61.2	(3)	47.0	60.7	63.8
(b)	(8)	49.2	82.6	(8)	70.5	81.2	(3)	56.2	67.2	81.3

Numbers in brackets () are the number of sites compared.

DISCUSSION

The trials results indicate that trifluralin 1lb/ac a.i. incorporated into the soil to a depth of 2in. will give effective weed control until time of harvest.

The only annual weeds that were found to give crop competition were C. album, Atriplex patula, P. aviculare, P. convolvulus, Galium aparine and Urtica urens. Unfortunately, only at sites 2, 3, 10 and 11 did C. album occur in sufficient numbers to be a problem in the crop, and at sites 2, 3 and 10 it was removed from the untreated area by handing pulling between two assessments. Control by all rates of trifluralin was satisfactory at this time. P. aviculare was the second dominant weed at sites 1, 7 and 10 and was well controlled. P. convolvulus at site 1 and U. urens at sites 2 and 8 were also well controlled but A. patula at site 1 and G. aparine at site 9 were more resistant.

The most commonly occurring weeds were Veronica spp. which included V. persica, V. hederifolia and V. polita, control was usually good but as with other small annual weeds such as S. media and Viola arvensis, almost no crop competition was exerted by these weeds.

Agropyron repens at site 9 and Agrostis gigantea at sites 6 and 13 were both well controlled by the 1 lb rate but not by the lower rates except by the 0.75 lb rate at site 6 where initial control was poor but improved as the season progressed.

The changes of weed spectrum during the summer are illustrated at site 7 where Senecio vulgaris was the dominant weed at the first assessment and was not controlled by trifluralin. Later when the S. vulgaris died naturally, C. album became the dominant weed and was well controlled by trifluralin.

Trifluralin as a brassica herbicide is only recommended at 1lb/ac a.i. but it was hoped that lower rates of use would have proved successful on some of the very light sugar beet growing soils. When general weed control at the first assessment is considered the 1lb rate gave moderate weed control, which was only a slight improvement over the equally performing lower rates. The second assessment shows a considerable improvement in weed control by the 1lb rate, a lesser improvement by the 0.75 lb rate and a worsening by the 0.5 lb rate, indicating that the 1 lb rate was needed for persistent general weed control. If a susceptible weed, such as C. album is considered, the 0.75 lb and possibly the 0.5 lb rates give as good control at both assessments, as the 1 lb rate, indicating that a rate lower than 1 lb will give persistent control of C. album.

A comparison of results and soil types shows that the range of soils considered in these trials had very little effect on the efficiency of trifluralin.

Generally the machine performed very satisfactorily but at some sites stones were a problem. This was particularly so on narrow drill widths where stones tended to be caught between the stems holding the Sinna weeder blades. It was for this reason that the blades could not be used at site 6 but the results were still satisfactory. At some sites stones were also pulled into the beet rows by the Sinna blades.

The movement of treated soil into the beet rows by the Sinna blades with consequent mounding or partial burying of the beet was viewed with concern by some growers. Results have shown no adverse effect on beet growth after treatment with trifluralin 1 lb/ac a.i. Some growers considered that the soil movement achieved by the Triple K harrow was superior to that by conventional inter-row hoe.

At farmer site 14 where Triple K harrows alone were used to incorporate trifluralin, a satisfactory control of C. album was achieved, but at site 15 where incorporation was by tractor hoe the weed control was virtually nil, showing this machine to be unsatisfactory for the incorporation of trifluralin.

In the U.S.A. some slight damage known as "necking" has been recorded on sugar beet following treatment with trifluralin. In these trials "necking" was noted at site 1 where 2 lb had been applied to very small beet. There was no damage by 1 lb/ac a.i. at any site.

The trials carried out showed that, under the 1968 weather conditions, trifluralin 1 lb/ac a.i. gave persistent general weed control in sugar beet, until time of harvest. Trifluralin 0.75 lb/ac a.i. gave reduced general weed control but still gave very good control of susceptible weeds including C. album. The machine proved to be satisfactory but improvements will be made for further trial work in 1969.

Acknowledgements

The authors thank Kongskilde U.K. for the loan of the Triple K harrow, Dorman Sprayers Company Limited for the provision of the spraying system and the British Sugar Corporation for the loan of the Sinna Weeder blades and selection of the trial sites, and the growers who assisted with the trials.

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Proc. 9th Brit. Weed Control Conf. (1968)

EPTC FOR THE CONTROL OF PERENNIAL GRASSES AND OTHER WEEDS IN SUGAR BEET

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Summary. At nine half-acre sites, sugar beet was drilled into soil treated with EPTC 4lb/ac a.i. at times varying from 1-30 days after application. Complete germination with no crop check took place provided 13 or more days elapsed between application and drilling. Average control of perennial grasses - including *Agropyron repens*, *Agrostis gigantea* and *A. tenuis* - was 92% just prior to singling and 84% at late season assessment. *Agropyron/Agrostis* control was satisfactory even at the earliest applied site in mid March. Satisfactory annual weed control was also found at sites where no further herbicide treatment was applied.

INTRODUCTION

Following successful trial results in 1966 (Bartlett and Marks 1966) EPTC was introduced commercially in 1967 for the control of perennial grasses in potatoes.

In the U.S.A. EPTC is registered for use on a wide variety of crops, including sugar beet. EPTC is recommended for sugar beet at 2lb/ac on light soils or 3lb/ac on heavy soils, for the control of annual grasses and many broad leaved weeds including - *Poa annua*, *Avena fatua*, *Stellaria media* and *Chenopodium album* (Anon. 1967).

Commercial and trial results have shown that EPTC will only act against growing shoots of perennial grasses such as *Agropyron repens* (Couch-grass), *Agrostis gigantea* (Common Bent-grass, Black Bent) and *Agrostis tenuis* (Common Bent-grass), collectively known as couch. Thus the earliest EPTC can be used in the spring depends on soil temperatures being adequate for the growth of couch.

Trial work in the U.K. has shown that rates of EPTC lower than 4lb/ac do not give satisfactory control of couch (Bartlett and Marks 1966). Glasshouse and limited small plot trials have indicated that sugar beet was sensitive to EPTC 4lb/ac if sown shortly after application.

The purpose of the trials described in this paper, was to determine the earliest possible time that couch could successfully be treated and the earliest possible time that sugar beet could safely be drilled after an application of EPTC at 4lb/ac.

METHODS AND MATERIALS

EPTC: S-ethyl NN dipropylthiolcarbanate - (used as Eptam) an e.c. containing 72% a.i. w/v at 4lb/ac a.i. at sites No. 1-8 and as a 10% a.i. granular formulation based on Fullers Earth SYK 22/44 at 4lb/ac a.i. at site No. 9.

All trials were grower applied and were half-acre in size. The material was supplied to growers with instructions to leave at least 14 days between application and drilling, that this was not strictly adhered to can be seen from the dates and site details included in Tables 1 and 2.

The EPTC granules at site 3 were applied overall using a Horstine Farmery Airflow granule applicator, the methiuron/chlorpropham was band applied.

Table 1

Site Details

Site No.	Location	Method of Incorp^n.	Appl^n. date	Drilling date	Soil data as %: Coarse Sand	Fine Sand	Silt	Clay	Organic matter w/w
1.	Suffolk	one way discing and harrowing	20.4.68	21.4.68	a. 66.4	27.0	1.4	5.2	0.6
					b. 58.8	26.6	5.8	8.8	1.8
2.	Holland Lincs.	rotavation	3.4.68	6.4.68	3.0	50.6	21.6	24.8	3.5
3.	E.Riding Yorks.	rotavation	5.4.68	9.4.68	27.0	60.6	6.0	6.4	2.5
4.	Kesteven Lincs.	rotavation	30.3.68	4.4.68	42.2	33.2	16.2	8.4	17.8
5.	Worcs.	rotavation	21.3.68	2.4.68	63.2	30.1	3.4	3.3	1.2
6.	W.Riding Yorks.	rotavation	5.4.68	18.4.68	22.6	49.2	13.4	14.8	2.3
7.	Notts.	rotavation	26.3.68	12.4.68	64.6	18.2	7.8	9.4	1.8
8.	Essex	spring tine harrows	16.3.68	7.4.68	26.4	36.6	17.4	19.6	1.2
9.	Essex	spring tine harrows	18.3.68	17.4.68	14.2	23.4	21.0	40.4	3.3

Table 2

Site Details

Site No.	Pre-emergence herbicide used on treated area	Rainfall in inches for 3 weeks after application			Air temp. °F for 3 weeks after application		
		Week 1	Week 2	Week 3	Week 1	Week 2	Week 3
1.	Untreated	0.40	0.52	0.52	54.8	49.1	49.1
2.	Untreated	0.03	0.12	0.40	38.0	45.7	56.2
3.	methiuron/chlorpropham 45lb/ac product	0.04	1.08	0.61	38.6	46.8	54.0
4.	medinoterb acetate/ propham 12½lb/ac product	0.21	0.01	0.55	41.3	39.8	49.3
5.	Untreated compared with pyrazon 1½lb/ac a.i.	0.53	0.25	0.04	46.4	47.3	38.7
6.	endothol/propham/medinoterb acetate 16pt/ac product	0.04	1.03	0.30	37.6	46.5	52.9
7.	pyrazon 1½lb/ac a.i.	0.09	0.10	0.00	49.5	36.6	40.8
8.	Untreated	0.40	0.20	0.30	44.0	50.8	41.4
9.	Untreated	0.52	0.10	0.20	46.6	49.6	39.3

Assessments of couch and annual weed control, with crop stand and crop vigour were made just prior to singling of the beet. Assessments were made by taking 10 quadrats of 4 x 50 in, along each beet row, in each treatment. An assessment of annual weed control could be made only at a few sites where either no additional pre-emergence herbicide had been band sprayed on top of the EPTC or tractor hoeing of the untreated had not taken place. The late season assessment was made in the sugar beet inter-rows using 10 quadrats of 960 in^2 per treatment.

RESULTS

Table 3

Details of weed control and crop stand from a pre-singling assessment, and couch control from a late season assessment

Site No.	Dominant couch species	No. days appl^{n}.- drilling	Pre-singling assessment: % beet stand	% beet vigour	Annual % weed control	% couch control	Late season Assessment: % couch control	Annual % weed control
1.	*Agrostis gigantea*	1	a) 71.2 b) 86.1	4.5 6.5	- -	99.8 95.2	94.5 77.3	- -
2.	*Agropyron repens*	3	67.3	6.7	-	100.0	95.2	-
3.	*Agropyron repens*	4	64.3	4.4	95.1	97.5	88.0	78.7
4.	*Agropyron repens*	5	98.1	10.0	89.1	98.5	-	-
5.	*Agropyron repens*	11	84.5	9.1	72.8	100.0	-	-
6.	*A. repens/ A. gigantea*	13	110.0	10.0	-	73.9	89.4	-
7.	*Agrostis tenuis*	16	100.5	10.0	-	85.2	65.8	-
8.	*Agrostis gigantea*	21	125.0	9.0	-	85.0	-	-
9.	*Agrostis gigantea*	30	109.0	9.8	92.6*	87.3	78.8	90.1*
Average values					87.4	92.2	84.1	

* *Alopecurus myosuroides* was the only annual weed at site 9.

DISCUSSION

At site 1 there were two distinct soil types although the soil analysis does not show much difference. The best couch control, particularly late season, and most crop damage, was found on the brown sandy area rather than the black sandy area. Crop drilling took place only one day after application and crop damage occurred, as might be expected.

Poor beet germination at site 2 resulted in the rest of the field, other than the EPTC trial, being re-drilled. The beet stand for the EPTC was compared with the second beet drilling and was reduced probably due to insufficient gap between application and drilling. Control of *A. repens* was 100% but that of *Phragmites communis* was nil.

Only four days elapsed between application of EPTC 10% granules and drilling at site 3, methiuron/chlorpropham granules were band applied on top of the EPTC granules, both crop stand and vigour were reduced. The combination of high temperatures and rainfall probably made theEPTC extremely active at this site. The late season assessment showed very good couch and annual weed control by the EPTC.

Weed competition was so severe in the untreated that the crop vigour was reduced to approximately 70% of that of the EPTC treated beet.

The soil at site 4 contained 18% organic matter. Medinoterb acetate/propham was band applied on the whole field including the EPTC plot, but crop stand and vigour were unaffected. Medinoterb acetate/propham gave a couch control of 53% and annual weed control of 78%. EPTC gave a control of couch of 99% and of annual weeds of 89%; this was composed in decreasing order of dominance of Stellaria media 96%, Polygonum lapathifolium 75%, P. convolvulus 100% and Chenopodium album 98%.

The soil at site 5 was very light and the EPTC plot was situated on a headland. The rest of the field was sprayed overall with pyrazon. The high temperatures and soil moisture probably made the EPTC very active and although 11 days elapsed before drilling some crop damage was apparent. Couch control was 100% and the control of Chrysanthemum segetum and Polygonum aviculare (the dominant weeds) was improved over the pyrazon by 73%.

At site 6 endothal/medinoterb acetate/propham was band sprayed over the EPTC, no damage occurred. Control of a mixture of A. repens and Agrostis gigantea was 74% at the first assessment and 89% at the second. The apparent improvement in control was due to a large increase in the untreated couch because of lack of smothering by the beet crop, which was suffering from calcium deficiency.

The soil at site 7 was extremely light and remained very dry for the first three weeks after application (only 0.19 in rainfall). This dryness of soil, accompanied by fairly warm conditions, should have given high activity by the EPTC. The level of control had dropped from 85% to 66% by the second assessment, but the reason for this drop was probably that the couch, which was Agrostis tenuis, reproduced by surface stolons as well as rhizomes, and these stolons may not have come in contact with EPTC treated soil.

At both sites 8 and 9 the EPTC was incorporated with spring tine harrows. Although more than 3 weeks elapsed between application and drilling there was an indication that crop vigour was very slightly reduced. This may have been due to the EPTC being retained longer by the clay soils than perhaps by the lighter more open soils at other sites. At site 9 both assessments showed a control of over 90% of Alopecurus myosuroides.

In these trials EPTC 4lb/ac gave a mean control of couch grass of 92.2%, from applications which commenced in mid-March and continued until just after mid-April. At sites 3 and 4 (Yorks) there were higher than average rainfall and temperatures, and in the Southern trials there were generally lower than average rainfall and temperatures in the period following application. All sites had several night frosts in this period. Application in mid-March was satisfactory in 1968 but no information was available for earlier applications.

The EPTC generally proved to be tolerated by the sugar beet provided 11 or more days elapsed between application and drilling. Beet drilled before 11 days suffered damage but all recovered to produce a satisfactory crop.

An annual weed assessment was possible at only four sites but the indications were that EPTC gave good control of annual weeds and that a further application of a pre-emergence herbicide was not necessary. Where an additional herbicide application was made there was no additional phytotoxicity to the beet. The possible exception was at site 3 where an application of methiuron/chlorpropham granules was made on top of EPTC granules.

The only tools at present recommended for the incorporation of EPTC to a depth of 6 in pre-planting of potatoes, are rotavators and disc harrows. At sites 8 and 9 satisfactory incorporation was achieved with spring tine harrows. It is possible that these and other tools are adequate for the shallow incorporation (2-3in) needed for couch control in sugar beet.

Acknowledgements

We wish to thank all the growers who carried out the trials, Horstine Farmery who carried out the granule application at site 3, and Mr. R. Wilson for technical assistance.

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Proc. 9th Brit. Weed Control Conf. (1968)

AN EVALUATION OF MIXTURES OF CHLORPROPHAM AND FENURON FOR WEED CONTROL IN SUGAR BEET GROWN ON PEAT SOILS

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Summary An examination has been made of chlorpropham and fenuron alone, and in different combinations, for weed control in sugar beet grown on soils with a high organic matter content.

Following the preliminary investigations of 1965, the individual chemicals, together with mixtures containing chlorpropham:fenuron of 4:1 and 8:1, were studied in greater detail in 1966 and 1967.

The treatments providing 2.0 + 0.5 and 4.0 + 0.5 lb a.i. per acre chlorpropham and fenuron respectively gave reductions in weed populations ranging from 25 to 70% with an equivalent effect on the vigour of those surviving these treatments. The beet were noticeably tolerant to all applications.

Although the results were not outstanding, it appeared that the 2.0 lb chlorpropham + 0.5 lb fenuron treatment would have been acceptable to many growers on peat soils in the absence of other more suitable chemicals. However, with the introduction of new pre- and post- emergence applied herbicides the chlorpropham/fenuron mixtures examined may already be of only limited application.

INTRODUCTION

With the availability of herbicides such as endothal + propham and pyrazon in 1964, and later lenacil, for broad spectrum annual weed control in sugar beet, the problems facing the beet grower on mineral soils of increased spring mechanisation due to a reduced labour force were eased substantially. These chemicals were generally ineffective on soils with a high organic matter content. On these soils hand and tractor hoeing could only be supplemented by the use of 'contact' materials applied before crop emergence and this was not proving to be too satisfactory.

At this time a chemical, or mixture of chemicals, to provide 'residual' weed control in sugar beet grown on peat soils was needed to ensure that sugar production from the Ely, Peterborough and Wissington areas of East Anglia was not jeopardised.

Of the chemicals available, chlorpropham and fenuron were considered by the Norfolk Agricultural Station to be the most likely herbicides to fulfil these requirements. Therefore, an experimental programme was initiated in 1965 and continued until 1967 to examine the pre-emergence use of the two materials alone and mixed together in different proportions.

In 1965 two sites were selected at Shippea Hill, near Ely, Cambridgeshire (site A) and at Holme Fen, Huntingdonshire (B). The treatments used were not identical at each centre, but between them three rates of chlorpropham alone, fenuron alone, and chlorpropham + fenuron mixtures in proportions of 1:1, 4:1 and 8:1 were examined. At least 2.0 in of rain fell in the four weeks following chemical application at both sites, even though they were sown and treated in the latter half of April.

In 1966 three investigations were completed at Mepal, near Chatteris, Cambridgeshire (C); Crowland, near Peterborough (D); and Methwold Hythe, near Downham Market, Norfolk (E). In each trial two levels of chlorpropham alone (1.0 and 2.0 lb a.i./ac) and fenuron alone (0.5 and 1.0 lb) were examined, together with three rates of two chlorpropham and fenuron combinations (4:1 and 8:1) which gave 0.125, 0.25 and 0.5 lb a.i./ac fenuron for each mixture. Drilling took place on 28th March at Crowland, 14th April at Methwold Hythe and 6th May at Mepal and the rain recorded at each site in the four weeks after treatment was 2.9, 2.1 and 0.8 inches respectively.

In 1967 it was intended to have three investigations again but one, at Prickwillow, near Ely, was lost as a result of a severe 'blow'. This left two sites at Methwold Hythe (E) and Yaxley, near Peterborough (F). The treatments were the same as those used in 1966. Both experiments were sown in the second half of April and at least 2.5 in of rain fell in the four weeks after herbicide application.

METHOD AND MATERIALS

All the investigations were conducted on commercial crops of sugar beet grown on soil with a high organic matter content (peats). All treatments were fully randomised and replicated. The plot size used was 1/200 ac.

The chemicals were applied overall as soon after drilling as possible in a water volume of 50 gal/ac. This was done with an Oxford Precision Sprayer fitted with Birchmeier Helico Sapphire 1.6 - 673a - 1.3 nozzles operating at a pressure of 25 or 30 lb/in^2.

All the materials used were formulated as emulsifiable concentrates and were available commercially. The chlorpropham and fenuron contained 40% and 10% active material respectively whilst the 4:1 mixture contained 20% chlorpropham + 5% fenuron and the 8:1 20% chlorpropham + 2.5% fenuron.

<u>Records</u>

(i) Pre-singling: Six or twelve random quadrat (18 x 4 in) counts were taken on each plot, the numbers of beet and the dominant weed species being recorded individually. In addition visual assessments of crop and weed vigour were taken on a scale 0 - 10. Where counts were not possible a visual assessment covering both population and vigour was taken.

(ii) Post-singling: A mid-season count of the beet in the centre two rows of each plot was made for the measurement of final population, together with a visual score for vigour.

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

Table 1

Summary of pre-singling assessments, 1965
(A = Shippea Hill; B = Holme Fen)

Treatment lb a.i./ac	Sugar Beet Braird A	Sugar Beet Visual Vigour A	Sugar Beet Visual Vigour B	Weeds Numbers A	Weeds Visual Vigour A	Weeds Visual Vigour B
	Scores and seedling counts as % controls					
Chlorpropham 1.0	78	82	102	110	78	44
" 2.0	105	82	97	32	33	50
" 4.0	79	60	91	32	28	30
Fenuron 1.0	-	-	66	-	-	21
" 2.0	-	-	81*	-	-	52
" 4.0	-	-	56*	-	-	45
Chlorpropham + fenuron						
0.5 + 0.125	81	98	91	73	89	69
1.0 + 0.25	93	87	91	71	61	57
2.0 + 0.5	75	82	86	92	44	44
Chlorpropham + fenuron						
1.0 + 0.125	87	87	91	74	33	33
2.0 + 0.25	90	60	86	25	22	28
4.0 + 0.50	79	27	81	20	17	18
Chlorpropham + fenuron						
0.5 + 0.5	-	-	91	-	-	56
1.0 + 1.0	-	-	81	-	-	34
2.0 + 2.0	-	-	91	-	-	70
Untreated controls	100 (38 seedlings/ 100 in)	100	100	100 (176 plants / yd^2)	100	100

* These treatments resulted in some mortality of seedlings in addition to loss of vigour.

RESULTS

The results from the two preliminary investigations in 1965 (Table 1) indicated that chlorpropham and fenuron alone and in combination gave a level of weed control with safety to the beet which had been difficult to attain before with other chemicals.

The herbicides were examined in greater detail in 1966 and 1967. With the difference in activity shown between chlorpropham and fenuron it was felt that a 1:1 combination was somewhat unbalanced for weed control on peat soils. The treatments were restricted to two levels each of chlorpropham and fenuron alone and three rates of two mixtures of the chemicals in the ratios of 4:1 and 8:1.

Effect on sugar beet: Pre-singling assessments on the crop clearly show (Table 2) a high tolerance by the beet seedlings towards the chemical treatments, particularly in respect of plant numbers. A greater effect was observed on the vigour of the crop but this was only outstanding at Crowland (D) in 1966 in the case of 1.0 lb fenuron. Following these results only small differences were found in the final beet populations, none of which could be attributed to herbicide treatment. (Table 3).

Table 2

Summary of pre-singling assessments on sugar beet, 1966 and 1967
(C = Mepal; D = Crowland; E = Methwold Hythe; F = Yaxley)

Treatment lb a.i./ac		1966 Braird C	1966 Braird D	1966 Braird E	1966 Vigour C	1966 Vigour D	1966 Vigour E	1967 Braird E	1967 Braird F	1967 Vigour E	1967 Vigour F
		Seedling counts and scores as % controls									
Chlorpropham	1.0	103	100	103	101	78	100	99	126	89	93
"	2.0	109	104	103	101	71	100	95	88	84	93
Fenuron	0.5	111	112	101	99	73	100	83	101	95	104
"	1.0	101	90	100	88	56	95	81	97	89	96
Chlorpropham + fenuron											
	0.5 + 0.125	115	104	104	96	81	100	103	89	92	96
	1.0 + 0.25	110	115	95	101	76	100	102	99	86	96
	2.0 + 0.5	105	104	103	91	63	98	93	106	84	87
Chlorpropham + fenuron											
	1.0 + 0.125	104	116	102	104	86	100	78	114	95	99
	2.0 + 0.25	105	112	98	96	89	100	94	101	95	93
	4.0 + 0.5	104	107	101	88	66	100	103	107	78	90
Untreated controls		100	100	100	100	100	100	100	100	100	100
(Seedlings/100 in)		(66)	(30)	(52)				(26)	(23)		
Sig diff (P = 0.05)		N S	N S	N S				N S	N S		
% S E		10.3	14.0	9.9				18.5	17.7		

Owing to late season crop variability, thought to be a result of restricted drainage and uneven perennial weed growth, it was possible to harvest only one experiment in each of the two years 1966 and 1967. In terms of yield of washed roots, their sugar content, and yield of sugar no outstanding differences were recorded (Table 3).

Effect on weeds: At most sites extremely high populations of weeds were encountered. The exception to this was Mepal (C) in 1966 where a very late sowing was followed by dry conditions for at least four weeks after herbicide application.

The pre-singling counts and visual assessments on all annual weeds clearly indicate that some control was achieved at every centre (Table 4). This was never exceptionally high but appeared to be useful under the conditions of high populations and excessive growth found on the soils in question.

Comparing the individual chemicals, Stellaria media and Urtica urens were more susceptible to chlorpropham and Chenopodium spp to fenuron. Consequently the mixtures, particularly at the levels giving 0.25 or 0.5 lb a.i./ac fenuron, tended to give a more consistent weed control than when chlorpropham or fenuron were used alone. The Polygonum spp were poorly controlled by all treatments and at Yaxley in 1967 tended to increase in numbers with increasing rates of herbicide. This result was probably caused by the higher chemical dosages reducing competition from the susceptible weed species and allowing the Polygonum spp to flourish. In terms of vigour the effect on this species was better, but on occasions the survival rate was significant.

Table 3

Summary of final beet populations and yields, 1966 and 1967
(C = Mepal; D = Crowland; E = Methwold Hythe; F = Yaxley)

Treatment lb a.i./ac	Populations (thousands/ac) 1966			1967	
	C	D	E	E	F
Chlorpropham 1.0	37.4	28.7	24.4	16.3	27.6
" 2.0	35.9	30.9	24.2	12.8	25.7
Fenuron 0.5	35.6	28.9	25.9	14.6	24.6
" 1.0	34.4	31.6	25.4	16.1	22.8
Chlorpropham + fenuron					
0.5 + 0.125	36.8	29.4	23.8	13.2	25.6
1.0 + 0.25	35.6	29.9	24.1	14.0	27.6
2.0 + 0.5	35.0	32.2	25.3	15.5	25.8
Chlorpropham + fenuron					
1.0 + 0.125	36.3	29.0	25.6	13.3	27.6
2.0 + 0.25	35.9	26.8	25.0	16.1	29.7
4.0 + 0.5	36.7	28.5	23.8	17.4	23.8
Untreated control	36.2	29.3	24.5	14.7	24.3
Sig diff (P = 0.05)	N S	N S	N S	N S	N S
% S E	3.8	12.7	8.3	18.9	12.6

Yields

Treatment lb a.i./ac	1966 (site C) Washed roots tons/ac	% sugar	Sugar yield cwt/ac	1967 (site F) Washed roots tons/ac	% sugar	Sugar yield cwt/ac
Chlorpropham 1.0	23.5	15.7	73.4	15.8	16.6	52.0
" 2.0	25.1	15.5	77.2	17.7	16.7	58.6
Fenuron 0.5	25.8	15.6	79.7	15.9	16.3	51.1
" 1.0	22.8	15.9	72.0	16.6	16.3	53.7
Chlorpropham + fenuron						
0.5 + 0.125	25.4	15.6	78.5	17.2	16.3	55.5
1.0 + 0.25	22.4	15.9	70.3	17.2	16.5	56.3
2.0 + 0.5	25.0	15.5	76.8	15.8	16.6	51.8
Chlorpropham + fenuron						
1.0 + 0.125	25.5	15.5	78.7	16.5	16.4	53.5
2.0 + 0.25	24.3	16.1	77.7	16.3	16.6	53.6
4.0 + 0.5	23.3	15.7	72.7	15.8	16.6	52.1
Untreated control	25.3	15.9	79.5	17.0	16.3	54.8
Sig diff (P = 0.05)	N S	N S	N S	N S	N S	N S
% S E	8.9	3.3	9.1	9.2	2.4	8.8

Table 4

Summary of pre-singling assessments on all annual weeds, 1966 and 1967
(C = Mepal; D = Crowland; E = Methwold Hythe; F = Yaxley)

Treatment lb a.i./ac	1966						1967			
	Number			Vigour			Number		Vigour	
	C	D	E	C	D	E	E	F	E	F
	Seedling counts and scores as % controls									
Chlorpropham 1.0	92	64	86	93	63	60	62	72	38	43
" 2.0	74	53	67	70	60	25	38	82	22	54
Fenuron 0.5	89	73	82	93	63	79	73	85	72	96
" 1.0	54	46	62	73	44	47	57	74	59	89
Chlorpropham + fenuron										
0.5 + 0.125	101	62	85	87	68	60	80	86	56	68
1.0 + 0.25	87	50	71	90	55	47	47	72	38	64
2.0 + 0.5	47	35	40	50	41	19	39	75	28	54
Chlorpropham + fenuron										
1.0 + 0.125	91	91	88	90	77	85	74	87	56	68
2.0 + 0.25	68	81	65	70	77	47	53	61	38	36
4.0 + 0.5	52	49	53	53	44	22	30	71	25	39
Untreated controls (plants/yd^2)	100 (38)	100 (275)	100 (325)	100	100	100	100 (530)	100 (390)	100	100

DISCUSSION

It had been hoped that greater activity would be shown by the various herbicides. Although the better treatments did not produce spectacular reductions in numbers of weeds, the vigour of those remaining was markedly reduced, producing results that were more encouraging than appears from consideration of weed population alone. This type of 'control' would seem to have some acceptability as enthusiasm was shown by several fen growers after seeing the effect of the better treatments in the field.

The partial resistance of Polygonum spp to the mixtures examined is a problem that must not be underestimated. On many peat soils they are the dominant weed and if poorly controlled can produce difficulties from singling until harvest. On soils where these species are not a serious problem then the 4:1 mixture at a level of 2.0 lb chlorpropham + 0.5 lb fenuron could offer useful weed control at a relatively low cost of approximately 80 shillings per acre. In an attempt to increase activity on weeds soil incorporation of the two mixtures used in 1966 and 1967 has been examined during 1968.

During these investigations two new materials for use on soils with a high organic matter content have become available. The mixture propham + medinoterb acetate was introduced by Bartlett and Emery (1966) and is only recommended on organic fen soils containing at least 7% organic matter. The properties of the other material propham + chlorpropham + fenuron have been described by Bracey (1967) and it would appear that the addition of propham to chlorpropham and fenuron helps considerably with the control of Polygonum spp. This mixture can be used on both peats and mineral soils. These two herbicidal mixtures are 'residual' in action and must be applied before crop emergence. In addition, a selective post-emergence applied 'contact' chemical, phenmedipham, has become available (Arndt et al. 1967) for use on all soil types. With one or other, or both of the herbicide types it should now be possible for the majority of beet growers on peat soils to overcome their weed problems in the spring. These developments may limit the application of the chlorpropham/fenuron mixtures examined in this report.

Acknowledgements

Appreciation is expressed to the several farmers who allowed these experiments on their beet crops and also to the field staff of the British Sugar Corporation Limited and the Norfolk Agricultural Station who assisted in many ways.

Thanks are also due to W. J. Craven and Company Limited of Evesham who kindly supplied the chemicals used.

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AN EVALUATION OF PYRAZON/PROPHAM MIXTURES FOR PRE-EMERGENCE WEED CONTROL IN SUGAR BEET

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Summary Experiments carried out in England and Scotland during the years 1966-67-68 are described in which mixtures of pyrazon and propham at various rates were compared with pyrazon alone at standard recommended rates and also with propham alone.

In all trials crop damage, in the form of temporary retardation, was greater from the mixtures containing the higher proportions of propham, but mixtures containing up to 1.5 lb propham caused little damage. The mixtures gave consistently better weed control in Scotland than either chemical applied alone, and pyrazon alone gave better weed control than propham alone; whereas, in the English trials, some mixtures gave better weed control than pyrazon alone, but at the expense of greater crop damage.

A mixture containing 1.4 lb pyrazon and 1.5 lb propham was successfully used on a commercial scale in Scotland during 1968, but no mixture under the English conditions was sufficiently superior to the recommended rates of pyrazon to warrant commercial usage.

INTRODUCTION

Pyrazon has been used on a commercial scale as a pre-emergence application to sugar beet in Britain for 5 years, but three problems that required investigation, in the light of commercial experience, were: (1) the variable and often inadequate weed control under Scottish conditions, probably attributed to climatic rather than soil differences (which is in line with Scandinavian findings); (2) some risks of crop damage on very light soils under certain weather conditions; and (3) the high farmer cost on heavy soils due to the higher rates of application required because of the adsorption factor.

Pre-emergence applications of propham have given short term and narrow spectrum weed control in Scotland, Erskine (1966) and log-trials in England during 1966 indicated that mixtures of propham and pyrazon would give good weed control with little risk of damage to the beet, Bray (1966).

Accordingly, trials with varying proportions of pyrazon and propham were laid down using rates based on commercial recommendations for both materials in relation to the soil type.

METHODS AND MATERIALS

The trials were carried out during the period 1966-68 on the farms of commercial growers in Fife, Perth, E.Lothian, and E.Anglia. The treatments were all applied pre-crop emergence immediately after drilling and the materials used were an 80% wettable powder formulation of pyrazon and a 50% wettable powder formulation of propham. These were applied alone at standard commercial rates and in mixtures ranging from 75% to 30% of the standard rate of pyrazon and from 75% to 50% of the standard rate of propham.

Application was overall by means of the Oxford Precision Sprayer using water vols. of 24-30 gal/ac with the exception of trial sites 26-29 inclusive which were treated by band sprayer at 21 gal/ac. Plot sizes ranged from 60 yd^2 to 120 yd^2 and treatments were randomised and replicated.

Assessments for weed control and crop damage were carried out by visual scoring by at least two assessors and weed counts, using, 1 ft^2 quadrats, were also taken on a sample of the trial sites.

Details of location, soil type and weed flora of the trial sites are shown in Table 1.

Table 1

No.	Location	Soil	Main Weeds
Scotland			
1966			
1	E.Lothian	L. loam	Polygonum aviculare (knotgrass), Chenopodium album (fathen), Stellaria media (chickweed), Fumaria officinalis (fumitory), Polygonum convolvulus (black bindweed), Veronica spp. (speedwell), Galeopsis tetrahit (hemp nettle.
2	E.Perths	S. loam	Chickweed, fathen, Poa, knotgrass, black bindweed Mysotis spp. (forget-me-not), Capsella bursa-pastoris (shepherd's purse), speedwell, Senecio vulgaris (groundsel), fumitory, Spergula arvensis (spurrey).
3	E.Fife	L. gravel loam	Galium aparine (cleavers), Atriplex patula (orache), fathen, speedwell, knotgrass.
4	S.E.Perths	Heavy clay	Cleavers, spurrey, Raphanus raphanistrum (wild radish).
1967			
5	W.Fife	Light sand	Chickweed, fathen, forget-me-not, Poa, black bindweed, Chrysanthemum segetum (corn marigold), speedwell, fumitory, spurrey, hemp nettle.
6	S.Fife (Coastal)	Light sand	Sinapsis arvensis (charlock), fathen, hemp nettle.
7	E.Fife	Medium loam	Hemp nettle, black bindweed, knotgrass, spurrey, chickweed, fumitory.
8	W.Fife	L. loam	Knotgrass, speedwell, fumitory, charlock.
9	E.Fife	S. loam	Black bindweed, spurrey, charlock, speedwell, knotgrass.
10	E.Fife	L. loam	Germander speedwell, knotgrass, black bindweed, charlock, Tripleurospermum maritimum (scentless mayweed).
11	E.Fife (Coastal)	L. loam	Buxbaum speedwell, charlock, fathen, Urtica urens (annual nettle), spurrey, corn marigold, groundsel, scentless mayweed.
12	E.Fife (Coastal)	Very l. loam	Charlock, chickweed, fathen.

Table 1 continued

No.	Location	Soil	Main Weeds
13	S.E.Fife (Coastal)	S. loam	Chickweed, knotgrass, charlock, speedwell, fathen, orache.
14	S.Fife (Coastal)	M. loam	Knotgrass, chickweed, scentless mayweed, fathen, charlock.
15	S.E.Fife	Sand (Black)	Fathen, knotgrass, chickweed, black bindweed, spurrey, hemp nettle.
16	S.E.Fife (Coastal)	Sand (Black)	Fathen, forget-me-not, hemp nettle, fumitory, speedwell, shepherd's purse.
17	N.E. Fife	L. loam	<u>Arthemis cotula</u> (stinking mayweed), groundsel, fathen, knotgrass.
18	S.Fife	L. loam	Chickweed, scentless mayweed, knotgrass, hemp nettle, Poa, black bindweed.
19	E.Fife (Coastal)	L. sandy loam	Scentless mayweed, chickweed, annual nettle.
<u>1968</u>			
20	N.E.Fife	Sandy loam	Charlock, speedwell, chickweed, fumitory.
21	N.W.Fife	L. sandy loam	Knotgrass, mayweed, hemp nettle, chickweed, speedwell, Poa.
22	E.Fife	L. loam	Cleavers, hemp nettle, chickweed, mayweed,knotgrass.
23	Central Fife	L. sandy loam	Chickweed, knotgrass, fathen, hemp nettle, spurrey.
24	S.E.Perths	Medium loam	Mayweed, chickweed, groundsell, knotgrass, fathen, fumitory.
25	N.Fife	L.loam	Mayweed, chickweed, speedwell, knotgrass, charlock, black bindweed.
<u>England</u>			
<u>1967</u>			
26	West Suffolk	Loamy fine sand	Knotgrass, fathen, orache, Mayweed sp., Veronica sp., <u>Viola arvensis</u> (field pansey).
27	West Norfolk	Coarse Sand (Breck)	Fathen, field pansy, black bindweed, knotgrass, shepherd's purse.
28	W.Suffolk	Loamy fine sand	Black bindweed, chickweed, knotgrass, fathen, Mayweed sp.
29	W.Suffolk	S. loam	Fathen, charlock, knotgrass, chickweed, Mayweed sp.
<u>1968</u>			
30	Cambridge	Medium loam	Black bindweed, <u>Anagallis arvensis</u> (scarlet pimpernel), field pansy, chickweed, runch.
31	N.Essex	Heavy loam	Runch, orache, knotgrass, Mayweed sp., black bindweed.
32	Cambridge	Clay	Fathen, orache, <u>Sonchus oleraceus</u> (annual sowthistle),knotgrass

RESULTS

Weed Control results, expressed as percentage reduction in weed cover, are shown in Table 2.

Table 2

Mix No.	Pyrazon a.i.	Propham a.i.	Scottish Sites Nos. 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Treatment Means
	2.4 lb	---	-	84	70	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	77.0
	2.8 lb	---	46	88	-	-	52	80	90	75	60	50	75	75	90	85	65	40	90	85	75	81	72	78	71	80	79	73.0
	3.2 lb	---	68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68.0
	3.68 lb	---	-	-	65	10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	37.0
1	0.84 lb	2.1 lb	-	-	-	-	85	85	40	-	70	40	80	70	80	70	65	60	75	90	65	-	-	-	-	-	-	69.0
2	1.12 lb	1.8 lb	-	-	-	-	76	90	75	-	70	60	80	70	65	80	70	75	80	90	70	-	-	-	-	-	-	75.0
3	1.4 lb	1.5 lb	-	-	-	-	89	90	80	80	85	70	80	75	70	95	75	70	85	80	75	83	81	76	85	90	86	81.0
4	1.4 lb	2.25 lb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	88	82	85	88	87	90	86.0
5	1.68 lb	1.2 lb	-	-	-	-	77	85	70	-	75	40	85	70	70	75	70	70	70	85	70	-	-	-	-	-	-	71.0
6	1.84 lb	1.5 lb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	81	83	86	88	86	86	85.0
7	1.84 lb	2.0 lb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	86	81	80	81	87	87	83.0
8	2.1 lb	2.25 lb	79	93	84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	85.0
9	2.2 lb	1.5 lb	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	86	82	80	86	90	85	85.0
10	2.7 lb	3.5 lb	-	-	-	14	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14.0
	---	3.0 lb	-	-	-	-	-	-	75	-	-	-	65	-	-	-	-	80	85	70	-	78	83	86	78	76	68	76.0
	Control		2	2	0	0	0	0	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	12	0	0	5	0.9

Mix No.	Pyrazon a.i.	Propham a.i.	English Sites Nos. 26	27	28	29	30	31	32	Treatment Means
	0.8 lb	---	91	97	89	90	-	-	-	91.8
	1.4 lb	---	94	99	96	97	-	-	-	96.5
11	1.1 lb	1.1 lb	94	98	95	96	-	-	-	95.7
12	0.88 lb	1.32 lb	96	98	92	95	-	-	-	94.0
13	0.66 lb	1.54 lb	93	98	94	95	-	-	-	95.0
	2.8 lb	---	-	-	-	-	94	-	-	94.0
14	1.05 lb	1.05 lb	-	-	-	-	80	-	-	80.0
15	1.4 lb	1.4 lb	-	-	-	-	85	-	-	85.0
16	1.75 lb	1.75 lb	-	-	-	-	86	-	-	86.0
	3.6 lb	---	-	-	-	-	-	72	65	68.5
17	1.8 lb	1.8 lb	-	-	-	-	-	65	49	57.0
18	2.25 lb	2.25 lb	-	-	-	-	-	72	65	68.5
19	2.7 lb	2.7 lb	-	-	-	-	-	78	72	75.0

Weed counts on two sites of similar soil type are shown in Table 3, one under Scottish and the other under English conditions.

Table 3

WEEDS	SCOTLAND SITE 2 WEED COUNTS IN 8 THROWS OF 1 FT^2 QUADRAT				ENGLAND SITE 30 WEED COUNTS IN 12 THROWS OF 1 FT^2 QUADRAT			
	Pyrazon 2.4 lb a.i.	Pyrazon 2.8 lb a.i.	Propham 2.25 lb a.i. Pyrazon 2.1 lb a.i.	Control	Pyrazon 2.8 lb a.i.	Propham 1.05 lb a.i. Pyrazon 1.05 lb a.i.	Propham 1.4 lb a.i. Pyrazon 1.4 lb a.i.	Propham 1.75 lb a.i. Pyrazon 1.75 lb a.i.
Chickweed	22	73	2	124	1	2	4	4
Fathen	22	17	28	106	0	2	4	0
Poa	8	12	-	368	-	-	-	-
Knotgrass	-	5	-	4	16	57	27	33
Black Bindweed	-	2	-	2	22	44	39	47
Forget-me-not	-	-	-	4	-	-	-	-
Shepherd's purse	-	-	-	4	-	-	-	-
Speedwell	-	-	-	2	-	-	-	-
Groundsel	-	-	-	1	-	-	-	-
Fumitory	-	-	-	1	-	-	-	-
Spurrey	-	-	-	1	-	-	-	-
Scarlet Pimpernel	-	-	-	-	12	69	55	45
Field Pansy	-	-	-	-	3	16	13	9

Crop damage results in which a mean percentage of 5% or less indicates crop retardation without loss of stand and figures above this indicate some thinning of the crop are shown in Table 4.

Table 4

SCOTTISH TRIALS

Mixture No.	Treatment/acre Pyrazon a.i.	Treatment/acre Propham a.i.	Mean %
S.P.	2.4 lb	---	1.0
S.P.	2.8 lb	---	0
S.P.	3.2 lb	---	0
1	0.84 lb	2.1 lb	1.4
2	1.12 lb	1.8 lb	2.5
3	1.4 lb	1.5 lb	1.8
4	1.4 lb	2.25 lb	11.2
5	1.68 lb	1.2 lb	1.1
6	1.84 lb	1.5 lb	2.8
7	1.84 lb	2.0 lb	7.4
8	2.1 lb	2.25 lb	7.5
9	2.2 lb	1.5 lb	3.8
	---	3.0 lb	8.3
U.C.	---	---	0.2

ENGLISH TRIALS

Mixture No.	Treatment/acre Pyrazon a.i.	Treatment/acre Propham a.i.	Mean %
S.P.	0.8 lb	---	1.7
S.P.	1.4 lb	---	7.7
11	1.1 lb	1.1 lb	4.5 *
12	0.88 lb	1.32 lb	4.3 *
13	0.66 lb	1.54 lb	5.0 *
S.P.	3.6 lb	---	2.5
17	1.8 lb	1.8 lb	4.5
18	2.25 lb	2.25 lb	6.5
19	2.7 lb	2.7 lb	8.5

(S.P.= Standard pyrazon treatment. U.C.=Untreated Control. *=Temporary chlorosis)

DISCUSSION

Under Scottish conditions, weed control was generally better from the mixtures than from pyrazon alone. Pyrazon at 2.8 lb/ac gave inadequate weed control on 6 sites of the 17 sites treated, whilst propham alone at 3.0 lb/ac gave inadequate weed control on two of the 11 sites treated, but crop damage was recorded on 6 of these sites, whereas there was no damage recorded on the pyrazon sites. Mixtures 1, 5 and 10 generally failed to give adequate weed control in relation to the soil types concerned, whilst mixtures 3, 6 and 9, in which propham was kept at a constant 1.5 lb/ac, but with rates of pyrazon varying from 1.4 to 2.2 lb/ac gave good weed control with the mean weed cover reduction improving from 81% to 85%, but with crop retardation varying only slightly from 1.8% to 3.8%. On comparing mixture 4 with mixture 3, where propham is increased from 1.5 lb/ac to 2.25 lb/ac while pyrazon remained at 1.4 lb/ac, weed control was again increased from 81% to 86%, but at the expense of a crop damage increase from 1.8% to 11.2%.

In the English trials, mixture 11 gave the better weed control of the mixtures used in the light soil series, but the crop showed chlorosis during the early stages of growth on all sites as a result of the pyrazon/propham mixtures, which was not recorded on the pyrazon alone plots. Weed control from mixture 11 was in line with the expected effect of this rate of pyrazon on these soils.

In the heavy soil trials, under English conditions, weed control from the mixtures was inferior to that obtained from the recommended rate of pyrazon unless the rate of the mixture, in total lb/ac, was 25% or more above the pyrazon rate used. At these levels, the mixture resulted in some loss of beet stand.

In all trials, irrespective of soil type, mixtures of pyrazon and propham containing more than 1.5 lb/ac of propham generally caused unacceptable levels of crop retardation with or without loss of stand. Under the English conditions, mixtures with 1.5 lb/ac or less of propham were not superior to the recommended rates of pyrazon, but in Scotland these mixtures gave better and more consistent weed control with little or no crop retardation, which was repeated over the commercially treated acreage, with 1.4 lb/ac pyrazon and 1.5 lb/ac propham, during 1968.

Acknowledgements

The authors wish to acknowledge the assistance of numerous farmers who kindly provided the facilities for field trials, and thanks are also due to Messrs. A. Mercer and H. Norris of the British Sugar Corporation, Messrs. K. Fraser, T. Robertson and J. Pike of Chemical Spraying Co., Limited, Fife, for help in finding sites and general assistance.

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Proc. 9th Brit. Weed Control Conf. (1968)

A GROWER'S EXPERIENCE WITH HERBICIDES FOR SUGAR BEET

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Summary This paper reviews a grower's experience over the last seven seasons (1962-68) with the use of herbicides on the sugar beet crop on a Norfolk estate.

INTRODUCTION

Sugar beet has been grown here since 1926 and for many years was regarded as a cleaning crop as a consequence of the large amount of hand work used on it in the early summer. Growers have always been quick to embrace any method which would reduce hand labour, such as, use of precision drills, rubbed or pelleted seed, thinners and herbicides. All these have been taken up with enthusiasm.

METHOD AND MATERIALS

The acreage of sugar beet now grown at Docking is five hundred acres approximately and cropping details are given as a background to this review.

Site and soil type - The soil in the parish of Docking is a light type, designated officially as containing 87% sand with a high proportion of flints and can 'blow' quite badly in unfavourable circumstances. The land lies 200-275 ft above sea level and the prevailing wind is north west. Average rainfall is light, between 23 and 24", chiefly falling during the winter months.

Fertilizer treatment - Preparation of the seed bed is as typical for the area. Ground carbonate of lime is applied at 30 cwt/ac everytime the beet comes into the rotation, in January and February. Kainit is applied about the same time at 4cwt/ac and in 1968 Kieserite at 3 cwt/ac was applied to 280 acres. A compound fertilizer, ratio 20.10.10., is put on 2-3 weeks before drilling at 8cwt/ac and the crop is top dressed with a 26% or 34% N. fertilizer at 2-4 cwt/acre.

Drilling - Drilling starts during the second half of March, using two Stanhay p.t.o. 8 row drills, row width 18", fitted with Dorman band sprayers. Rather than rely entirely on the alarm devices on these machines, a second man is employed to walk behind to help with the stone clearing. He also assists with herbicide mixing.

Herbicide mixing - Experiences gained from early experimenting with herbicides showed the value of pre-mixing the required dose of chemical with the correct amount of water before filling the spray tank. This method also ensures that topping up can be carried out and the tank does not empty in the middle of a drilling run.

Weed flora - The main weeds on the farm are: Polygonum aviculare (knotgrass), Stellaria media (chickweed), Veronica persica (buxbaum's speedwell), Senecio vulgaris (groundsel) Chenopodium album (fathen), Polygonum convolvulus (black bindweed) and some Fumaria officinalis (fumitory).

RESULTS

Experiences with herbicides - Field experiments with a range of herbicides and application techniques Ripper (1956) were carried out on the farm from 1956 but commercial usage only started in 1962.

1962. Propham/endothal, (Murbetex) was used on about half the acreage, at the recommended rate using rubbed and graded seed at 1½" spacing. Weed control was unsatisfactory on a twenty acre field which was early drilled; this had to be redrilled. Otherwise, results were very satisfactory, the weeds being well controlled with the exception of Chenopodium album (fathen).

1963. After the experience of the previous year, propham/endothal was used on the whole acreage with the exception of one field that had a low weed population. The same methods were used as in 1962 but the rate of chemical was reduced to slightly below the recommended rate. Singling work was speeded up but Chenopodium album was very troublesome and either had to be hand pulled or it became an impediment to mechanical harvesting.

1964. Propham/endothal was used on the whole acreage and singling went well but Chenopodium album was still troublesome.

1965. This year the acreage was divided between pyrazon (Pyramin) and propham/endothal the former at the recommended rate, 2½ lb/30 gallons, the latter at a rate of 15 pints in 30 gallons of water to apply to 3.7 acres. The week-end of the 16th May was very warm, and one day the temperature rose to 80°F. for an hour. The beet was at various stages of growth, from seedlings to four true leaf stage but irrespective of size there was complete death of all plants including weeds, on the light sharp soils, about 90 acres in all that were pyrazon treated. On the stronger soils the beet plants were a little retarded but eventually grew away well from a clean seed bed with little or no germination of Chenopodium album. The propham/endothal treated crop was retarded in some areas but finished as a good crop.

1966. In addition to the two chemicals used previously, lenacil (Venzar) was tried at a rate of 1½ lb in 30 gallons of water on 3.7 acres. There was a little 'scorching' but no serious trouble and we found there was control of Avena fatua (wild oats). The dosage rate of pyrazon was reduced to 2¼ lb in 30 gallons of water.

1967. The acreage was divided between propham/endothal, pyrazon and lenacil. The first gave the poorest control of weeds, but was the safest on the lightest soils with the highest sand content.

1968. Continued as in 1967 but using endothal/propham/medinoterb (Murbetex Plus) on the lightest soils and lenacil where there was a likelihood of a growth of Avena fatua. An acreage was tried using pelleted seed at 7" spacing with endothal/propham/medinoterb on the seedbed, followed by phenmedipham (Betanal) band sprayed with a converted Dorman machine, using no hand work. The second operation was late but was very promising and a larger acreage will be done this way in the future.

For some drillings this year the soil was very dry and propham/endothal/medinoterb failed to control Chenopodium album. On two fields of very sandy soil the amount of pyrazon was reduced to 1¾ lb, this operation was fortunately followed by showers of rain and a very satisfactory clean crop resulted.

DISCUSSION

It has been possible, at Docking, to reduce the cost of hand labour from £6.9/acre in 1962 to £6.2/acre in 1968. Wages over the seven seasons have risen by an average of 2.8% per year but costs of singling have fallen by an average of 2.9% per year, helped by the fact that a small but increasing acreage, 5 - 8% has been grown entirely mechanically. Were it not for the excessive growth of Chenopodium album, this acreage would be much greater but in July when the main farm work has eased, I indulge in the luxury of hand pulling Chenopodium album on some of the weediest fields; in the future with the better management of phenmedipham I hope to obviate this. One pleasant side effect noticed since using herbicides is the complete absence of "damping-off" of which used to affect seedlings on the early drilled fields every year.

In Norfolk beet producers have become dependant on herbicides as the pressure of low returns has led to reduction of permanent staff. Gang labour is still available but charges are exorbitant unless the crop has been treated with a herbicide. Growers are grateful for the products produced so far but some hope for a broader spectrum post-emergent herbicide.

I think the ultimate could be a granular herbicide of slow release which could be applied at the same time as the fertilizer. This may be a dream but they sometimes come true.

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Proc. 9th Brit. Weed Control Conf. (1968)

THE RECOVERY FROM INHIBITION OF PHOTOSYNTHESIS BY ROOT-APPLIED HERBICIDES AS AN INDICATION OF HERBICIDE INACTIVATION

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Summary Herbicide inactivation in various plant species is characterized by recovery from photosynthesis inhibition following removal of the herbicides from the root environment. In this way inactivation in plants is classified as high, weak, or absent. Herbicide inactivation is increased at higher temperature. Special cases are reported of tolerance of carrot, hyacinth and strawberry to some herbicides, resulting in smaller effects on photosynthesis, and a sometimes rather low, constant level of inhibition upon removal of the herbicide. The results are discussed in relation to selectivity in the field. High herbicide inactivation mostly enables a seed bed application, which is more restricted with weak inactivation. However, selective applications of herbicides which are not inactivated are only feasible in perennial and established annual crops.

INTRODUCTION

Many herbicides are absorbed by the roots and remain active in the soil for a certain period of time. Generally, their selective use is based on a combination of factors, some of which restrict leaching of the herbicides from the soil surface to the rooting zone of the crop plant. Deep-rooting perennial crop plants are reasonably well protected against a number of these herbicides, but such depth-protection is less pronounced during the early growing stage of most annual crops. Under these conditions, the selective use of soil-acting herbicides may depend on soil type, rainfall and other environmental factors. The safest applications will be those, however, in which crop plants also show physiological tolerance to the herbicides, so that limited uptake by the roots does not seriously affect plant growth and development.

The effects of various herbicides on plants are diverse. An increasing number, however, specifically inhibit photosynthesis. This group includes the substituted ureas, most of the diazines, the triazines, some of the amides, the quaternary ammonium compounds, and some other herbicides. The inhibition of photosynthesis of intact plants can be measured quantitatively in experiments of rather short duration. A comparison between the reaction of different plant species is possible, and the soil factor can be excluded by using nutrient solution. In contrast to leaf-application of a herbicide there is continuous uptake of a herbicide added to the nutrient solution, which may result in a progressive decrease of photosynthesis with time. The capacity of a plant species to inactivate the herbicide taken up from the nutrient solution can be studied by removing the herbicide from the root environment at a certain level of inhibition of photosynthesis, and following photosynthesis during a subsequent period. Inactivation of the herbicide inside the plant will then be reflected by a recovery of photosynthesis. The first experiments with maize, a plant which is known to metabolize simazine (Castelfranco et al 1961, Hamilton and Moreland 1962, Roth and Knüsli 1961), have demonstrated this.

Some of our results with various plant species and herbicides have been published earlier (Van Oorschot and Haker 1964, Van Oorschot 1965, Van Oorschot 1968). In the present paper a number of more recent observations are included in a comparative survey of our data on herbicide inactivation as established by the technique described. In addition, data are presented on selective inhibition of photosynthesis in some plants by different herbicides added to the nutrient solution.

MATERIAL AND METHODS

The apparatus used for the measurement and recording of photosynthesis (as CO_2 uptake) and transpiration of intact plants has been described previously (Van Oorschot and Belksma 1961). Experimental procedure is described by Van Oorschot (1965). In a later phase of our studies a larger installation with better control of environmental conditions was used (Louwerse and Van Oorschot 1969), and calculations of CO_2 uptake, transpiration, temperatures etc. based on the recorded data were made with an IBM-1620 computer.

RESULTS

Terbacil and bromacil in Mentha spp. and Agropyron repens

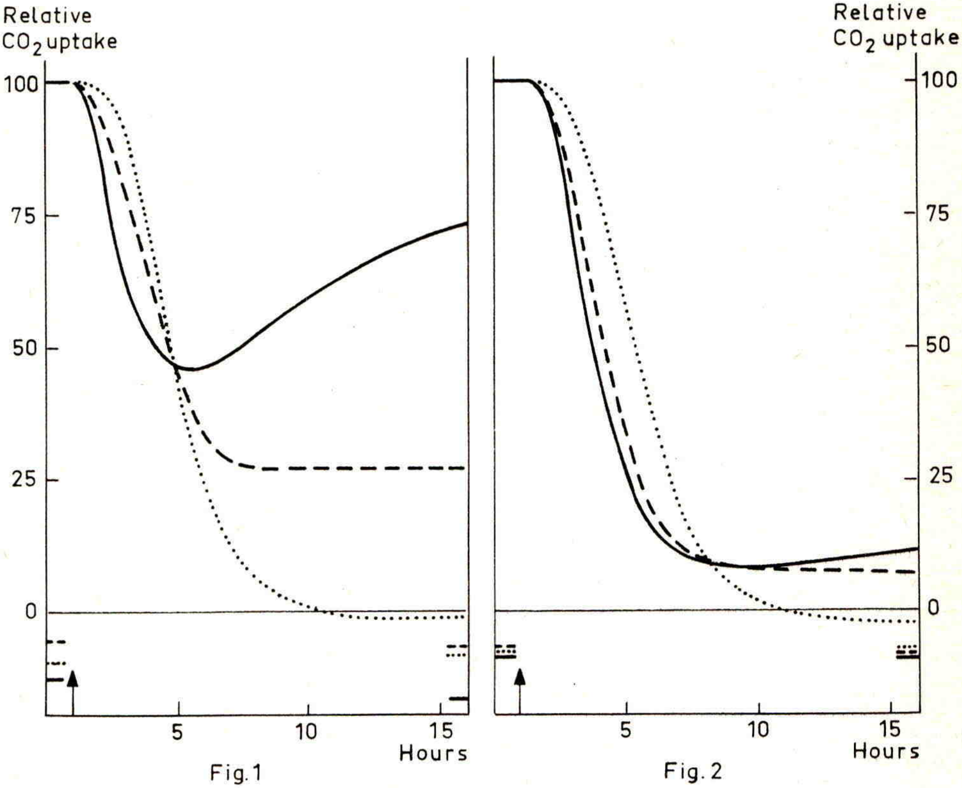

Fig. 1 Removal from the root environment of terbacil (applied at ↑) between 46 and 52 % inhibition of *Mentha piperita* (——), *Mentha viridis* (– –) and *Agropyron repens* (....).

Fig. 2 Removal from the root environment of bromacil (applied at ↑) between 50 and 55 % inhibition of *Mentha piperita* (——), *Mentha viridis* (– –) and *Agropyron repens* (....).

The results of experiments with terbacil on Mentha piperita (peppermint), Mentha viridis and Agropyron repens (couch grass) are shown in Fig. 1. Respiration during the dark periods at the beginning and at the end of the experiments is indicated by short horizontal dashes on the ordinates. The curve for peppermint is an average of 3 replicates, the others are from single experiments. On exposure of the roots to a nutrient solution containing 2×10^{-5} M terbacil, all species show gradual decrease in CO_2 uptake. The differences in reaction may partly be due to differences in the rate of transpiration (Van Oorschot 1969). In between the 46 and 52 % level of inhibition the herbicide-containing nutrient solution was removed, the roots were rinsed with water and a herbicide-free nutrient solution was applied. In all experiments with peppermint a gradual recovery was observed, in one experiment the CO_2 uptake even recovered to the initial reference value. The same procedure resulted in negative values for the CO_2 uptake of couch grass, while that of Mentha viridis decreased to a constant level of about 27 %. The difference between these plant species is in accordance with the selectivity of terbacil in the field (Van Staalduine 1968).

The results of similar experiments with the related bromacil on the same plant species are given in Fig. 2 (average of 2 replicates with peppermint, single experiments of the others). The herbicide was removed from the root environment when inhibition attained 50 - 55 %. Although a slight tendency for recovery of CO_2 uptake of peppermint was present, the curve is completely different from that with terbacil. Mentha viridis also seems more sensitive to bromacil, while the reaction of couch grass is similar for both herbicides. These results are also in accordance with field observations (Van Staalduine 1968). From the results with terbacil and bromacil it

Table 1

High herbicide inactivation

Herbicide 2×10^{-5} M (2×10^{-5} M: *)	Plant species average 3 expts (single expt *)	Leaf temp. °C	Relative CO_2 uptake: At removal of herbicide	Minimum value	12 Hours after removal
simazine	maize	28	50	35	70
atrazine*	maize	25	59	40	63
pyrazon	sugar beet	26	50	50	94
pyrazon	Viola tricolor*	23	53	39	60
5-amino-4-bromo-2-phenyl-3-pyridazone	sugar beet*	24	45	45	77
lenacil	Viola tricolor*	23	62	62	80
5-bromo-6-methyl-3-phenyluracil	flax	25	50	47	64
terbacil	peppermint	27	54	46	73
monuron	Plantago lanceolata	26	50	12	56
cycluron	sugar beet	25	50	37	69
cycluron	tomato*	25	10	7	52
N'-4-(butoxyphenyl)-NN-dimethylurea*	onion	23	50	8	51
monolinuron	beans* (Berna)	25	47	14	48
1-(3-chloro-4-methyl phenyl)-3-methyl-2-pyrrolidione	tomato	25	45	28	62
phenmedipham 1)	sugar beet*	23	65	44	70

1) corrected for effect of formulating material on CO_2 uptake

may be concluded that peppermint has a large capacity to inactivate terbacil, and a very small one to do so with bromacil. With Mentha viridis this capacity is not evident, although the reaction to terbacil is less pronounced than that to bromacil.

Comparative characterization of recovery

An adequate way to characterize briefly the recovery from photosynthesis inhibition is the relative value of CO_2 uptake 12 hours after removal of the herbicide from the root environment compared to the value at which the herbicide was removed (mostly around 50 % inhibition). In addition, the minimum value of CO_2 uptake during this period will also demonstrate the rate of the recovery process. In this way the recovery of some plant species from inhibition by various herbicides is presented in Table 1 and 2. If, at the end of the experiment - 12 hours after removal of the herbicide - CO_2 uptake surpassed the value of that at the moment of removal, the plant species-herbicide combination has been included in Table 1. Comparatively, this may be classified as high herbicide inactivation, in contrast to the weak herbicide inactivation given in Table 2, summarizing recoveries in CO_2 uptake above the minimum value, but below that at the moment of removal of the herbicide. However, it must be realized that the distinction between the groups is rather arbitrary. Absence of herbicide inactivation, as, for example, with couch grass and Mentha viridis in Fig. 1, indicated by no recovery in CO_2 uptake during the same period of 12 hours is given in Table 4.

Most of the data in Table 1 represent average values of experiments with small variations in the replicates, except for those of atrazine/maize, terbacil/peppermint and N'-4-(butoxyphenyl)-NN-dimethylurea/onions. In some experiments a 10-fold herbicide concentration was used since 2×10^{-5} M had hardly any effect on CO_2 uptake. The low minimum value in some plant species, compared to the value at removal of the herbicide, may be related to the larger root system (plantain) or storage organs (onions), which may cause continued supply of herbicide from these organs to the leaves after removal of the herbicide from the solution, and consequently a lag period in recovery. This is, however, unlikely for beans. Practical use of most of these herbicides is technically possible on the seed bed of these crops.

Table 2

Weak herbicide inactivation

Herbicide 2×10^{-5} M (2×10^{-4} M*)	Plant species average 3 expts (single expt *)	Leaf temp. °C	Relative CO_2 uptake: At removal of herbicide	Minimum value	12 Hours after removal
2-methoxy-4,6-bis (1-methoxy-3-propyl amino)-s-triazine	beans	23	50	24	35
	oats	24	50	10	13
	tomato*	25	40	-3	18
pyrazon	oats	24	50	23	43
pyrazon	tomato*	25	48	26	41
pyrazon	beans*	26	50	32	41
5-amino-4-bromo-2-phenyl-3-pyridazone	winter wheat*	24	52	3	13
	A. myosuroides*	23	45	6	10
bromacil	peppermint	25	52	8	11
5-bromo-6-methyl-3-phenyluracil	sugar beet*	25	50	33	48
cycluron	maize	25	50	11	20
cycluron	oats*	24	44	13	37
monolinuron	peppermint*	25	55	7	14
monolinuron	beans (Elan, Lotus)	25	66	12	34
benzthiazuron	sugar beet*	28	50	6	15
propanil*	rice	25	65	50	62

Some of the data in Table 2 represent averages of 2-3 replicates, but most are from single experiments. The varieties of beans (Phaseolus vulgaris) in this table showing a weak inactivation of monolinuron are of another type to that in Table 1. So far various plant species have been found to weakly inactivate pyrazon and a related pyridazone derivative. In general, a seed bed application of these herbicides is much more restricted than of those in Table 1.

Table 1 and 2 also show the leaf temperatures, at which the experiments were made. The importance of this will be evident from the results given in Table 3. At a higher temperature the recovery in CO_2 uptake is higher. It has, however, to be taken into account that at lower temperatures untreated plants show some decrease in CO_2 uptake during a similar period, but this does not affect the conclusion that herbicide inactivation is increased at higher temperatures. The weak inactivation of benzthiazuron in sugar beets at 28°C is absent at a temperature of 23°C.

Table 3

Effect of temperature on herbicide inactivation

CO_2 values for maize are from Van Oorschot (1965), and represent averages of 3 replicates as those for peppermint at 27°C. Other values are from single but comparable experiments.

Herbicide 2×10^{-5} M	Plant species	Leaf temp. °C	Relative CO_2 uptake: At removal of herbicide	Minimum value	10 Hours after removal
simazine	maize	28	50	35	65
		19	50	32	40 2)
pyrazon 1)	sugar beet	29	56	32	86
		18	49	36	52 2)
terbacil	peppermint	27	54	46	68
		18	57	34	36 2)
benzthiazuron	sugar beet	28	50	6	9
		23	45	25	25

1) 10^{-4} M

2) At these temperatures CO_2 uptake of untreated plants decreased to 79, 85 and 75 % respectively.

In Table 4 various herbicides and plant species are listed in which no recovery in CO_2 uptake was observed under similar experimental conditions as in Table 1 and 2 (leaf temperature 22-27°C, herbicide concentration 2×10^{-5} M, removal at about 50 % inhibition). As a result, this list covers rather large differences as, for example, between Mentha viridis and couch grass with terbacil in Fig. 1. Some recovery may have occurred had the period of measurement been longer (see Table 6). Only for some plant species, e.g. apples and black currants, the experimental period was extended to 2-3 days. Among the herbicides listed as showing no inactivation in the given plant species are many which are in selective use in the field, e.g. simazine, desmetryne, pyrazon, lenacil, bromacil, diuron, metobromuron and buturon (Sijtsma and Veenstra 1968). However, their use is restricted to perennial and established annual crops.

Table 4

Absence of herbicide inactivation

simazine:	strawberry, black currant, asparagus, apple (G. Del.), sugar beet, chicory
prometryne:	onion
desmetryne:	head cabbage
methoprotryne:	winterwheat
2-methoxy-4,6-bis(1-methoxy-3-propylamino)-s-triazine:	sugar beet
2-ethylamino-4-methylthio-6-t-butylamino-s-triazine:	winterwheat, A. myosuroides
2-azido-4-ethylamino-6-t-butylamino-s-triazine:	rice, maize, flax, sugar beet
pyrazon:	tulip, onion
5-amino-4-bromo-2-phenyl-3-pyridazone:	winterwheat, Alopecurus myosuroides
lenacil:	sugar beet, strawberry, Agropyron repens, spinach, beans
5-bromo-6-methyl-3-phenyluracil:	beans
bromacil:	apple, black currant, strawberry, Agropyron repens, Mentha viridis
terbacil:	strawberry, Agropyron repens, Mentha viridis
monuron:	asparagus, maize, strawberry
diuron:	asparagus, tulip, broad beans, maize
N'-4-(butoxyphenyl)-NN-dimethylurea:	beans
fluometuron:	maize
metobromuron:	potato, peas
chlorbromuron:	peas
buturon:	winterwheat, Poa pratensis, Alopecurus myosuroides, Poa annua
benzthiazuron:	Stellaria media, sugar beet
1-(3-chloro-4-methylphenyl)-3-methyl-2-pyrrolidione:	potato, onion, rice, P. convolvulus
propanil:	sugar beet
2-trifluoromethyl-6-chloroimidazo [4,5-6] pyridine:	maize, sugar beet
2-t-butyl-6-chloroimidazo [4,5-6] pyridine:	maize, sugar beet

Special cases of tolerance to some herbicides

Photosynthesis-inhibiting herbicides which can be used in carrot growing have only a small or negligible effect on CO_2 uptake of carrots. This has been observed earlier with propazine, prometryne, linuron and N'-(3-trifluoromethylphenyl)-N-methoxy-N-methylurea (Van Oorschot, 1964). In addition, chlorbromuron, cypromid, solan, monalide and 1-(3-chloro-4-methylphenyl)-3-methyl-2-pyrrolidione did hardly affect the CO_2 uptake of carrots. In contrast with this, there is a large inhibition by simazine, diuron, fluometuron, N'-4-(butoxyphenyl)-NN-dimethylurea, N'-(3-chlorophenyl)-NN-dimethylurea and N'-(3-methylphenyl)-NN-dimethylurea.

In hyacinths a similar phenomenon was observed. Table 5 shows for this crop the effect of continuous exposure to some herbicides on CO_2 uptake. Compared with other bulb plants like tulips and onions the reaction of CO_2 uptake of hyacinths on herbicides in the nutrient solution is much slower. The results show that the CO_2 uptake of hyacinths was unaffected by lenacil, somewhat decreased by linuron, and much more inhibited by simazine and pyrazon. These results are in agreement with field data obtained after applying these herbicides in the root environment of this crop (De Rooy, 1968).

Table 5

Effect of some herbicides on CO_2 uptake of hyacinths

(Continuous light, leaf temperature 22-23°C)

Herbicide 2×10^{-5} M	Relative CO_2 uptake after 12 hrs	24 hrs	36 hrs
lenacil	101	102	104
linuron	96	88	72
simazine	93	65	24
pyrazon	87	40	16

The small effect of some herbicides on the CO_2 uptake of carrots and hyacinths was to some extent also observed with lenacil on strawberries. The effect of this herbicide on CO_2 uptake of strawberries was lower than that of simazine (Van Oorschot and Haker, 1964), bromacil, terbacil and monuron. However, in experiments as mentioned before, removal of lenacil from the root environment did not result in recovery from photosynthesis inhibition, but to a fixation at a more or less constant level of CO_2 uptake. The results of experiments of longer duration with lenacil are presented in Table 6, compared with those with simazine and terbacil. The herbicides were removed by the end of the first light period. 17 Hours of light was alternated by 7 hours of darkness. The leaf temperature during the light was 23-24°C. To keep photosynthesis of the untreated plants at a constant level, all plants were used with only full-grown leaves, removing regularly the young developing leaves during the dark periods. CO_2 uptake of the untreated plants only varied within 4 %. The results show that CO_2 uptake of plants treated with lenacil even during 3 days remained at a more or less constant, rather high level, whereas similar treatment with simazine resulted in a low level. This is in accordance with the selectivity in the field (e.g. Goddrie 1966). It was surprising that photosynthesis of the plants treated with terbacil gradually recovered during the 2nd and 3rd day up to 40 %, which is in contrast to experiments of shorter duration.

Table 6

Effect of removing some herbicides from the roots on CO_2 uptake of strawberries

Herbicide	Conc. in 10^{-5} M	Variety	Relative CO_2 uptake by the end of 1st day	2nd day	3rd day	4th day
lenacil	1	Senga sengana	69	57	55	57
	1	Talisman	69	67	64	62
	2	Senga sengana	63	66	57	-
	2	Redgauntlet	62	62	-	-
simazine	2	Senga sengana	62	10	4	-
terbacil	2	Senga sengana	60	17	40	-

DISCUSSION

Recovery from inhibition of photosynthesis after removal of the herbicide from the root environment is considered an indication of herbicide inactivation. It is assumed that the herbicide is absorbed by the roots and translocated to the leaves, where it primarily inhibits photosynthesis. This assumption is probably justified, since the effect of these herbicides on photosynthesis is much more pronounced and precedes the effects on transpiration (Van Oorschot, 1965). The reduction in transpiration probably is a secondary effect, since inhibition of photosynthesis will result in partial closure of the stomata. A more direct effect on transpiration was observed in experiments in which herbicides like DNOC, ioxynil and chlorflurazole were added to the nutrient solution.

In these experiments the site of herbicide inactivation is probably located in the leaves. Comparing these results with data on biochemical detoxification, there is agreement for simazine and atrazine in maize (Castelfranco et al 1961, Hamilton and Moreland 1962, Negi et al 1964, Roth and Knüsli 1961), and monuron in plantain (Swanson and Swanson, 1968). However, a further and quantitative comparison is not yet possible. Moreover, other processes than biochemical detoxification could be responsible for herbicide inactivation.

So far only some plant species have been shown to have a large - but not absolute - capacity to inactivate a herbicide; some others have a small capacity, but most of the investigated herbicides are not inactivated in various plant species under the present experimental conditions. However, an experiment of longer duration with strawberries and terbacil shows that a more gradual inactivation may not have been detected in the short experiments, whose results are listed in Table 4. This could be a reason for the discrepancy with Luckwill and Caseley (1966) with regard to simazine and apples, although in this case the experimental period was longer. The use of intact plants of apples instead of detached leaves may, however, require even longer periods before inactivation becomes apparent.

The results with carrots and hyacinths may indicate that their physiological tolerance to some herbicides is also determined by other factors. The smaller effect of these herbicides may be due to a very high rate of inactivation in the leaves, less translocation to the leaves, or inactivation between the absorption site and the leaves. Results with linuron on parsnips obtained by Hogue and Warren (1968) indicated the first two mechanisms of selectivity in this plant species. The reaction of strawberries to lenacil is to some extent comparable to that of carrots and hyacinths. Here, however, the results could indicate less translocation of lenacil to the leaves of strawberries, but once present in these leaves lenacil seems hardly inactivated. Some other results as, for example, found in Mentha viridis treated with terbacil could to some extent indicate the same.

Under normal conditions in the field the actual concentration of herbicides in the root zone will be considerably lower than in these experiments, so that the rate of inactivation may equal the rate of uptake. The penetration into the root zone will be determined by the solubility of the herbicide in water, adsorption to soil constituents and rainfall. Absence of herbicide inactivation in established crops may be counterbalanced by its low solubility in water, restricting penetration into the soil. In some cases, selective applications of such herbicides listed in Table 4 are marginal, as e.g. simazine in strawberry, pyrazon in onion, lenacil in sugar beet and diuron in tulip. In general, there is a good correlation between the results of these physiological experiments and the selective performance of these herbicides in the field. These studies made in a rather early phase of evaluation of a herbicide will give a reasonable indication of the potential use in the field.

Acknowledgments

Thanks are due to Miss J. Jochemsen, Mr. M. Belksma and Mr. W. Hardeman for helpful technical assistance and cultivation of the plants. I am also indebted to the various chemical companies for supplying the non-formulated, purified herbicides.

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