Proc. 10th Br. Weed Control Conf. 1970

FURTHER EVALUATION OF PEA HERBICIDES FOR USE IN SCOTLAND

H. M. Lawson
Scottish Horticultural Research Institute, Invergowrie, Dundee
T. G. Rubens
East of Scotland College of Agriculture, Edinburgh

Summary Results of replicated experiments and demonstration trials in Eastern Scotland during 1969 and 1970 confirmed that dinoseb amine is still one of the most reliable and effective pea herbicides. By comparison prometryne and aziprotryne, applied before crop and weed emergence were much less effective. Aziprotryne gave best results when applied just as weeds emerged, but application at later stages of growth of the weeds gave poor weed control. Chloropropham/fenuron/monolinuron (Molinex) applied pre-emergence gave effective weed control but stunted a proportion of the crop. The addition of a small quantity of simazine to aziprotryne improved weed control compared with aziprotryne alone in 1970 but not in 1969. DW 3418* showed promise as a pre-emergence herbicide treatment.

INTRODUCTION

Following previous encouraging results with a number of residual herbi -cides in peas (Lawson 1968), replicated experiments were carried out at Invergowrie in 1969 and 1970 to gain further information on commercially available herbicides and to evaluate herbicides and mixtures still in the development stage. These experiments were supported by a series of demonstration trials where a number of herbicides were examined for efficacy under practical farm conditions. Despite the known disadvantages of dinoseb amine, in terms of toxicity both to man and crop and the limitations in its spectrum of weed control, almost the whole of the Scottish pea crop is still treated with this herbicide.

METHODS AND MATERIALS

Two detailed experiments were carried out, one in 1969 with four replicates of nine treatments and one in 1970 with three replicates of twelve treatments. The seed was drilled in rows 4 in. apart in beds 5 ft wide and 16 ft long. Herbicide treatments were applied by Oxford Precision Sprayer in 60 gal water/ac. Pea seedling and weed counts were made on 2 x 1 yd^2 quadrats/plot. The crops were vined and the distribution of peas in size grades assessed together with yield and tenderometer values.

*2-(4-chloro-6-ethylamino-s-triazin-2-ylamino-2-methyl-propionitrile)

Table 1

Details of pea herbicide demonstration sites

1969	Broomhall	Inchture	Omachie	Fithie	Woodhill	Balmyle
Soil % sand	16	29	62	65	70	77
physical % silt	54	43	22	17	15	9
analysis % clay	27	25	11	15	12	12
% loss on ignition	8	7	9	5	7	4
Pea cultivar	Sprite	Jade	SF	Surprise	Jade	DSP
Date sown	24/3/69	7/4/69	3/4/69	3/4/69	10/4/69	18/5/69
Pre-em. herbicide						
Prometryne lb/ac	1.50	1.50	1.25	1.25	1.25	1.25
Aziprotryne lb/ac	2.00	2.00	1.78	1.78	1.78	1.78
Date applied	17/4/69	9/4/69	4/4/69	4/4/69	17/4/69	22/5/69
Post-em. herbicide						
Aziprotryne lb/ac	1.78	1.78	1.78	-	1.78	1.78
Date applied	23/5/69	23/5/69	6/6/69	-	5/6/69	22/6/69
Crop height (in.)	2-3	3	8-10		4-6	4
Weed size	2 t.l.	2-3 t.l.	3-5t.l.	-	3-5t.l.	3t.l.
Dinoseb amine lb/ac	1.85	1.85	1.85	2.10	1.85	1.85
Date applied	5/6/69	5/6/69	5/6/69	10/6/69	5/6/69	24/6/69
Crop height (in.)	6-8	6	8-10	6-8	4-6	4
Weed size	3-5 t.l.	2-3 t.l.	3-5 t.l.	3-5 t.l.	3-5 t.l.	3 t.l.

1970	Broomhall	Inchture	Omachie	Emmock	Woodhill	Balmyle
Soil % sand	22	33	55	65	91	69
physical % silt	53	44	29	17	5	17
analysis % clay	22	20	15	13	4	12
% loss on ignition	7	6	4	8	4	6
Pea cultivar	DSP	DSP	Surprise	DSP	DSP	Jade
Date sown	11/5/70	4/5/70	26/3/70	11/5/70	6/5/70	21/4/70
Pre-em. herbicide						
Prometryne lb/ac	1.50	1.50	1.50	1.25	1.25	1.50
C/f/m lb/ac (total)	1.88	1.88	1.25	1.25	1.25	1.25
Date applied	15/5/70	15/5/70	22/4/70	15/5/70	13/5/70	24/4/70
Post-em. herbicide						
Aziprotryne lb/ac	2.28	2.28	1.78	1.95	1.95	1.78
Date applied*	22/5/70	22/5/70	5/5/70	25/5/70	23/5/70	15/5/70
Crop height (in.)	0-½	½-1	1-1½	0-½	0-½	½-1
Dinoseb amine lb/ac	1.85	1.39	1.85	1.85	1.85	1.85
Date applied	5/6/70	29/5/70	26/5/70	10/6/70	15/6/70	27/5/70
Crop height (in.)	1-2	3-4	6-8	4-6	6	8-10
Weed size	1-2 t.l.	1-2 t.l.	large	large	3-4 t.l.	large

DSP = Dark Skinned Perfection   SF = Superfection

*Weeds just emerging   C/f/m = Chloropropham/fenuron/monolinuron

Unreplicated demonstration trials, each of four herbicide treatments, were laid out at six sites in 1969, covering a range of pea varieties, sowing dates and soil types. Similar trials were carried out in 1970, five of them on adjacent fields at the same farms as in 1969. Site details are given in Table 1. Herbicide applications were made on plots of ½-1 acre using previously calibrated farm sprayers. Treatments were applied at dosages and as nearly as possible at the stages of growth of crop and weeds recommended by the manufacturers. Pea seedling and weed counts were taken on 10 x 1 yd^2 quadrats across the plot. Crop and weeds were scored 1-2 weeks after the application of the last treatments. All herbicide rates in this report are quoted as lb or oz a.i./ac.

RESULTS

Expt. 1 1969, Invergowrie. Herbicide treatments are shown in Table 2. Soil physical analysis was - % sand 77.9; % silt 11.2; % clay 7.9; % loss on ignition 5.9. The cultivar Jade was sown on 16 April. Pre-emergence herbicides were applied two days after sowing and post-emergence herbicides on 2 June when the crop was 4-6 in. high and the weeds ranged in size from cotyledon to 3-4 true leaves. Prolonged wet weather followed sowing and over 5 in. of rain fell during May. Post-emergence applications were delayed by adverse soil conditions.

Table 2

Experiment 1 1969 Crop and weed records

Treatment	Rate lb/ac	Plant count /2 yd^2 2/6/69	Wt. peas vined kg/plot 7/8/69	Tenderometer values	Total broad-leaved weeds /2 yd^2 18/6/69	*Poa annua* /2 yd^2 18/6/69	Overall weed score 0-10 18/6/69
Unweeded		95	5.50	148	254	208	-
Pre-em.							
Prometryne	1.25	82	5.33	144	261	113	3
Aziprotryne	1.78	87	6.31	148	202	145	3
Aziprotryne+ simazine	1.78+ 0.125	96	6.09	144	256	91	3
Post-em.							
Dinoseb amine	1.85	97*	5.61	148	26	334	7
Aziprotryne	1.78	98*	5.99	141	125	119	5
Aziprotryne+ simazine	1.78+ 0.125	83*	6.17	146	132	137	5
Aziprotryne	3.60	89*	5.87	143	19	32	9
Aziprotryne+ simazine	3.60+ 0.25	83*	6.34	146	10	27	9
S.E.mean ±		8	0.43	3	54	52	-

*Not yet treated Weed score key - 0 = no effect, 10 = complete kill

The level of weed control on plots treated before crop emergence was very low (Table 2). Both prometryne and aziprotryne gave poor control of many species and the addition of a small quantity of simazine to aziprotryne made no difference to the overall performance. Of the post-emergence treatments, dinoseb amine gave excellent control of nearly all weeds except Poa annua. Aziprotryne at 1.78 lb/ac and the same dosage plus simazine at 2 oz/ac gave poor control of broad leaved weed species. Double rates of these two treatments applied post-emergence, mainly to examine crop tolerance, gave excellent weed control. There was little to choose between the two formulations.

No crop injury attributable to pre-emergence treatments was noted, despite the very wet weather which persisted for many weeks after application. Treatment with dinoseb amine caused some minor scorching. No significant differences were found between treatments in pea seedling establishment (Table 2). Since pre-emergence treatments and the untreated control carried a fairly high weed population, harvest records may reflect some level of weed competition. Nevertheless, there were no significant differences between any herbicide treatments and the untreated control in yield and size distribution of peas, or their tenderometer values.

Pea herbicide demonstrations 1969. Very wet weather followed pre-emergence application at five sites and the control of normally susceptible weeds by prometryne and aziprotryne was poor (Table 3). The sixth site (Balmyle) was not sown until 18 May when weather and soil conditions were more favourable and the control of weeds by both treatments was excellent. Post-emergence applications of aziprotryne were made a little later than recommended at Omachie and Woodhill due to the bad weather. At Balmyle the weeds were just at, and at Broomhall and Inchture well within, the recommended size for spray application. Nevertheless, this treatment gave unsatisfactory weed control at all six sites. At Inchture post-emergence treatment with aziprotryne was slightly more effective than pre-emergence treatment; at Balmyle the opposite was true and elsewhere there was very little difference. At all six sites dinoseb amine gave excellent commercial weed control. At none of the sites was any visible evidence seen of adverse effect on the crop due either to prometryne or aziprotryne. Dinoseb amine caused slight scorch in wheelings at one site.

Expt. 2 1970, Invergowrie. Herbicide treatments are shown in Table 4. Soil physical analysis was - % sand 66.7; % silt 14.4; % clay 14.9; % loss on ignition 7.9. The cultivar Jade was sown on 22 April. Pre-emergence herbicides were applied 6 days later and post-emergence treatments were applied on 29 May when the crop was up to 6 in. high and the weeds ranged in size from cotyledon to four true leaves. Rainfall was light during the weeks immediately following sowing. All herbicide treatments gave an acceptable level of overall weed control (Table 4) with the exception of aziprotryne at 1.95 lb/ac. The double rate of chloropropham/fenuron/monolinuron kept plots almost weedfree until harvest. DW 3418 gave outstanding pre-emergence weed control; $1\frac{1}{2}$ lb/ac giving virtually complete control of all weeds and 3 lb/ac keeping plots completely weedfree throughout the season. Dinoseb amine at 1.85 lb/ac was slightly more effective than post-emergence treatment with DW 3418 at $1\frac{1}{2}$ lb/ac and not quite as effective as the 3 lb/ac

Table 3

Summary of assessments made on demonstration sites 1969/70

Site and treatment		Total weeds /sq.yd.	Overall weed score 0-10	Pea count /sq.yd.		Total weeds /sq.yd.	Overall weed score 0-10	Pea count /sq.yd.	Crop vigour score 0-10
	1	165	-	47	1	17	-	66	0
	2	89	3	45	2	16	5	65	0
Inchture	3	203	0	45	6	2	9	67	1
	4	97	3	44	7	6	9	71	0
	5	131	7	54	5	6	9	70	1
	1	144	-	58	1	17	-	65	0
	2	48	6	60	2	21	6	56	0
Broomhall	3	78	5	68	6	8	8	56	1
	4	89	5	62	7	7	8	56	0
	5	31	8	64	5	0	10	60	1
	1	318	-	96	1	391	-	79	0
	2	191	3	85	2	59	7	86	0
Omachie	3	141	4	95	6	46	8	76	3
	4	143	5	96	7	155	4	75	0
	5	26	8	89	5	86	8	80	1
	1	355	-	91	1	306	-	48	0
Fithie 69	2	194	2	90	2	-	3	-	0
Emmock	3	203	4	83	6	74	7	40	1
70	4	-	-	-	7	51	7	43	0
	5	97	7	95	5	61	8	43	3
	1	89	-	55	1	10	-	63	0
	2	67	2	65	2	7	7	65	0
Woodhill	3	83	2	70	6	6	7	61	1
	4	75	2	55	7	3	9	66	0
	5	24	8	56	5	7	8	63	1
	1	111	-	63	1	154	-	81	0
	2	8	9	71	2	47	6	89	0
Balmyle	3	5	9	70	6	0	10	68	3
	4	48	6	63	7	6	9	85	0
	5	16	8	63	5	101	5	73	1

Treatment key 1 = Untreated control, 2 = prometryne pre-em., 3 = aziprotryne pre-em., 4 = aziprotryne post-em., 5 = dinoseb amine post-em., 6 = Chlorpropham/fenuron/monolinuron, 7 = aziprotryne at weed emergence.

Weed and crop score key. 0 = no effect 10 = complete kill rate. P. annua and P. aviculare were resistant to DW 3418 at both rates as well as to dinoseb amine.

Table 4

Experiment 2 1970 8/6/70 — Crop and weed records 28/7/70

Treatment	Rate lb/ac	Total broad-leaved weeds /2 yd^2	Poa annua /2 yd^2	Overall weed score 0-10	Crop vigour score 0-10	Yield peas kg/ plot	Yield peas (gm)/kg haulm	Tender-ometer values
Handweeded		-	-	-	0	3.90	98.0	93
Unweeded		133	126	-	0	2.98	73.7	87
Pre-em.								
Prometryne	1.25	26	53	7	0	3.61	88.2	89
Aziprotryne	1.95	76	47	6	0	3.15	76.9	87
Aziprotryne+ simazine	1.95+ 0.125	26	33	7	0	3.58	84.9	87
C/f/m(Total)	1.25	38	10	7	2	3.11	69.9	87
C/f/m(Total)	2.50	11	0	9	4	2.48	56.6	83
DW 3418	1.50	5	2	9	0	3.92	85.0	84
DW 3418	3.00	0	0	10	2	3.25	70.4	85
Post-em.								
DW 3418	1.50	15	101	7	1	3.59	81.8	88
DW 3418	3.00	7	87	8	1	3.65	81.5	88
Dinoseb amine	1.85	6	157	8	1	3.51	78.1	88
S.E. mean ±		12	23	-	-	0.30	7.9	3

C/f/m = Chloropropham/fenuron/monolinuron
Weed and crop score key - 0 = no effect, 10 = complete kill

There were no significant differences between treatments in numbers of pea seedlings emerged but chloropropham/fenuron/monolinuron at both rates caused stunting and malformation of a proportion of the crop (Table 4). Adjacent plants grew away normally and tillered to fill the available space. Some stunted plants sent out new shoots later in the season, but these did not produce pods in time for vining. Pre-emergence applications of DW 3418 caused some initial discolouration of pea seedlings and the 3 lb/ac rate visibly checked growth for a few weeks. Post-emergence treatment with DW 3418 and dinoseb amine burned the crop slightly, but growth was not visibly retarded. By comparison with the handweeded control treatment, chlorpropham/fenuron/monolinuron at the double rate, included mainly to assess crop tolerance, significantly reduced the total yield of peas vined. Also significantly affected were the distribution of peas in various size grades and the tenderometer readings at harvest. Lack of space precludes the presentation of detailed data but lower yields on plots treated with this herbicide were due to a higher proportion of peas in the smaller size grades and to delayed maturity. Significant reductions were also found in the yield of peas/kg. haulm vined on plots treated with either rate of chloropropham/fenuron/monolinuron and with DW 3418 at 3 lb/ac applied pre-emergence. None of the other herbicide treatments significantly affected yield or maturity.

Pea herbicide demonstrations 1970 Prometryne gave satisfactory weed control at only two sites (Table 3). At Emmock the farmer followed treatment with prometryne by a further treatment with dinoseb amine before any weed or crop counts could be made. Aziprotryne applied at weed emergence gave satisfactory weed control at five sites. The sixth site (Omachie) was treated with 1.78 lb/ac - the lowest rate used in 1970 - and this failed to control *Polygonum aviculare* and *Chenopodium album*. Dinoseb amine also gave adequate control at five of the six sites, the exception being Balmyle, which had high populations of *P. aviculare* and *Spergula arvensis*. Chlorpropham/fenuron/monolinuron gave satisfactory weed control at all six sites.

Dinoseb amine caused slight scorch at five sites and severe scorch at Emmock (Table 3). Prometryne and aziprotryne had no visible effect on crop growth at any site, but chlorpropham/fenuron/monolinuron stunted a proportion of crop plants at all six sites. At Omachie and Balmyle a number of plants turned yellow and died after emergence and at Balmyle the crop on the plot treated with this herbicide was for several weeks visibly shorter than the crop on other plots. Stunted plants at other sites were masked within a few weeks by compensatory growth by adjacent plants. Because of the earlier evidence of crop injury, samples of vine from adjacent areas on plots treated with prometryne and chloropropham/fenuron/monolinuron were taken at harvest from several sites. Sample size was 2 yd^2 or 3 yd^2 per plot depending on the density of the crop. Four samples were taken per plot and weeds were removed before vining. Values for plots treated with chlorpropham/fenuron/monolinuron are expressed as a percentage of those for plots treated with prometryne (Table 5).

Table 5

Yield records from 1970 demonstration plots treated with chloropropham/fenuron/monolinuron

Site	wt. vine /unit area	wt. peas vined	wt. peas /kg vine	Tencerometer reading
Balmyle	108	78	72	93
Emmock	109	95	94	93
Broomhall	111	103	93	100
Inchture	100	100	100	102
Mean	107	94	90	97

The data suggests that a substantial reduction in yield may have occurred at Balmyle, where crop injury had been scored 3 out of 10 earlier in the season. Unfortunately, it was not possible to harvest samples from Omachie which had been similarly scored. The data from Balmyle, Emmock and Broomhall also suggest that at these sites greater amounts of vine were produced per unit area on plots treated with chloropropham/fenuron/monolinuron compared with those treated with prometryne, but that the yield of peas per unit weight of vine was lower. At all four sites prometryne had given considerably poorer weed control.

DISCUSSION

Pre-emergence treatment with prometryne gave acceptable weed control at only 4 out of 14 sites, while aziprotryne applied at this stage of growth was acceptable at only 1 out of 8 sites. Unusually wet weather in 1969 may have contributed to these poor results but 1970 weather was much more favourable. Neither treatment caused any visible injury to treated crops. The much higher levels of weed control obtained with chlorpropham/fenuron/monolinuron were marred by the unacceptable degree of crop injury at several sites. The symptoms were similar to those reported by King and Hancock (1962) as typical of the effects of chlorpropham on peas grown on sandy soils. Apart from the direct effect of severe stunting on overall crop yield, the extent of the uneven and delayed maturity which may result from less severe stunting requires further examination before the formulation can be recommended to growers of processing crops. Symptoms were noted on every treated crop, regardless of application rate, and there appeared to be no obvious relationship between the severity of stunting and such factors as soil type, sowing date or crop cultivar. Post-emergence treatments with aziprotryne in 1969 were consistently ineffective on weeds, but higher dosages used in 1970, with application just as weeds emerged, gave acceptable weed control at 5 of the 6 sites treated. No crop injury resulted from either treatment. The addition of 2 oz/ac simazine to aziprotryne increased the overall weed control in 1970 but not in 1969. DW 3418 was very effective as a pre-emergence treatment at 1.5 lb/ac but 3 lb/ac affected crop growth. Lower application rates may be worth examination.

Dinoseb amine gave acceptable weed control at 13 out of 14 sites treated and burned the crop severely at only one site. This degree of reliability compared with the performance in these trials of most of the more expensive alternatives makes it unlikely that there will be any rapid swing away from the traditional herbicide treatment.

Acknowledgements

Thanks are due to the chemical firms who supplied samples of herbicides, to the farmers who permitted the use of their crops and to Mr. D. Forsyth who supervised the spraying and assessment on the demonstration sites.

References

KING, J.M. and HANCOCK, D.H. (1962). Experiments on the control of broad-leaved weeds in peas - a progress report 1961-62. Proc. 6th Brit. Weed Control Conf. 491-505.

LAWSON, H.M. (1968). Experiments with herbicides in peas and French beans - a progress report. Proc. 9th Brit. Weed Control Conf. 420-425.

EVALUATION OF PRE- AND POST-EMERGENCE HERBICIDES IN PEAS

J. C. Cassidy

Kinsealy Research Centre, Dublin, 5.

Summary Peas showed good tolerance to pre- and early post-emergence applications of aziprotryne - no crop damage occurring at doses up to 4.0 lb/ac. More effective weed control was obtained with post-emergence application provided weeds were not advanced beyond the 2-leaf stage. The addition of simazine 0.125 and 0.25 lb/ac to aziprotryne improved residual control and did not affect selectivity.

Methabenzthiazuron and DW 3418 (2 - (4-chloro-6-ethylamino-S-triazine - 2 - ylamino - 2 methyl - proprionitrile) tested for the first time in 1970, were very promising for pre-emergence application. Both herbicides showed a high degree of selectivity and controlled a wide spectrum of important weed species. DW 3418 was particularly effective against Sinapis arvensis. The crop was less tolerant to early post-emergence treatment with DW 3418 1.5 lb/ac, which caused severe scorch and reduction in vigour. Results with prometryne, prometryne + linuron and dinoseb-amine are also included.

INTRODUCTION

Prometryne applied pre-emergence and dinoseb-amine post-emergence are the two main herbicides used for weed control in peas in Ireland. Both materials have certain limitations - control of Sinapis arvensis, a common weed in most pea growing areas, can be variable with prometryne while the attainment of satisfactory results with dinoseb is greatly influenced by weather conditions. The main purpose of the trials carried out in 1969 and 1970 was to determine if any of the more recently introduced herbicides for peas would be more effective and reliable than the standard treatments.

METHODS AND MATERIALS

In 1969, five experiments were conducted - three in Co. Carlow and two in the Midleton area of Co. Cork. A further four experiments were carried out in 1970 - two in the Carlow area and two in Cork. Experiments in all cases were of a randomised block design with four replicates. Plot size was either 10 yd x 2 yd or 10 yd x 3 yd. Sprays were applied at a volume of 40 gal/ac using a pressure retaining knapsack sprayer. All doses are given as lb/ac a.i. Plant and weed counts were recorded and experiments in the Carlow area were harvested using a small plot viner to obtain yield data. In addition, visual assessments of treatment effect on crop and weeds were made at different stages during the period of the experiment.

Weed counts were made within an area of a square foot quadrat thrown at random a number of times in each plot and plant stand was determined from counts made within eight 3 ft. length of row per plot.

RESULTS

1969 experiments. Sites A and B

Aziprotryne at doses of 1.8 lb and 2.5 lb/ac and mixtures of aziprotryne 1.8 lb and simazine (0.125 lb and 0.25 lb/ac) applied pre-emergence and early post-emergence were compared with the standard treatment - prometryne pre-emergence at 1.25 lb/ac at sites A and B. The crops at these sites were drilled in late February and pre-emergence treatments were applied under damp soil conditions three weeks after sowing, when the peas were nearing emergence. Application of post-emergence treatments was carried out two weeks later. At this stage the peas had one leaf well developed and weeds were in the cotyledon stage. These treatments were applied under warm sunny (air temp. 60°F) conditions and the soil surface was dry. The main weed species at site A in order of prevalence were *Veronica* spp., *Poa annua*, *Chenopodium album* and *Polygonum persicaria*, whilst at site B *Veronica* spp. *Chenopodium album*, *Stellaria media* and *Polygonum persicaria* were the principal species. Treatments and results are given in Table 1.

Table 1

Effect of treatments on crop and weeds, Sites A, B, 1969

Treatment	Dose lb/ac	Plant stand as % of control		Assessments				% weed kill[1]			
				A(22/4/'69)		B(23/4/'69)		Site A	Site B		
		A	B	Crop	Weeds	Crop	Weeds	V.s.	P.p.	C.a.	S.m.
Prometryne[x]	1.25	88	95	8.5	9.8	9.5	8.6	76	60	91	53
Aziprotryne[x]	1.8	97	107	9.4	9.1	9.9	8.5	67	44	88	84
Aziprotryne[x]	2.6	101	114	9.1	9.5	9.9	9.6	68	65	97	89
Aziprotryne[x] + Simazine	1.8 + 0.125	102	109	9.6	9.3	9.8	9.1	70	90	92	73
Aziprotryne[x] + Simazine	1.8 + 0.25	89	100	8.9	9.8	9.9	9.4	72	90	100	91
Aziprotryne	1.8	106	120	9.5	9.4	9.9	9.3	73	10	92	84
Aziprotryne	2.6	99	105	9.1	9.6	9.4	9.6	89	58	97	89
Aziprotryne + Simazine	1.8 + 0.125	93	96	9.8	9.6	9.5	9.5	85	19	91	90
Aziprotryne + Simazine	1.8 + 0.25	100	99	9.3	10.0	9.8	9.6	90	62	96	97
Control (untreated)		100	100	9.4	0.9	9.6	1.0	0	0	0	0
Weeds/ft^2 in control plots								24.1	3.3	5.6	4.4

[x] applied pre-emergence

[1] Weed counts taken at Sites A & B, eight and five weeks respectively after application of pre-emergence treatments.

Rating scale: Crop 0(complete kill) - 10(no damage), Weeds 0(Dense cover of weeds) - 10(No weeds)

V.s. = *Veronica* spp., P.p. = *Polygonum persicaria*, C.a. = *Chenopodium album*, S.m. = *Stellaria media*.

At site A on a sandy loam (clay 23.6%, O.M. 4.6%) there was a slight depression in stand and vigour in plots treated with prometryne at 1.25 lb/ac. This effect was also apparent where the higher dose of simazine was added to aziprotryne pre-emergence. No crop damage occurred with any of the other treatments. On the relatively lighter soil at site B (clay 14.4%, O.M. 5.7%) all treatments showed high crop selectivity but weed control, especially with pre-emergence application of prometryne at 1.25 lb and aziprotryne at 1.8 lb/ac was not as effective as at site A. The addition of simazine even at the low dose of 0.125 lb to aziprotryne 1.8 lb/ac gave much improved control of Polygonum persicaria. At this site also Polygonum persicaria was poorly controlled by aziprotryne at 1.8 lb/ac when sprayed at the cotyledon stage. Increasing the dose to 2.6 lb or with the addition of simazine 0.25 lb/ac gave better control. Differences between the effectiveness of treatments were not very pronounced at site A. However the addition of simazine to the normal dose (1.8 lb/ac) of aziprotryne did appear to be worthwhile for both pre- and early post-emergence application.

Sites C, D and E Treatments were similar to those applied at sites A and B except that aziprotryne at a dose of 4.0 lb and dinoseb amine at 1.85 lb were included and only the 0.125 lb/ac dose of simazine was used in combination with aziprotryne. Also post-emergence treatments were not applied at as early a stage as at the other sites. At sites C and D the peas had 2 - 3 leaves and weeds were at the cotyledon to two true leaf stage. At site E post-emergence treatments were applied at a more advanced stage - peas 9-12 in. high and weeds with 4 - 8 true leaves. Pre-emergence applications were made in all cases nine days after drilling.

Weed populations were low at sites D and E, the main weeds were Veronica spp., Sinapis arvensis and Fumaria officinalis at site D and Poa annua, Veronica spp. and Capsella bursa-pastoris at site E. Chrysanthemum segetum was the principal species at site C with Polygonum aviculare occurring in smaller numbers. Treatment and results are given in Table 2.

Plant counts, visual assessments and yield data recorded at the three sites (coarse sandy loam ca clay 14%, O.M. 4.0%) showed that all treatments were highly selective. Slight scorch of the foliage was evident where aziprotryne at 4.0 lb/ac was applied at the 2 - 3 leaf stage but this damage was quickly ourgrown and final yields were not affected. At site C where a very heavy infestation of Chrysanthemum segetum occurred all pre- and post-emergence treatments gave excellent control of this species. Polygonum aviculare however, was not so well controlled at this site except with the higher doses of aziprotryne at both stages of application.

At site D, aziprotryne at 1.8 lb/ac pre-emergence was not as effective as when applied post-emergence, particularly for control of Sinapis arvensis and Polygonum persicaria. However at both stages of application this treatment gave excellent control of Fumaria officinalis and Veronica spp. as did the other treatments.

All pre-emergence treatments gave excellent weed control at Site E. Weeds were advanced in growth (4 - 8 leaves) when post-emergence treatments were applied at this site and no control of Poa annua was obtained with aziprotryne or dinoseb-amine. Control of Capsella bursa-pastoris and Polygonum aviculare was also poor with aziprotryne at this stage but dinoseb-amine gave effective control of Capsella.

1970 experiments

In 1970, aziprotryne and the mixture of aziprotryne + simazine were further evaluated at sites F (clay 18.8%, O.M. 6.4%) and G (clay 23.3%, O.M. 5.4%) in Co. Cork and at sites H (clay 17.6%, O.M. 3.0%) and I (clay 14.0%, O.M. 2.1%) in Co. Carlow for pre- and early post-emergence application. Methabenzthiazuron, DW 3418 and a mixture of prometryne + linuron were also examined in these experiments.

Table 2

Effect of treatments on crop and weeds, Sites C, D, E, 1969

Treatment	Dose lb/ac	Yield cwts/ac		Pea stand as % of control			% weed kill					Assessments Mean of 3 sites	
							C		D	E			
		C	E	C	D	E	C.s.	P.av	S.a.	C.bp.	P.a	Crop	Weeds
Prometryne*	1.25	81	46	131	117	89	99	73	100	100	100	9.9	9.4
Aziprotryne*	1.8	71	47	96	96	117	99	67	71	97	100	10	8.4
Aziprotryne*	2.5	75	43	114	100	116	100	80	91	95	98	10	9.3
Aziprotryne*	4.0	68	41	149	112	99	100	91	98	100	100	10	9.9
Aziprotryne* + Simazine	1.8 + 0.125	71	48	139	119	103	99	66	93	100	100	10	9.2
Aziprotryne	1.8	67	39	114	107	82	98	49	98	34	0	10	6.9
Aziprotryne	4.0	73	40	112	119	94	100	93	100	16	0	9.1	8.3
Aziprotryne + Simazine	1.8 + 0.125	na	40	n.a.	101	109	n.a.	n.a.	100	17	0	10	7.2
Dinoseb amine	1.85	67	44	112	132	107	100	68	100	99	0	10	8.1
Control		69	40	100	100	100	0	0	0	0	0	10	0.0
S.E. (df = 27)		2.9	2.2										
No. of plants and weeds/ ft^2 in control plots				6.3	7.4	7.0	18.4	4.1	1.8	2.9	9.0		

Rating scale as in Table 1.
*Applied pre-emergence, n.a. = not applied
C.s. = *Chrysanthemum segetum*
P.av. = *Polygonum aviculare*
S.a. = *Sinapis arvensis*
P.a. = *Poa annua*
C.bp. = *Capsella bursa-pastoris*

Peas were drilled in early March at sites F and G and pre-emergence treatments were applied under dry soil conditions after 13 and seven days respectively from sowing. At site F the crop was at the 1-leaf stage and weeds just emerging when post-emergence spraying was done, whereas at site G the crop had three leaves and weeds were at the cotyledon - 2-true leaf stage. Weather was dry and mild at both sites at time of application.

Sinapis arvensis was the predominant species at site F with *Polygonum aviculare* and *Polygonum persicaria* occurring in lesser numbers. At site G, *Anagallis arvensis* and *Poa annua* were the main species. Treatments and results are given in Table 3.

Assessments taken at site F, six and three weeks after application of pre- and post-emergence treatments respectively showed that all treatments were highly selective except DW 3418 at 1.5 lb/ac applied post-emergence. This treatment caused severe scorch and reduction in crop vigour and this damage was also evident at site G.

Table 3

Effect of treatments on crop and weeds, Sites F, G, 1970

Treatment	Dose lb/ac	% pea stand[1] G	Assessments (24/4/'70) Crop (F)	% weed kill[2] Site F S.a.	P.p.	P.av.	Site G A.a.	P.a.
Prometryne	1.25	97	9.1	46	49	80	19	75
Aziprotryne	1.8	102	9.5	53	30	79	22	81
Aziprotryne + Simazine	1.8 0.25	101	9.5	43	57	78	26	81
Methabenz-thiazuron	1.5	100	9.5	69	43	42	27	87
"	3.0	95	9.5	88	60	69	73	97
DW 3418	1.5	100	9.6	92	67	81	62	86
DW 3418	3.0	100	9.1	97	91	92	93	98
Prometryne + Linuron	0.75 0.375	98	9.6	63	30	48	23	85
Aziprotryne	1.8	95	8.9	68	84	96	96	97
Aziprotryne + Simazine	1.8 0.25	103	9.1	90	89	82	95	97
DW 3418	1.5	92	6.8	99	97	96	97	99
Control		100	9.9	0	0	0	0	0
No. of plants and weeds $/ft^2$ in control plots		7.6		10.2	4.6	2.7	10.4	6.9

[1]As % of control plot. [2]Recorded in mid-May. Rating scale as in Table 1.

S.a. = *Sinapis arvensis*; P.p. = *Polygonum persicaria*; P.av. = *Polygonum aviculare*; A.a. = *Anagallis arvensis*; P.a. = *Poa annua*.

Pre-emergence application of prometryne at 1.25 lb, aziprotryne at 1.8 lb and aziprotryne at 1.8 lb + simazine at 0.25 lb/ac gave poor control of *Sinapis arvensis*, *Polygonum persicaria* and *Anagallis arvensis*. Much improved control of these species was obtained where aziprotryne and aziprotryne/simazine were applied post-emergence.

Most effective control of *Sinapis* was given by DW 3418 applied either pre- or post-emergence. This herbicide also provided excellent control of the other weed species present at these sites either at a dose of 3.0 lb applied pre-emergence or 1.5 lb/ac post-emergence. Control of *Polygonum persicaria* and *Anagallis arvensis* was only moderate at the 1.5 lb dose applied pre-emergence. With the exception of *Poa annua* most of the main weed species present were only moderately controlled with methabenzthiazuron at 1.5 lb/ac. Control was improved with the 3.0 lb dose but *Polygonum* spp. still showed some resistance.

The mixture of prometryne 0.75 lb + linuron 0.375 lb/ac was less effective than prometryne alone particularly for control of *Polygonum* spp.

In the experiments at Sites H, I, treatments were similar to those applied at the other sites except that dinoseb-amine was included as a standard in addition to prometryne. The crops at these sites were also drilled in early March and pre-emergence applications were made 15 days after sowing at site H and after 10 days at site I. At both sites, post-emergence treatments were applied at the 3 - 4 leaf stage of the crop in late April when the weeds had 1 - 2 true leaves. Conditions were favourable at both stages of application - moist soil for the pre-emergence and dry, mild weather for the post-emergence treatments.

Weed populations were high at both sites - over $80/ft^2$ at site H and $70/ft^2$ at site I. The main species were Poa annua, Polygonum persicaria, Polygonum aviculare, Veronica spp., Capsella bursa-pastoris and Spergula arvensis at the former and Polygonum aviculare, Poa annua, Veronica spp., Papaver rhoeas and Viola tricolor at the latter site. Results are given in Table 4.

Table 4

Effects of treatments on crop and weeds, Site H, I, 1970

Treatment	Dose lb/ac	Plants per ft^2 H	Plants per ft^2 I	Yield cwts/ac H	Yield cwts/ac I	Assessments Site H Crop	Assessments Site I Crop	Assessments Site I Weeds	% weed kill[1] Site H P.p.	Site H Sp.a.	Site H P.a.	Site I P.av.	Site I V.t.
Prometryne*	1.25	7.2	6.1	50	53	9.6	9.0	8.8	48	92	74	78	0
Aziprotryne*	1.8	6.5	6.3	51	54	9.5	9.8	9.3	42	80	34	86	45
Aziprotryne* + Simazine	1.8 0.25	7.5	6.5	63	53	9.5	9.5	9.1	85	98	97	91	60
Methabenz-* thiazuron	1.5	7.3	7.0	46	48	9.4	9.4	9.8	91	96	97	94	75
"	3.0	6.3	5.4	53	43	8.8	7.1	9.6	100	100	100	99	98
DW 3418*	1.5	7.1	5.8	51	56	9.4	8.8	9.0	65	96	95	74	35
DW 3418*	3.0	7.4	4.4	57	50	9.1	7.8	9.6	93	100	99	95	85
Prometryne* + Linuron	0.75 0.375	6.8	6.0	43	53	9.5	8.9	9.0	70	99	82	84	50
Aziprotryne	1.8	7.0	5.4	43	51	n.a.	n.a.	n.a.	88	94	57	61	60
Aziprotryne + Simazine	1.8 0.25	7.8	6.1	49	53	n.a.	n.a.	n.a.	95	97	80	58	96
DW 3418	1.5	8.1	4.7	52	42	n.a.	n.a.	n.a.	98	100	99	94	98
Dinoseb-amine	1.85	7.2	5.5	46	54	n.a.	n.a.	n.a.	92	58	0	51	14
Control (untreated)		7.4	5.6	38	49	9.7	9.8	2.6	0	0	0	0	0
S.E. (df_2= 51)		0.44	0.52	3.0	2.9								
Weeds/ft^2 in control plots									12.3	3.3	29.6	26.6	3.2

[1] Recorded in mid-June. *Sprayed pre-emergence.

n.a. = not applied when assessments were taken. P.p. = Polygonum persicaria; P.av. = P. aviculare; Sp.a. = Spergula arvensis; P.a. = Poa annua; V.t. = Viola tricolor. Rating scale as in Table 1.

Assessments taken six weeks after application of pre-emergence treatments (immediately before post-emergence spraying was carried out) showed that the twice normal doses (3.0 lb) of DW 3418 and methabenzthiazuron were the only treatments which were causing any crop injury. Leaf scorch and moderate reduction in vigour occurred in plots where these treatments were applied and these effects were more pronounced at site I where the soil was lighter in texture. The figures for plant stand (Table 4) indicate that a reduction occurred at site H with methabenzthiazuron at 3.0 lb and at site I with DW 3418 at 3.0 lb/ac. However, at both sites the crop outgrew this damage and only in plots treated with methabenzthiazuron at 3.0 lb/ac at site I was there a tendency for yield to be depressed compared to control or standard treatments.

Of the post-emergence treatments only DW 3418 at 1.5 lb/ac caused significant injury. Leaf scorch and reduction in vigour were more severe than with dinoseb-amine particularly at site I.

For weed control, all pre-emergence treatments compared more than favourably with prometryne at 1.25 lb/ac when assessments were made six weeks after application.

Weed counts, taken eight weeks later, showed that prometryne had given slightly better residual control of Polygonum aviculare and Poa annua than aziprotryne at 1.8 lb/ac but that all the other pre-emergence treatments had maintained their superiority over prometryne. The addition of simazine at 0.25 lb/ac to aziprotryne gave greatly improved residual control particularly at site H. However at both sites post-emergence treatment with aziprotryne and aziprotryne/simazine was more effective than pre-emergence applications of these treatments except for control of Polygonum aviculare. Excellent prolonged control was obtained in plots treated pre-emergence with DW 3418 at 3.0 lb, methabenzthiazuron at 1.5 and 3.0 lb and with DW 3418 at 1.5 lb/ac applied post-emergence. Control of Polygonum spp. was much better at these sites with methabenzthiazuron than at sites F and G.

Viola tricolor was completely resistant to prometryne and only poorly controlled by aziprotryne at 1.8 lb and DW 3418 at 1.5 lb/ac of the pre-emergence treatments. Post-emergence application of dinoseb-amine also failed to control this species. In addition to the weed species already mentioned all treatments, both pre- and post-emergence, gave highly satisfactory control of Veronica spp., Spergula arvensis and Capsella bursa-pastoris at site H and of Papaver rhoeas and Veronica spp. at site I.

DISCUSSION

The results obtained in this series of experiments with aziprotryne are in agreement with earlier investigations (Cassidy and Doherty 1968, Lawson 1968, Marks and Smith 1968) and show that this herbicide is very safe either for pre- or post-emergence application in peas. In most cases, however, aziprotryne was slightly less effective as a pre-emergence treatment than prometryne - the standard treatment - and the addition of simazine at doses up to 0.25 lb/ac gave improved weed control without affecting selectivity. Early post-emergence application of aziprotryne was generally more satisfactory than pre-emergence provided that weeds had not advanced beyond the two true leaf stage at spraying.

Methabenzthiazuron and DW 3418 applied pre-emergence showed excellent selectivity at a dose of 1.5 lb/ac in all experiments. Even twice normal doses of these herbicides did not cause serious crop damage. Both herbicides controlled a wide range of important weed species but DW 3418 was more effective against Sinapis arvensis - a prevalent weed in some pea growing areas. The results suggest that DW 3418 may be less affected by dry soil conditions at application than methabenzthiazuron. Where pre-emergence treatments were applied to dry soils at sites F and G, control particularly of Polygonum spp. was better with DW 3418 whereas at site H and I methabenzthiazuron was more effective against these species following application under moist soil conditions.

DW 3418 at 1.5 lb/ac although very effective was too damaging to the crop as an early post-emergence treatment. Reduction in plant stand and a serious check to crop vigour occurred at this stage of application.

The mixture of prometryne 0.75 lb + linuron 0.375 lb/ac did not achieve the purpose for which it was tested, namely to provide better control of Sinapis arvensis than prometryne alone.

On the basis of the preliminary results obtained in these experiments it appears that there are a number of herbicides or herbicidal mixtures which can be used satisfactorily as alternatives to prometryne or dinoseb-amine for weed control in peas.

Acknowledgments

The author wishes to thank Messrs. P. J. Doherty, P. Marren and J. J. O'Donovan for assistance in the carrying out of these experiments and to the firms who supplied samples of herbicides.

References

CASSIDY, J. C. and DOHERTY, P. J. (1968) Weed control trials in peas : 1964-1968 Proc. 9th Br. Weed Control Conf. 414-419.

LAWSON, H. M. (1968) Experiments with herbicides in peas and French beans - a progress report. Proc. 9th Br. Weed Control Conf. 420-425.

MARKS, T. G. and SMITH, J. M. (1968) Trials with 2-azido-4-isopropylamino-6-methylthio-s-triazine, C7019, as a herbicide for peas. Proc. 9th Br. Weed Control Conf. 426-431.

Proc. 10th Br. Weed Control Conf. 1970

EVALUATION OF PRE-EMERGENCE HERBICIDES FOR PEAS AND BEANS

H. A. Roberts and R. T. Hewson
National Vegetable Research Station, Wellesbourne, Warwick

Summary Several experimental pre-emergence herbicides were compared with standard treatments for peas, broad beans and dwarf beans on a sandy loam in 1969 and 1970. On peas, good results were obtained with 4,5,7-trichlorobenzthiadiazole-2,1,3 (Ph 40-21) at 4 and 8 lb/ac and with terbuthylazine 0.5 lb/ac, although the latter caused slight crop injury. Excellent weed control was obtained with 2-(4-chloro-6-ethylamino-s-triazine-2-ylamino)-2-methyl-propionitrile (DW 3418) 1 and 2 lb/ac but the crop was sometimes injured. Ph 40-21 and DW 3418 gave good weed control without injuring broad beans in 1970. Of treatments examined on dwarf beans the standard, dinoseb-acetate + monolinuron, and paraquat + monolinuron gave the best results in each year, while the results with Ph 40-21 were also promising.

INTRODUCTION

Pre-emergence treatments for the control of annual weeds in peas, broad beans and dwarf French beans are widely used and have proved generally to be satisfactory. There is still a need, however, to determine whether any of the newer experimental herbicides offer any advantage in terms of weed control and selectivity. Several materials of this kind were therefore compared with standard treatments in field tests on a sandy loam during 1969 and 1970.

METHODS AND MATERIALS

The experiments were of randomised block design with three or four replicates and a plot size of 8 yd^2. Except where stated, the treatments were applied shortly after drilling. The volume was 100 gal/ac and doses are given as lb/ac a.i. Weed kill was assessed by counting survivors in a number of random quadrats on each plot. Visual scores were also made at various times on a scale of 0 (no effect) to 10 (complete kill) and those made at the time of harvest are quoted. On this scale a value of 7 represents commercially acceptable control. Crop injury was assessed on the same scale and at the normal time of harvest total crop weight (pods + haulm) was recorded on each plot. The treated plots were not weeded, and both unweeded and hand-weeded controls were included. Crop weights are expressed as percentages of those on the hand-weeded plots, and values significantly less are indicated by single ($P = 0.05$) or double ($P = 0.01$) asterisks.

RESULTS

Peas

There were four experiments, two in each year, and the results are shown in

Table 1

Pre-emergence herbicides on peas (cv. Kelvedon Wonder), 1969

Herbicide and dose (lb/ac)		Drilled 25th March: Weed control (%)	Weed control (0-10)	Crop Injury (0-10)	Crop Wt (%)	Drilled 1st May: Weed control (%)	Weed control (0-10)	Crop Injury (0-10)	Crop Wt (%)
Terbuthylazine	0.5	98	8.7	0.0	94	99	9.3	1.0	99
Simazine	0.5	92	7.7	1.3	83	100	9.3	3.3	89*
Methabenzthiazuron	2.0	96	8.0	1.3	86	99	8.7	0.3	101
VCS-438	2.0	98	8.7	0.7	87	98	8.7	1.7	98
"	4.0	99	9.5	4.0	81*	100	9.7	5.0	78**
RH-315	1.5	96	8.3	0.0	99	99	9.0	4.0	94
DW 3418	2.0	100	9.7	2.7	95	100	10	3.7	94
Diphenamid + dinoseb	2.4 + 1.8	94	7.7	0.7	97	96	8.0	4.0	91
Ph 40-21	4.0	-	-	-	-	98	8.7	0.7	96
Aziprotryne	1.8	88	7.0	0.0	96	98	8.3	0.0	99
" post-em.	1.8	99	8.3	0.7	93	100	8.3	0.0	99
Control unweeded			(34 weeds/ft²)		81*		(26 weeds/ft²)		94
Rainfall in first 3 weeks			0.48 in.'				1.58 in.		

' Includes one irrigation of 0.25 in.

Table 2

Pre-emergence herbicides on peas (cv. Kelvedon Wonder), 1970

Herbicide and dose (lb/ac)		Drilled 20th April: Weed control (%)	Weed control (0-10)	Crop Injury (0-10)	Crop Wt (%)	Drilled 18th May: Weed control (%)	Weed control (0-10)	Crop Injury (0-10)	Crop Wt (%)
Terbuthylazine	0.5	95	9.7	3.0	84	98	9.0	1.3	104
Terbuthylazine + terbutryne	0.3 + 0.7	95	9.3	3.7	87	100	9.8	1.0	99
RH-315	1.5	72	8.0	0.7	94	66	6.3	0.0	89
DW 3418	1.0	100	9.8	3.0	87	89	8.5	0.7	101
"	2.0	97	9.8	6.0	50**	87	8.7	1.3	96
Diphenamid + dinoseb	2.0 + 1.5	79	8.3	0.0	92	85	6.3	0.3	92
Ph 40-21	4.0	93	9.0	0.0	89	83	8.0	0.3	92
"	8.0	98	9.5	0.3	97	94	8.8	0.7	92
Aziprotryne	1.8	91	9.0	0.0	87	53	8.0	0.0	94
Aziprotryne post-em.	1.8	83	8.2	1.7	96	92	8.7	0.7	96
Control unweeded			(3 weeds/ft²)		85		(4 weeds/ft²)		79*
Rainfall in first 3 weeks			1.47 in.				1.80 in.'		

' Includes three irrigations of 0.25 in.

Tables 1 and 2. Aziprotryne was included as the standard, and gave good results whether applied shortly after drilling or post-emergence at the appropriate stage of weed growth. The main surviving weed was *Polygonum aviculare*, and, in one experiment, *Galium aparine*. Terbuthylazine (A-1862) at 0.5 lb/ac gave consistently good weed control and caused less crop injury than simazine with which it was compared in 1969. *Aethusa cynapium* was tolerant to terbuthylazine. In 1970, there was some crop injury in the April experiment, both with terbuthylazine alone and in a mixture with terbutryne (Table 2). Methabenzthiazuron at 2.0 lb/ac gave good weed control, with *Polygonum* spp. the main survivors, and only slight crop injury. With 2-(3',4'-dichlorophenyl)-4-methyl-3,5-diketo-1,2,4-oxadiazole (VCS-438) there was complete weed kill except for *Fumaria officinalis* and *Veronica* spp., but each dose caused some crop injury and the weight was reduced by 4.0 lb/ac (Table 1). N-(1,1-dimethylpropynyl)-3,5-dichlorobenzamide (RH-315) at 1.5 lb/ac gave good weed control, except for Compositae, and the crop weights were not significantly less than those of the weeded controls. In one experiment, however, where appreciable rain fell shortly after application, RH-315 caused pronounced stunting of a small proportion of the plants. With 2-(4-chloro-6-ethylamino-s-triazine-2-ylamino)-2-methyl-propionitrile (DW 3418) most weeds other than some *Polygonum aviculare* and *Galium aparine* were killed, but all applications resulted in some leaf chlorosis and necrosis of the crop; this was especially marked in the first experiment in 1970, when 2 lb/ac caused serious crop injury. A formulation of diphenamid + dinoseb (Enide Dinitro) gave moderately good weed control, except for *Galium aparine* in one experiment, but in one experiment there was some initial stunting of the crop. The results obtained with 4,5,7-trichlorobenzthiadiazole-2,1,3 (Ph 40-21) were promising. Weed control was moderately good with 4 lb/ac, while 8 lb/ac caused negligible crop injury.

Broad beans

There were two experiments, one in 1969 and one in 1970, and the results are summarised in Table 3.

Table 3

Pre-emergence herbicides on broad beans (cv. Triple White)

Herbicide and dose (lb/ac)		1969 Weed control (%)	1969 Weed control (0-10)	1969 Crop Injury (0-10)	1969 Crop Wt (%)	1970 Weed control (%)	1970 Weed control (0-10)	1970 Crop Injury (0-10)	1970 Crop Wt (%)
Terbuthylazine	0.75	100	9.8	2.3	94	100	9.2	1.0	123
Methabenzthiazuron	2.0	89	6.5	0.5	90	-	-	-	-
VCS-438	1.0	-	-	-	-	93	7.0	0.3	133
"	2.0	95	8.0	3.8	79**	94	8.0	0.3	101
RH-315	1.5	96	8.5	0.8	90	96	7.0	2.3	93
Diphenamid + dinoseb	2.4 + 1.8'	89	7.0	4.3	75**	99	6.7	2.3	122
Ph 40-21	4.0	-	-	-	-	98	8.0	0.3	102
"	8.0	-	-	-	-	100	9.2	0.0	125
DW 3418	1.0	-	-	-	-	99	8.3	0.7	125
"	2.0	-	-	-	-	100	9.2	0.0	137
Simazine	0.75	96	9.5	1.0	88	99	9.0	0.0	113
Control unweeded		(30 weeds/ft^2)			51**	(50 weeds/ft^2)			39**
Rainfall in first 3 weeks		0.27 in.				1.58 in.			

' 2.0 + 1.5 lb/ac in 1970

In each year the standard simazine treatment performed well, killing all weeds except for a few <u>Polygonum aviculare</u>, <u>P. convolvulus</u> and <u>Atriplex patula</u>. Terbuthylazine was slightly more effective than simazine against these species, and although there was rather greater crop injury, especially after heavy rain in May 1969, this was not reflected in final crop weight. VCS-438 gave good weed control, with <u>Fumaria officinalis</u>, <u>Veronica persica</u> and <u>V. hederifolia</u> the main survivors, but in 1969 the crop developed chlorosis, with stunting and leaf necrosis, and final weight was depressed. In 1970 there was little visible injury, but crop weight with 2.0 lb/ac of VCS-438 was significantly less than that with 1 lb/ac.

RH-315 gave good weed control, but in both years caused stunting of a proportion of the crop plants, and in 1970 crop weight was significantly less than that with most other treatments. Diphenamid + dinoseb gave moderately good weed control in both years, but caused pronounced chlorosis of the foliage at an early stage of growth. This effect soon disappeared in 1969, but later in the year following heavy rain, there was stunting and severe distortion of some of the plants and final crop weight was significantly depressed. In 1970 the initial chlorosis was more severe, but the crop recovered; plants on other plots treated with diphenamid alone at 2.0 lb/ac showed identical symptoms. Methabenzthiazuron, examined in 1969 only, gave less effective weed control than the other treatments.

Each of the herbicides used for the first time in 1970 gave excellent results. With Ph 40-21, the only weeds present at harvest were a few <u>Polygonum aviculare</u> and <u>Tripleurospermum maritimum</u> ssp. <u>inodorum</u> while with DW 3418 only a few <u>P. aviculare</u> and <u>Galium aparine</u> remained. Neither herbicide affected the crop. In both years, crop weight was severely depressed on the plots which were not weeded. In 1970 especially, there was competition for water. This occurred to some extent also on the weeded control plots where some weeds had been left, so that crop weights on plots treated with herbicides were generally higher.

<u>Dwarf beans</u>

There were two experiments, one in 1969 and one in 1970, and the results are summarised in Table 4.

Table 4

<u>Pre-emergence herbicides on dwarf beans (cv. Processor)</u>

Herbicide and dose (lb/ac)		1969 Weed control (%)	1969 Weed control (0-10)	1969 Crop Injury (0-10)	1969 Crop Wt (%)	1970 Weed control (%)	1970 Weed control (0-10)	1970 Crop Injury (0-10)	1970 Crop Wt (%)
Diphenamid dinoseb	2.4 + 1.8'	80	7.7	0.0	95	95	7.0	0.0	84**
VCS-438	1.0	90	7.7	3.3	102	-	-	-	-
"	2.0	84	7.7	4.0	94	-	-	-	-
RH-315	1.5	80	7.7	2.7	81	93	6.7	0.0	39**
Ph 40-21	4.0	80	7.0	0.0	99	98	7.7	0.0	87**
"	8.0	97	8.3	1.7	97	99	9.3	0.0	98
DW 3418	1.0	-	-	-	-	99	9.5	5.7	56**
"	2.0	-	-	-	-	100	9.7	7.3	52**
Paraquat monolinuron	0.5 + 0.7	90	8.7	0.0	108	94	9.3	0.0	115
Dinoseb-acetate monolinuron	1.6 + 0.6	95	8.7	0.0	106	98	9.3	0.0	110
Control unweeded		(6 weeds/ft^2)			78*	(11 weeds/ft^2)			24**
Rainfall in first 3 weeks		1.21 in.''				1.38 in.'''			

' 2.0 + 1.5 lb/ac in 1970
'' Includes one irrigation of 0.25 in.
''' Includes three irrigations of 0.25 in.

In each year the best treatment was the standard dinoseb-acetate + monolinuron (Ivorin) which gave very good weed control without crop damage. Paraquat + monlinuron (Gramonol), which was applied a week after drilling, also gave excellent results. DW 3418 gave comparable weed control, but caused severe crop damage and killed some of the plants. VCS-438 also injured the crop, and in 1969 application of RH-315 resulted in abnormalities of the leaves; these were more pronounced in other plants treated with 3 lb/ac, when crop weight was significantly depressed. Diphenamid + dinoseb and Ph 40-21 at 4 lb/ac did not affect the crop, but in 1970 surviving plants of the dominant weed, Chenopodium album, grew large and competed with the crop. At 8.0 lb/ac, Ph 40-21 gave good control, and the only effect on the crop was some marbling of the unifoliate leaves in 1969.

DISCUSSION

The performance of the treatments used as standards was good, and in agreement with previous results on the same soil. Aziprotryne proved effective on peas (Roberts & Hewson, 1968), simazine on broad beans (Roberts & Wilson, 1961) and dinoseb-acetate + monolinuron on dwarf beans (Roberts & Wilson, 1966). The mixture of paraquat + monolinuron also gave excellent results on dwarf beans, confirming the experience of King (1968). The experimental treatments also gave good weed control, except for the surviving species already mentioned. Other species present included Poa annua, Stellaria media, Chenopodium album, Capsella bursa-pastoris, Urtica urens and Solanum nigrum, and these were usually killed by all the treatments.

Ph 40-21 showed a high degree of selectivity in all three crops. Weed control was usually, although not always, adequate with 4.0 lb/ac, while 8 lb/ac gave consistently good control with little evidence of any crop injury. Terbuthylazine at 0.75 lb/ac gave slightly better weed control than simazine at the same dose in broad beans, but also caused rather more crop injury after rainfall (Table 3). In peas, 0.5 lb/ac gave good weed control, but this treatment and the combination with terbutryne resulted in some crop injury in 1970 (Table 2). Weed control was also good with DW 3418, and in broad beans an excellent result was obtained in the single year in which it was tested. Although selective in peas (Chapman et al., 1968), with 2.0 lb/ac there was always visible crop damage and in one experiment a 50% reduction in crop weight (Table 2). The lower dose of 1.0 lb/ac also caused injury in this experiment. Such doses appear to be too high for this soil, but in view of the good weed control lower doses may merit examination. DW 3418 proved highly damaging in dwarf beans, and seems unlikely to have any potential use in this crop. The other herbicides examined, methabenzthiazuron, VCS-438, RH-315 and diphenamid + dinoseb did not appear to offer any advantages over the standard treatments.

Conclusions from these experiments must be tentative, since yield and maturity were not assessed. The results suggest, however, that of the experimental treatments examined, the most promising were Ph 40-21 on all three crops, terbuthylazine on peas and broad beans, and DW 3418 on broad beans.

Acknowledgments

We are grateful to the various firms who provided samples of herbicides and to Mr. R. E. Meadas for assistance.

References

CHAPMAN, T., JORDAN, D., PAYNE, D.H., HUGHES, W.J. & SCHIEFERSTEIN, R.H. (1968) WL 19,805 - a new triazine herbicide. Proc. 9th Br. Weed Control Conf., 1018-25.

KING, J.M. (1968) Weed control experiments in dwarf French and broad beans. Proc. 9th Br. Weed Control Conf., 449-54.

ROBERTS, H.A. & HEWSON, R.T. (1968) Evaluation of 2-azido-4-isopropylamino-6-methylthio-s-triazine (C 7019) for weed control in vegetable crops. Proc. 9th Br. Weed Control Conf., 361-6.

ROBERTS, H.A. & WILSON, B.J. (1961) Chemical weed control in spring-sown broad beans. Weed Res., 1, 289-300.

ROBERTS, H.A. & WILSON, B.J. (1966) Evaluation of herbicides for weed control in dwarf beans. Proc. 8th Br. Weed Control Conf., 672-8.

RECENT INVESTIGATIONS ON THE BIOLOGICAL CONTROL OF SOME TROPICAL AND SUBTROPICAL WEEDS

F.D. Bennett
Commonwealth Institute of Biological Control, Gordon Street, Curepe, Trinidad

Summary A resumé of investigations on the biological control of weeds undertaken by the West Indian Station of the Commonwealth Institute of Biological Control is given. Since its inception in 1946 the W.I. Station has been involved with research on the biological control of eleven species of weeds. Outstanding control of two, Cordia curassavica (Jacq.) R. & S. in Mauritius and Opuntia spp. in Nevis, has been achieved by the introduction of phytophagous insects, and encouraging results have been achieved against Tribulus cistoides L. in St. Kitts. The complex of insects associated with several weeds including the important aquatic weeds Eichhornia crassipes (Mart.) Solms. and Salvinia auriculata Aubl. as well as the terrestrial species Eupatorium odoratum L. are currently under investigation.

INTRODUCTION

The encouraging results, in some cases outstanding successes, achieved in the biological control of certain weeds coupled with the growing concern over pollution and other possible detrimental side-effects that may arise from the application of herbicides have resulted in increased inquiries for investigations of the biotic agents of several other weeds. The biological method has particular appeal for situations in agriculture and forestry and additionally water impoundments, rivers etc. where the derived revenue will not support the costs of repeated applications of herbicides or of mechanical control.

Zwölfer (1968) has reviewed the investigations on weed projects undertaken by the European Station of the Commonwealth Institute of Biological Control (CIBC). In addition to the European Station and the South American Station at Bariloche, Argentina, also in the Temperate Zone, CIBC has developed several Stations in the Tropics and Sub-tropics:- Uganda and Ghana in Africa; India, Pakistan and Sabah in Asia; and Trinidad in the West Indies. Frequently in projects on biological control of weeds two or more of the Stations as well as the research departments of one or more governments participate in the same project. This report is restricted to weed problems in which the W.I. Station has participated.

METHOD AND MATERIALS

Zwölfer (1967 and 1968) has outlined points to be taken into consideration and the steps usually involved in the attempted biological control of an alien weed species. Upon receipt of a request for information on the possibilities of the control of a weed from a contributing organization the available information on its distribution, its status as a pest, its natural enemies, its affinities to economic plants and the possible repercussions arising from its control are reviewed.

Frequently in the tropics this information is very scanty. A survey of the fauna and pathogens in its native habitat (and elsewhere) followed by 'screening tests' of promising agents to evaluate their host ranges and potential are undertaken. In the tropics where insects breed throughout the year and have several generations these tests may proceed at a rapid rate. Once recommendations for the introduction and release of candidate species in the target area are approved disease-free stocks are sent for release. If establishment and a rapid build up occurs follow-up studies are conducted to evaluate the results.

The W.I. Station, CIBC, has participated with one or more of these steps dependent on the weed species and the area involved. With projects involving New World species which have become pests elsewhere original faunistic surveys, screening tests and shipment of candidate organisms have been undertaken. In some instances the organizing of shipments of controlling agents investigated by other research organizations has been all that was required. Finally, the introduction, breeding, release and follow-up studies of candidate species provided by other organizations for the control of native or exotic weeds in the West Indies have been undertaken.

WEED PROJECTS HANDLED BY THE W.I. STATION, CIBC

The W.I. Station was established in 1946 to investigate the possibilities of biological control of Cordia curassivaca (Jacq.) R. & S., a boraginaceous neotropical weed, which had become a problem in Mauritius. Since its inception numerous other projects on the biological control of weeds and insect pests have been undertaken. Weeds on which investigations have been undertaken are listed in Table 1, and pertinent details are provided below.

Cordia curassavica (Jacq.) R. & S. (Boraginaceae)

Cordia curassavica (= C. macrostachya (Jacq.)), a shrub growing about 15 ft in height was accidentally introduced into Mauritius with sugarcane plants from the West Indies about 1900. It rapidly became a serious pest of pasture-lands and plantations of Mauritius hemp (Furcraea gigantea (Vent.). Investigations in Trinidad indicated that a complex of insects restricted to C. curassavica occurred. Two defoliating beetles Physonota alutacea (Boh.) and Schematiza cordiae Barber were proven to be host-specific and in cage tests capable of causing adequate damage to greatly retard the rate of growth and to reduce seed production (Simmonds, 1949; 1951). However, the heavy attack of natural enemies prevents the build-up of populations of either species in Trinidad.

Both species were shipped to Mauritius but only S. cordiae released in 1948 became established. By 1950 many Cordia bushes had already been killed and populations of 15,000 to 20,000 beetles per bush were reported (Williams, 1952). A minute seed-destroying wasp Eurytoma sp. was also investigated and shipped. It became established immediately and at times destroys 75% of the seeds (Simmonds, 1958).

The weed on open lands was quickly brought under complete control, mainly by S. cordiae (Williams, 1952) although Eurytoma sp., by causing a reduction of viable seeds has limited the rate of recolonization (Simmonds, 1958). Additional species of insects specific to C. curassavica occur in Trinidad but were not required because control was so successful. The economics of this outstandingly successful example of biological control have been reviewed by Simmonds (1967) and are referred to later in the discussion.

Lantana camara L. (Verbenaceae)

Lantana camara, a native of Central and South America and the West Indies, has become a weed in various parts of Africa, Asia, Australia and the Pacific. Attempts

Table 1

Summary of investigations on the biological control of weeds undertaken by personnel of the W.I. Station, CIBC

Species	Investigations for	General inventory	Special studies	Organisms shipped (or received)	Remarks
TERRESTRIAL WEEDS					
Cordia curassavica	Mauritius	+	+	+	Excellent control
Lantana camara	Africa	+	+	+	Organisms established
Stachytarpheta spp.	Fiji	+			Investigations not continued
Elephantopus mollis	Fiji	+	+	+	Establishment
Opuntia spp.	West Indies*			+	Excellent control
Opuntia megacantha	South Africa	+			
Baccharis halimifolia	Australia	+			
Tribulus cistoides	St. Kitts			+	Satisfactory control
Eupatorium odoratum	Nigeria	+	+	+	Investigations continuing
AQUATIC WEEDS					
Salvinia auriculata	Africa*	+	+	+	Investigations continuing
Eichhornia crassipes	ODM* (Africa and Asia)	+	+	+	Investigations continuing

* See text for details

to control it in Hawaii by the introduction of insects date back to 1902 and results in those islands range from partial to almost complete success dependent on the altitude, rainfall and soil conditions. A large complex of insects occurs in the Neotropics and several species have been tried elsewhere. The search for additional candidate species is still being continued by the CSIRO, Australia, (K.L.S. Harley, pers. comm., 1970).

The W.I. Station, CIBC, has carried out original host-specificity tests complimentary to those undertaken in Hawaii on the defoliator *Diastema tigris* Guen. (Bennett, 1963), the leaf miners *Uroplata girardi* Pic. (Bennett and Maraj, 1967) and *Octotoma scabripennis* (Guerin), and the stem borer *Plagiohammus spinipennis* (Thoms.), and has on various occasions supplied stocks of the defoliators *Syngamia haemorrhoidalis* Guen., *Diastema tigris*, *Catabena esula* (Druce), the lace bugs *Teleonemia scrupulosa* Stal. and *Teleonemia* sp., the leaf miner *U. girardi* and the seedfly *Ophiomyia lantanae* (Frogg.) for experimental purposes, for laboratory cultures, or for direct liberation. Consignments of one or more of these species have been sent from Trinidad to Australia, Hawaii, India, Pakistan, Uganda, Zambia and South Africa. The establishment of certain species in East Africa has been reported (Greathead, 1968), but further introductions are necessary if satisfactory control is to be achieved.

Stachytarpheta spp. (Verbenaceae)

A preliminary survey of the insects attacking Stachytarpheta cayennensis (L.C. Rich.) Vahl. and S. jamaicensis (L.) Vahl., was undertaken in 1952-53 on behalf of Fiji where S. urticaefolia (Salisb) Sines was considered to be a problem. A complex of cecidomyiids damages the developing seeds and lepidopterous and coleopterous defoliators also occur, but a shifting of priorities by the Fijian authorities precluded detailed studies.

Elephantopus mollis H.B.K. (Compositae)

Following preliminary studies of the phytophagous species attacking E. mollis in Trinidad in 1952-54 the tephritid Tetuarista obscuriventus (Loew) which develops in the flower heads was sent to Fiji in 1957. Establishment was followed by a rapid build-up. B.H. O'Connor (in lit., 1963) reported that the rapid population build-up of T. obscuriventus had not noticeably affected the status of the weed. In 1962 this species was transferred from Fiji to Hawaii. Establishment again occurred but its effect on seed production and the rate of recolonization of the weed has not been assessed in detail.

Baccharis halimifolia L. (Compositae)

B. halimifolia, a native of the south-eastern United States, has become a weed in Queensland, Australia, and also in the coastal areas of the Black Sea, USSR.

At the request of Australia, preliminary surveys of the insects attacking Baccharis spp. were carried out in south-eastern United States in 1960 and in south-eastern Brazil in 1961 and 1963 by personnel from the W.I. Station. In both areas there occur several insects with adequate potential to warrant further investigations. Several species including the defoliating chrysomelid Trirhabda baccharidis Web., and the stem boring pterophorids Oidaematophorus spp., on which further work was recommended have been investigated in Florida and shipped to Queensland by Australian scientists.

Eupatorium odoratum L. (Compositae)

Native to the Neotropics Eupatorium odoratum over the years has become a weed in several parts of Asia and Africa (Bennett and Rao, 1968). At the request of Nigeria detailed investigations on potential controlling agents were started in Trinidad in 1966. The results of preliminary surveys (Cruttwell, 1968) and of host-specificity tests with two species, Ammalo insulata Walker (= arravaca of Cruttwell, 1968), (Bennett and Cruttwell, 1970), and Apion brunneonigrum Beguin-Billecoq. (Cruttwell, 1970) indicated that the prospects of biological control of this weed in Africa and Asia are promising. Precautions have been taken to prevent the introduction into Nigeria of a virus disease of A. insulata, which may play an important role in restricting populations of this species in Trinidad. These include the shipment of apparently disease-free eggs to the Indian Station, CIBC, where breeding could be undertaken without the likelihood (which exists in Trinidad) of introducing virus particles on the foliage utilised for rearing larvae. According to recent reports (Dr. V.P. Rao, pers. comm., Sept. 3, 1970) no evidence of disease has appeared in their cultures after three generations and therefore subcultures of this defoliator have been sent to Nigeria for further study prior to release. Apion brunneonigrum which destroys the developing seeds has also been tested in Trinidad and recommended for trial in Nigeria.

Opuntia megacantha (Salm-Dyck) (Cactaceae)

An exploratory survey of insects attacking O. megacantha (Salm-Dyck) was undertaken in Mexico on behalf of South Africa in 1963 (author's unpublished reports), but the recommendations calling for further investigation have not been pursued. Earlier CIBC had sent the cactus weevil Cactophagus spinolae (Gylh.) from Mexico to South Africa (Sellers, 1952). Although established in restricted areas it has not provided adequate control.

Opuntia spp. (Cactaceae)

The classical example of biological control of prickly pear cactus (Opuntia spp.) in Australia by the introduction of Cactoblastis cactorum (Berg.) is too well-known to comment further. The West Indian Station, CIBC, arranged for the release of this species as well as of Dactylopius spp. in Nevis in 1957 and subsequently in other islands in the West Indies from stocks obtained from South Africa. Excellent control of Opuntia spp. (including O. tricantha Willd.), by C. cactorum resulted in Nevis and Montserrat (Simmonds and Bennett, 1966). Elsewhere in the Caribbean C. cactorum is established in Antigua, St. Kitts, the U.S. Virgin Islands and recently (June, 1970) releases have been made in the Cayman Islands.

In addition to releases in the West Indies stocks of C. cactorum have been sent from Trinidad to Kenya and Israel, but establishment has apparently not occurred in either area.

Tribulus cistoides L. (Zygophyllaceae)

The puncture vine T. cistoides apparently became established at the edges of the airport in St. Kitts in the early 1950's, although it has been present elsewhere in the West Indies, e.g. Jamaica and Puerto Rico, for many years. Known locally as airport weed and initially considered to be a desirable ornamental in St. Kitts its eventual establishment and subsequent rapid spread to poorly managed pasture-lands caused concern. In view of the successful introduction of two European curculionids, the stem weevil Microlarinus lypriformis (Woll.) and the seed weevil M. lareynii (J.D.), into the United States (Huffaker et al., 1961) and Hawaii (Davis and Krauss, 1966) a biological control programme was recommended for St. Kitts. Stocks of the stem weevil were obtained from Hawaii and released in St. Kitts in November, 1966. Establishment was rapid. Four months after the release every stem sampled near the liberation site was infested and 72% of the sampled internodes had been attacked. Many plants were killed outright as a direct result of weevil damage. Virtually solid stands of the weed in pasture-lands had disappeared within one year. Similarly on embankments near the airport extensive stands were decimated and have since been largely replaced by other plants (author's unpublished reports). There has been little subsequent spread of this weed in St. Kitts as the continuous attack has placed this weed at a competitive disadvantage to other plants.

In October, 1968 the seed weevil M. lareynii was introduced into St. Kitts from California. It was recovered in April, 1969 but was not observed during a short visit in October of the same year. Although probably still present in St. Kitts it has not increased in the explosive fashion exhibited by the stem weevil.

M. lypriformis was also released in Nevis in late 1968 after the discovery of a small stand of T. cistoides at the airport. Establishment occurred and the activity of the weevil has apparently curtailed the spread of the weed.

It is of interest to note that in St. Kitts M. lypriformis also readily attacked two related weeds belonging to the same family, Kallstroemia maxima (L.) Torr. and Gray and K. pubescens (F. Don) Dandy. Although attacked plants succumb more rapidly than those of T. cistoides these annuals frequently set seed before being attacked and these produce a new crop of plants with the advent of the rains.

It is also of interest that plants of Kallstroemia spp. more than a mile from the nearest plant of T. cistoides were attacked by M. lypriformis. Finally, although two species of indigenous parasites Eupelmus cushmani (Crawford) and Catolaccus aeneoviridis Girault have been reared from M. lypriformis the incidence of attack has been too low to affect its efficiency. Goeden and Ricker (1970) have discussed the effect of parasite attack on Microlarinus spp. in California.

Cuscuta spp. (Convolvulaceae)

Following the result of an independent investigation on the natural enemies of Cuscuta spp. at the Pakistan Station, CIBC, (Baloch et al., 1967a and b) two insects, Melanagromyza cuscutae Hering and Smicronyx cuscutae Mshl., were sent to the Barbados Sub-Station, CIBC, in 1967 (Carl, 1967) where they were released against Cuscuta americana L. and C. indecora Choisy which are parasitic on ornamental shrubs and trees. Although M. cuscutae was successfully propagated for three generations and released, it apparently did not become established. Investigations on other Cuscuta insects in Pakistan are continuing and their introduction into Barbados and elsewhere in the West Indies is under consideration.

Salvinia auriculata Aubl. (Salvinaceae)

This fern, a native of South America has been a serious aquatic weed in rice areas in Ceylon for many years and more recently has demonstrated its explosive growth rate on Lake Kariba. A survey of the insects attacking this plant in South America and Trinidad followed by detailed host-specificity studies of three insects, the grasshopper Paulinia acuminata DeGeer, the weevil Cyrtobagous singularis Hulst., and the caterpillar Samea multiplicalis Guen. have been undertaken (Bennett, 1968 and 1970). Shipments of P. acuminata have been made from Trinidad to Africa for further study and release on Lake Kariba and Lake Naivasha. Preliminary results with P. acuminata have not been encouraging. This, in part at least, is due to climatic differences and hence a trial with material of this species from a cooler region in South America was recommended. Accordingly stocks were obtained from Argentina for trial on Lake Kariba (P. Thomas, pers. comm., 1970). Shipments of S. multiplicalis have also been made to Kenya, but attempts to breed it for release on Lake Naivasha have been unsuccessful.

Eichhornia crassipes (Mart.) Solms. (Pontederiaceae)

Inventory surveys of the natural enemies of E. crassipes, considered on a world-wide basis to be the most serious aquatic weed, have been undertaken by personnel from the W.I. Station in South America, the West Indies, and south-eastern United States at the request of the Ministry of Overseas Development, Great Britain (Zwölfer and Bennett, 1968; Bennett, 1968 and 1970). Several species of insects and mites are under study in Trinidad and cultures of four of these Acigona ignitalis, Epipagis albiguttalis, Neochetina sp., all insects occurring in Trinidad and Orthogalumna terebrantis, a mite obtained from Florida, USA, have been sent to India for further screening and the production of disease-free cultures prior to conducting field trials in Africa and Asia.

WEEDS ON WHICH INVESTIGATIONS HAVE BEEN REQUESTED

Recently (August, 1970) investigations on four weeds Bidens pilosa L. (Compositae), Portulaca oleracea L. (Portulacaceae), Euphorbia prunifolia (Euphorbiaceae) and Mimosa spp. (Leguminosae) have been authorised by Papua and New Guinea. Inquiries from India about the possibility of natural enemies of the aquatic weed Ipomea aquatica Forssk. (Convolvulaceae) and of Parthenium hysterophorus L. (Compositae) are receiving attention although the former is not native to Trinidad. Proposals have also been put forth for an investigation of agents that might be useful for the control of Mikania micrantha H.B.K., a neotropical species which has become widespread in the Old World Tropics.

DISCUSSION

Since its inception in 1946 the West Indian Station, CIBC, has been involved in investigations on the biological control of eleven weeds, and studies have recently been started on others. These have resulted in the spectacular, complete biological control of two of these i.e. Cordia curassivaca in Mauritius, for which the W.I. Station carried out exploratory work, screening tests, and provided the controlling agents; and Opuntia spp. in Nevis where the W.I. Station received stocks of Cactoblastis cactorum from South Africa, mass-propagated and released it and carried out an evaluation survey. Simmonds (1967) reported that the control of Cordia in Mauritius has resulted in an annual return of £100,000 without any further expenditure for control of this weed after the initial investigations. Similarly he estimated that an annual expenditure between £10,000 and £20,000 per annum would have been necessary to achieve the same consistent level of control of Opuntia spp. obtained by the introduction of Cactoblastis into Nevis at a cost of less than £550. The more recent successful control of Tribulus cistoides in St. Kitts cannot be as readily evaluated. The introduction of Microlarinus lypriformis has greatly reduced the rate of spread and precluded the necessity of other methods of control for this weed.

Investigations on several of the other projects have not yet arrived at the stage where introductions can be made and hence their value cannot be ascertained.

The 'time lag' i.e. the period between the start of investigations and the time control is achieved may be listed as one of the disadvantages of the biological method of weed control when comparing it to the rapid results obtained by chemical control. Nevertheless, in instances where basic investigations on the biological control of a specific weed have already been carried out it is at times possible to achieve rapid control when these results are applied to the same or related weeds in a new area e.g. the rapid control of Tribulus cistoides obtained in St. Kitts. The fact that biological control once established is usually perpetual and without further costs has special appeal particularly where the economic returns from lands (and waters) are too low to warrant the repeated application of herbicides. Needless to say there are many introduced weeds (some would claim that these are in the majority) which, for one or more reasons, are not amenable to biological control. Similarly many endemic weeds are not promising candidates for this method, although consideration to certain of these should be given: for example certain species of Opuntia successfully attacked by Cactoblastis cactorum are native to the West Indies. Wilson (1964) has also discussed this aspect. Certainly the economic gain obtained from successful instances suggests that at least preliminary consideration should be given to the biological method wherever weed problems occur.

Acknowledgements

Mr. C.J. Davis, Chief, Entomology Division, Department of Agriculture, Honolulu, Hawaii, and Dr. R.D. Goeden, Assistant Entomologist, Division of Biological Control, University of California, Riverside, California, kindly provided stocks of the insects released for puncture vine in St. Kitts.

References

BALOCH, G.M., MOHYUDDIN, A.I. and GHANI, M.A. (1967a) Biological control of Cuscuta spp. 1. Cuscuta spp. and insects associated with these in West Pakistan. Tech. Bull. Commonw. Inst. biol. Control, 8, 149-158.

BALOCH, G.M., MOHYUDDIN, A.I. and GHANI, M.A. (1967b) Biological control of Cuscuta spp. II. Biology and host plant range of Melanagromyza cuscutae Hering: (Dipt. Agromyzidae). Entomophaga, 12, 481-489.

BALOCH, G.M. (1968) Possibilities for biological control of some species of Cuscuta (Convolvulaceae). PANS(C), 14, 27-33.

BENNETT, F.D. (1963) Feeding tests with the Lantana noctuid Diastema tigris Guen. Tech. Bull. Commonw. Inst. biol. Control, 3, 83-87.

BENNETT, F.D. (1966) Investigations on the insects attacking the aquatic ferns, Salvinia spp. in Trinidad and Northern South America. Proc. sth. Weed Conf., 19, 497-504.

BENNETT, F.D. (1967) Notes on the possibility of biological control of the water-hyacinth Eichhornia crassipes. PANS(C), 13, (4), 304-309.

BENNETT, F.D. (1968) Insects and mites as potential controlling agents of water-hyacinth, Eichhornia crassipes (Mart.) Solms. Proc. 9th Br. Weed Control Conf., 832-835.

BENNETT, F.D. (1970) Insects attacking water-hyacinth in the West Indies, British Honduras, and the U.S.A. Hyacinth Control J., 8 (in press).

BENNETT, F.D. and CRUTTWELL, R.E. (1969) Host specificity tests with Ammalo insulata (Walk.) Arctiidae, a potential agent for the control of Eupatorium odoratum Linn., Compositae. Commonw. Inst. biol. Control. Unpublished report, pp.9.

BENNETT, F.D. and MARAJ, S. (1967) Host specificity tests with Uroplata girardi Pic., a leaf-mining Hispid from Lantana camara L. Tech. Bull. Commonw. Inst. biol. Control, 9, 61-72.

BENNETT, F.D. and RAO, V.P. (1968) Distribution of an introduced weed Eupatorium odoratum Linn. (Compositae) in Asia and Africa and possibilities of its biological control. Proc. 9th Commonw. For. Conf., pp.7.

BENNETT, F.D. and ZWOLFER, H. (1968) Exploration for natural enemies of the water-hyacinth in northern South America and Trinidad. Hyacinth Control J., 7, 44-52.

CARL, K. (1967) Report for Barbados Sub-Station. In Commonwealth Institute of Biological Control Report of Work carried out during 1967, 80-83.

CRUTTWELL, R.E. (1968) Preliminary survey of potential biological control agents of Eupatorium odoratum in Trinidad. Proc. 9th Br. Weed Control Conf., 836-841.

CRUTTWELL, R.E. (1970) Report on studies of Apion brunneonigrum B.B., a weevil attacking Eupatorium odoratum L. (Compositae) in Trinidad. Commonw. Inst. biol. Control. Unpublished report, pp.8.

DAVIS, C.J. and KRAUSS, N.L.H. (1966) Recent introductions for biological control. Proc. Hawaii. ent. Soc., 19, 201-207.

GOEDEN, R.D. and RICKER, D.W. (1970) Parasitization of introduced puncture vine weevils by indigenous Chalcidoidea in southern California. J. econ. Ent., 63, 827-831.

GREATHEAD, D.J. (1968) Biological control of Lantana - A review and discussion of recent developments in East Africa. PANS(C), 14, 167-175.

HUFFAKER, C.B., RICKER, D.W. and KENNET, C.E. (1961) Biological control of puncture vine with imported weevils. Calif. Agric., 15, 11-12.

SELLERS, W.F. (1952) The collection of the cactus weevil Cactobagous spinolae (Gylk.) and its despatch to South Africa. Bull. ent. Res., 43, 43-50.

SIMMONDS, F.J. (1949) Insects attacking Cordia macrostachya (Jacq.) Roem & Schult. in the West Indies. I. Physonata alutacea Boh. Can. Ent., 81, pp.15.

SIMMONDS, F.J. (1949) Insects attacking Cordia macrostachya (Jacq.) Roem. & Schult. in the West Indies. II. Schematiza cordiae Barb. (Coleoptera:Galerucidae). Can. Ent., 81, 275-282.

SIMMONDS, F.J. (1951) Further effects of the defoliation of Cordia macrostachya (Jacq.) R. & S. Can. Ent., 83, 24-27.

SIMMONDS, F.J. (1958) The control of Cordia macrostachya in Mauritius. Proc. 10th Int. Congr. Ent., 4, 553-555.

SIMMONDS, F.J. (1967) The economics of biological control. Jl R. Soc. Arts, 880-898.

SIMMONDS, F.J. and BENNETT, F.D. (1966) Biological control of Opuntia spp. by Cactoblastis cactorum in the Leeward Islands (West Indies). Entomophaga, 11, 183-189.

WILLIAMS, J.R. (1952) The control of the black sage in Mauritius by Schematiza cordiae (Barb (Col. Galerucidae). Bull. ent. Res., 42, 455-464.

WILSON, F. (1964) The biological control of weeds. A. Rev. Ent., 9, 225-244.

ZWOLFER, H. (1967) Insect introductions and biological control. IUCN, 9, 141-150.

ZWOLFER, H. (1968) Some aspects of biological weed control in Europe and North America. Proc. 9th Br. Weed Control Conf., 1147-1156.

A STUDY OF THE BIOLOGY OF ROTTBOELLIA EXALTATA LINN.f.

P.E.L. Thomas
Department of Research & Specialist Services, Henderson Research Station, seconded to Dept. of Agriculture, University College of Rhodesia, Salisbury, Rhodesia

Summary Rottboellia exaltata, a tall growing annual grass, is a weed of arable land in parts of Central Africa, the Philippines, the Southern United States, West Indies, New Guinea and Australia. It is resistant to selective maize (Zea mays) herbicides.

In preliminary studies of seed dormancy removal of caryopses from the husk caused appreciable increases in germination though the majority of newly harvested caryopses still needed a period of after-ripening before they germinated. Age, storage temperature, wetting and drying of seed are probably the major factors influencing dormancy of the in-husk seed.

In studies in one season, R. exaltata produced more than 2000 kg seed/ha or approximately 200 million seed/ha. Soil fertility influenced seed yield while plant population had only a small effect on seed production. In field experiments seed was found not to persist for longer than two to three years. Means of dissemination of R. exaltata seed are discussed.

Most R. exaltata plants were found to emerge from the top 5 to 7 cm of soil. Interplant competition in dense natural populations reduced the number of plants from 1670 plants/m^2 to only 200 plants/m^2 within 20 weeks. Rhodesian single hybrid maize grew more rapidly than R. exaltata and remained taller for at least the first twelve weeks after sowing.

R. exaltata is susceptible to several diseases and can be infected by two nematode species.

INTRODUCTION

Rottboellia exaltata is a tall growing annual grass which occurs in many tropical and subtropical countries but is considered a serious weed only in isolated localities.

A detailed study on R. exaltata is being carried out because this weed is resistant to selective maize herbicides in Rhodesia. Preliminary results of studies of seed and plant characteristics are summarised in this report.

DESCRIPTION

R. exaltata is a short-day plant with a critical photoperiod (Heslop-Harrison, 1959). Botanical characteristics of this plant are given by

Hitchcock (1936) and Bor (1960). R. exaltata belongs to the tribe Andropogoneae and is known by various common names. For example, it is called 'Itch grass' in Australia, 'Aguingay' in the Philippines, 'Racul grass' in Louisinana, U.S.A., 'Mulungwe' or 'Guineafowl grass' in Zambia, and 'Shamva grass', 'Guineafowl grass' or 'Kokomo grass' in Rhodesia.

DISTRIBUTION

According to Hitchcock (1936) R. exaltata was first classified in India in 1779, and introduced to the West Indies from Southern Asia. It is widely distributed in the tropics and subtropics (Fernandez, 1963; Millhollon, 1965; Rehbein, 1963; and Rattray, 1960).

R. exaltata is a serious weed in only a few localities. For example, at the 1958 African Weed Control Conference there were only two references to this weed, one in Southern Rhodesia and the other in Tanganyika. At the Third East African Herbicide Conference held in 1964 only Hopkinson mentioned R. exaltata as a problem-weed in Tanganyika sisal. It has, however, reached serious proportions in parts of Rhodesia and Zambia (Smith, 1969; Thomas, 1970).

Outside Africa R. exaltata is considered a serious weed of sugar cane in the Philippines (Fernandez, 1963), Louisiana, U.S.A. (Millhollon, 1965) and to a limited extent in Australia (Rehbein, 1963). Kasasian (1962) mentions it is a weed of various West Indian crops. Recently Vance (1970) has reported it to be a problem weed in sorghum grown in the Markham Valley of New Guinea.

BIOLOGY STUDIES

Seed Dormancy

Studies were conducted on seed harvested in March 1969 and 1970, and stored at room temperature (approximately 15 to 30°C), unless otherwise stated. Most seed viability tests were made using 50 seeds per replicate. The seeds were put in 8 cm petri dishes on filter paper which was watered with tapwater and kept at 30°C in a constant-temperature room. Treatments were replicated 4 times.

Removal of the husk (enveloping bracts) from R. exaltata seed increased germination considerably. However, caryopses thus treated did not all germinate, indicating the need for a period of after-ripening. For example, 17% of well-filled, dehusked caryopses germinated within one month of harvest, 37% after three months, 58% after four months, 62% after five months while 95% germinated twelve months after harvest. Of seed which had not been dehusked 0 to 10% germinated within five months and approximately 50% by twelve months after harvest. This degree of dormancy does not appear to occur in the field and studies are in progress to confirm this observation.

The studies have shown that caryopses become imbibed while in the husk. Crushing, pricking or partial removal of the husk generally resulted in improved germination. Dehusked caryopses placed among mashed up husks germinated as well as caryopses with husks completely removed.

The restricting influence of the husk on germination was not overcome by treatment either with 0.2% potassium nitrate, or with 100 p.p.m. giberellic acid or by increasing the oxygen supply.

Temperature and/or wetting beforehand affected germination of in-husk seed, as did temperature during germination. For example, 27% of in-husk seed germinated after exposure for 14 days to the sun, rain and alternating temperatures (10°C to 49°C) while 5% of the seed stored at room temperature germinated. Generally more seed germinated (in or out of the husk) when incubated at 30°C or at fluctuating temperatures (30°C for 8 hours and 15°C for 16 hours) than at 20°C or at 10°C. When incubated at 35°C or when temperature fluctuated from 35 to 20°C seed developed a fungus infection which resulted in poor germination.

Regular monthly tests are being made on viability of seed stored either indoors, on the soil surface or 2.5 cm deep in soil, each regime with and without regular watering. Only limited results are at present available. A similar laboratory experiment compared seed stored for one month at room temperature, 10°C, 45°C or alternated between 10°C and 45°C for 16 hours and 8 hours respectively. Half of the seed was immersed in water (of similar temperature to the treatment concerned) for ten minutes on each of six occasions during storage while the other half was kept dry. Results obtained appear in Table 1.

Table 1

Germination percentage of R. exaltata seed as influenced by temperature and regular wetting during storage (mean of four replicates)

Storage Treatment		Germination% In-husk	Germination% Dehusked*
Constant 10°C	Wet	6.0	51.5
	Dry	3.0	54.0
Room temperature (approx.10°C to 25°C)	Wet	14.0	63.5
	Dry	5.0	54.5
10°C for 16 hours and 45°C for 8 hours	Wet	14.0	69.0
	Dry	7.0	59.5
Constant 45°C	Wet	55.0	76.0
	Dry	10.5	60.5

*seeds were dehusked after temperature and wetting treatments had been applied.

Dry storage at high temperatures increased the germination of both in-husk and dehusked seed. At the three lower storage temperatures, immersion of in-husk seed in water for short periods resulted in two- to threefold increases in germination, while at the higher temperature, a fivefold increase was recorded.

Seed Production

Monthly sowings of R. exaltata were made from October 10th, 1969 until January 10th, 1970. The first inflorescences emerged 59 to 61 days after sowing and seed started shedding 12 to 21 days later. Spikelets shed at the tip of an inflorescence were light green coloured, usually poorly filled and immature. The remaining spikelets had a brownish, reddish or bluish tinge which usually indicated mature, well-filled seeds. At the end of the season light green, and immature spikelets were shed from all parts of the inflorescence.

In 1968/69 R. exaltata was found to produce 167.8 million seeds/ha weighing 1640 kg/ha with a germination percentage of 54.

The effect of plant population and soil fertility on R. exaltata seed production was studied on a relatively fertile clay loam soil during the summer of 1969/70 (Table 2).

Table 2

R.exaltata seed yield as influenced by plant population and soil fertility (mean of five replicates)

Population	Fertilizer level	Seed yield (kg/ha)
43 plants/m^2	no added fertilizer	1828
	high fertilizer level	2118
172 plants/m^2	no added fertilizer	1799
	high fertilizer level	2148
	L. S. D. (5%)	268

*High fertility level received 132 kg N + 59 kg P_2O_5 and 45 kg K_2O/ha.
Seed yield was affected by soil fertility but not by a fourfold increase in population.

Seed Dissemination

R. exaltata seed floats in water and this is a means of dissemination. So too is uncleaned machinery, equipment, bags, clothing, etc. R.exaltata seed is relatively easily separated from crop seed and is thus not likely to be introduced by it, possible exceptions being poorly cleaned wheat and sorghum seed.

R. exaltata is known as 'guineafowl grass' in Zambia and Rhodesia. This is probably because of the large amounts of R. exaltata seed eaten by the helmeted guineafowl (Numida meleagris). Angus & Wilson (1964) found that during the winter months R. exaltata, Eleusine indica and Zea mays made up 95 to 100% of the diet of guineafowl in Zambia. Recently Barry (1970) reported from the Rhodesian Lowveld that he had difficulty in harvesting R. exaltata seed due to quelea (Quelea lathami), other grain eating birds and field rats eating it.

During 1969-70 the author fed seed of R. exaltata to quelea (Q.lathami), laughing doves (Streptopelia senegalensis) which were reluctant to eat it, helmeted guineafowl, leghorn hens, sheep and steers. Droppings from the various birds or animals were collected and germinated in petri dishes, glasshouse pots or in the field. No viable seed passed through quelea or laughing doves. Of the seed fed to helmeted guineafowl and which passed through the digestive tracts approximately 0.3% was viable while approximately 2% of seed fed to domestic fowls was undigested and viable. Of seed fed to sheep approximately 0.03% viable seed was recovered in manure while approximately 0.5% was recovered in steer manure.

These studies indicate that small grain-eating birds could drastically reduce R. exaltata seed populations and are not likely to disseminate seed. The helmeted guineafowl will readily eat R. exaltata seed and disseminate it. Sheep eating silage, hay or fodder contaminated with R. exaltata seed would pass only limited amounts of viable seed in their droppings while steers would pass considerably more.

Seed Burial

In August,1967 R. exaltata seeds were buried in nylon covered fibre glass mosquito gauze cylinders. One hundred seeds were buried at each of the following depths : 2.5, 5.0, 7.5, 15.0, 22.5 and 30.0 cm. Seeds were removed and tested for viability in February 1968, 1969 and 1970. The results obtained are presented in Table 3.

Table 3

Percentage viable R. exaltata seed recovered at various soil depths after one to three years burial (mean of four replicates)

Depth of burial(cm)	Number of years buried and when sampled One(Feb.1968)	Two(Feb.1969)	Three(Feb.1970)
2.5	8.8	3.0	0.3
5.0	8.8	5.5	1.0
7.5	9.0	2.8	1.5
15.0	15.3	6.3	0.0
22.0	25.3	16.5	0.0
30.0	24.8	17.0	0.5
Mean	15.3	8.5	0.5

In the first two years more seeds survived at the greater depths than when buried near the soil surface. The majority of R. exaltata seeds buried at all depths for three years lost their viability.

Several other weeds were included in this experiment for the purpose of comparison. Results obtained with Eleusine indica were : 46.5% viable seed survived after burial for one year, 59.5% after two years and 36.1% after three years.

Seed Longevity

In September,1966 one thousand viable R. exaltata seeds were dug in to a depth of 22.5 cm on each of twenty-four 1.5 m^2 plots. In subsequent summer seasons differential cultivation treatments were imposed and the numbers of emerged R. exaltata plants counted. The effects of treatments are shown in Table 4.

Table 4

Number of emerged R. exaltata plants, as a percentage of viable seed originally sown, as influenced by cultivation treatment and age (mean of six replicates)

Cultivation frequency	Dec.1966 to Nov.1967	Dec.1967 to Nov.1968	Dec.1968 to Nov.1969	Total
No cultivation	12.1	3.2	0.0	15.3
Once annually	11.7	5.2	0.0	16.9
Every quarter	10.1	3.9	0.0	14.0
Every month	17.1	2.1	0.0	19.2
Mean	12.8	3.6	0.0	16.4
			L.S.D. (5%)	3.3

Cultivation was to a depth of 22.5 cm. No germination took place between December 1969 and July 1970 when plots were thoroughly searched for *R. exaltata* seeds but none could be found. Thus in this case seeds did not remain viable for longer than two years. More seed germinated in the first year when the soil was cultivated frequently.

Several other weeds were included in this experiment. Some examples of the mean number of emerged plants as per cent of viable seed originally sown were (6 replicates) :

	1966/67	1967/68	1968/69
Eleusine indica	3.8	3.2	5.5
Nicandra physalodes	11.4	11.5	8.9
Datura stramonium	48.1	5.3	3.8

These results show that, in contrast to *R. exaltata*, seed of these weeds was still germinating after three years.

A large scale observation is under way to ascertain whether *R.exaltata* seed will persist for longer than two years. Care is being taken to ensure that no further seed is shed. Several Rhodesian farmers have asserted that *R. exaltata* seed buried at a depth of more than 30 cm (in a dam wall or in a contour bank) will germinate after several years when brought to the soil surface. However, this is not likely to be an important source of reinfestation.

Plant behaviour

Observations were made on the depth from which seed emerged at nine different sites in the Mazoe Valley. The results obtained are summarised in Table 5.

Table 5

Number of *R. exaltata* plants emerged from various soil depths as a percentage of all plants samples (mean of nine sites)

Depth (cm)	% of all plants	Remarks
0 to 1	6.7	
1 to 2	16.1	22.8% from the top 2 cm
2 to 3	23.0	45.8% from the top 3 cm
3 to 4	19.4	65.2% from the top 4 cm
4 to 5	12.9	78.1% from the top 5 cm
5 to 6	8.0	86.1% from the top 6 cm
6 to 7	4.6	90.7% from the top 7 cm
7 to 8	3.4	9.3% from 7 to 15 cm
8 to 9	2.1	
9 to 10	2.1	
10 to 11	0.7	
11 to 12	0.5	
12 to 13	0.3	
13 to 14	0.1	
14 to 15	0.1	

Plants emerged from depths of up to 15 cm but the majority came from the top 5 - 7 cm.

Natural populations of *R. exaltata* consisted of an average of 1670 plants/m^2 (ranging from 1140 to 2540/m^2) shortly after germination but fell to 200 plants/m^2 (range of 85 to 365/m^2) twenty weeks later,presumably as a result of interplant competition. The most rapid losses occurred during periods of soil moisture stress.

Maize (Zea mays) and R. exaltata were sown in separate plots at monthly intervals from October 10th, 1969 until January 10th, 1970, and observed at regular intervals. R. exaltata usually emerged one or two days before maize but the maize grew more rapidly after emergence until both plants reached their maximum height 10 to 12 weeks after sowing. Information on height differences, leaf and tiller number is summarised in Table 6.

Table 6

Difference in height between maize and R. exaltata, and leaf and tiller number at different times after sowing (means from four sowing dates)

	Weeks after sowing									
	1	2	3	4	5	6	7	8	9	10
Height difference(cm)*	2	15	30	38	44	73	77	44	41	36
Leaf number**										
Maize	2	5	8	9	11	12	13	14	15	15
R.exaltata	2	3-4	5	5	5	6	8	9	9-10	9-10
Tiller number										
R.exaltata	0	0-2	1-3	2-4	3-8	4-9	4-10	4-12	4-12	4-12

*Maize height minus R.exaltata height
**Leaf number on main stem

These findings help to explain results obtained in field competition studies (Richards and Thomas, 1970) where (a) R. exaltata, which grew with maize for the first 8 weeks only and was then removed, did not affect final yield, (b) R. exaltata established two weeks later than maize, did not affect final yield, and (c) only high populations of R. exaltata offered serious competition to maize.

In Rhodesia, Whiteside (1966) observed that R. exaltata was susceptible to a rust disease, Puccinia rottboelliae Syd ; two types of leaf spot, Cercospera sp and Pyricularia setariae Nisikado; a smut disease,Sphacelotheca ophiuri (P.Henn.) Ling.; and maize streak virus, Storey.

Martin (1969) found that R. exaltata could be infected by the root-knot nematodes, Meloidogyne javanica and M.incognita var acrita in Rhodesia.

Seed and plant behaviour studies are continuing and results will be published as soon as possible or in the author's thesis which is being prepared in the Department of Agriculture, University College of Rhodesia for presentation in 1972.

Acknowledgements

The author is grateful to the Rhodesia Grain Producers Association for establishing the Hastings Grain Fellowship which has made this detailed study possible. He is also grateful to colleagues at Henderson Research Station and the Departments of Agriculture and Botany at the University College of Rhodesia for providing the facilities, advice and assistance in carrying out this work. Drs. J.C.S. Allison and R.C. Elliott kindly assisted in the preparation of this paper.

References

ANGUS, A and WILSON, K.J. (1964) Observations on the diet of some game birds and Columbidae in Northern Rhodesia. 1. The helmeted guineafowl (Numida meleagris). The Puku Occ., Papers Dept. Game and Fisheries, N. Rhod., No.2, 1-9

BARRY, A.J. (1970) Personal communication

BOR, N.L. (1960) Grasses of Burma, Ceylon, India and Pakistan (excluding Bambuseae). Permagon Press, London, p 208

FERNANDEZ, D.B. (1963) Studies on Rottboellia exaltata L.f. I. Biology and II Control. Paper read at Philippine Sugar Technologists Convention.

HESLOP-HARRISON, J. (1959) Photoperiod and fertility in Rottboellia exaltata L.f. Ann., Bot., 23, 345-349

HITCHCOCK, D. (1936) Manual of grasses of the West Indies. Misc., Publ., No.243, Govt. Printing Office, Washington, U.S.A. p 418

KASASIAN, L. (1962) Chemical weed control in citrus. Weed Control Ext., Circ., Univ., Coll., West Indies, 4, 3

MARTIN, G.C. (1969) Plants infected with root-knot nematodes. Rhod.,agric. J. Bul. No.8

MILLHOLLON, R.W. (1965) Growth characteristics and control of Rottboellia exaltata L.f., a new weed in sugar cane. The Sugar Bul, 82-88

RATTRAY, J.M. (1960) The grass cover of Africa. F.A.O. Agric., Studies No.49

REHBEIN, C.A. (1963) Itch grass. The Cane Growers Quarterly Bul, 26, 94-95

RICHARDS, P.V.M. and THOMAS, P.E.L. (1970) An approach to the control of Rottboellia exaltata in maize. Proc. 10th Br. Weed Control Conf.

SMITH, J.A. (1969) Personal communication

THOMAS, P.E.L. (1970) A survey of the weeds of arable lands in Rhodesia. Rhod. agric.J, 67, (2), 3-4

VANCE, P.N. (1970) Personal communication

WHITESIDE, J.O. (1966) A revised list of plant diseases in Rhodesia. Kirkia, 5, 2, 137

Proc. 10th Br. Weed Control Conf. 1970

CHEMICAL CONTROL OF WHITE HORSENETTLE (SOLANUM ELAEAGNIFOLIUM CAV.)

D. Daniel Sundararaj and M. Balasubramanian
Agricultural College & Research Institute, Coimbatore-3, India

Summary Solanum elaeagnifolium Cav. from Tropical America is a pernicious weed in Tamilnadu State. As it spreads through the fragmentation of the roots, cultural methods are not satisfactory as they spread the weed by the pieces of roots cut during cultivation. Chemicals, such as 2,4-D salts, have been found to be quite satisfactory, moreover they are economical and can be used selectively in cereals. The investigations presented here suggest that the use of 2,4-D salts (sodium or amine) at frequent intervals will ensure substantial reduction in the growth of the weed and considerably reduce subsequent regrowth during soil preparation. Reductions to as low as 5% have been found possible within 60 weeks of the initial spraying. The corresponding data for handweeding or no-weeding treatments show 100% and more regrowth in spite of repeated hoeing and digging (thrice in 60 weeks period).

INTRODUCTION

White horsenettle (Solanum elaeagnifolium Cav.) is a tropical American weed of recent introduction in the Tamilnadu State of India. This deep-rooted pernicious weed propagates by root cuttings and poses a problem for its control by conventional mechanical means, which only perpetuate the weed by fragmentation of the roots. Work already done on the chemical control of this weed suggests the potentialities of chemical weed control for such perennial weeds (Balasubramanian and Rao, 1968). The investigations presented in this paper discuss the merits of continuous and repeated applications of the herbicides in comparison to handweeding or no-weeding practices.

METHOD AND MATERIALS

The trials were conducted for two years on the land of a private farmer which had been severely infested with the weed for nearly a decade. The first part of the trial deals with the exploratory investigations and the second part details the effects of the repeated application of herbicides on the weed. The herbicides were used as foliar sprays with Teepol as wetting agent, using a spray volume of 50 gal per ac. The field layout was a replicated randomised blocks design with plot size of 15 ft x 10 ft. The observations on weed mortality and green shoot counts were made in random quadrats measuring 3 ft x 3 ft, and four such quadrats were fixed for each plot. The average of the 12 quadrats was calculated for the interpretation of the results for each treatment. Observations were made weekly, but space only permits the final results to be presented here.

<u>Treatments</u> (First part of the trial, period - 12 weeks)

1. control - no weeding or spraying of herbicides
2. 2,4-D amine.................. at 3.2 lb a.i./ac (Bladex G at 3 l./ac)
3. esters of 2,4-D + 2,4,5-T.... at 2.6 lb a.i./ac (Bladex I at 3 l./ac)
4. amitrole..................... at 1.6 lb a.i./ac (Bladex O at 3 l./ac)

<u>Treatments</u> (Second part of the trial, period - 60 weeks)

1. control - handweeding on the day of spraying herbicides
2. no weeding - no weeding or spraying of herbicides at all
3. 2,4-D sodium at 1.8 lb a.i./ac (Bladex A at 1 kg/ac)
4. 2,4-D sodium at 3.5 lb a.i./ac (Bladex A at 2 kg/ac)
5. 2,4-D amine at 1.1 lb a.i./ac (Bladex G at 1 l./ac)
6. 2,4-D amine at 2.1 lb a.i./ac (Bladex G at 2 l./ac)

The second part of the trials was conducted in three stages, each consisting of spraying alternated with digging (to simulate tillage and induce regrowth of weeds), the spraying treatments were given as per schedule after sufficient weed growth and the trials were conducted in three stages as follows:-

Stage	Interval after digging, for weed build up	Period of weed control (regrowth less than 20%)
First stage	45 days	63 days (9 weeks)
Second stage	120 days*	70 days (10 weeks)
Third stage	40 days	84 days (12 weeks)

(* - the weed build up was delayed due to drought)

RESULTS

The final observations made on the mortality and green shoot counts are presented in the following table.

Table 1

<u>Comparative statement of green shoot counts during three stages</u>
(Expressed as % of initial population of first stage)

Treatment	FIRST STAGE Initial * count	FIRST STAGE Final count	SECOND STAGE Initial ** count	SECOND STAGE Final count	THIRD STAGE Initial *** count	THIRD STAGE Final count
handweeding (control)	100.0	110.9	112.2	112.6	57.3	103.9
no weeding	100.0	106.1	101.2	115.5	74.7	99.1
sodium 2,4-D at 1.8±	100.0	2.6	86.8	19.4	23.7	11.1
sodium 2,4-D at 3.5±	100.0	1.4	83.5	18.8	31.5	5.6
amine 2,4-D at 1.1±	100.0	3.6	73.8	18.8	24.6	3.6
amine 2,4-D at 2.1±	100.0	2.1	66.5	20.8	27.5	4.6

(± - Herbicide doses indicate lb a.i./ac)
(*,**,*** - An interval of 45 days, 120 days and 40 days were given respectively after digging, to secure a uniform weed stand for spraying)

DISCUSSION

First part of the trial The observations indicate a steady increase in weed growth, if left unchecked, recording a 66% increase over the initial stand in ten weeks; herbicides on the other hand, showed a decline in the green shoot counts. 2,4-D salts, singly and in mixture, killed the aerial shoots completely in about a fortnight, however, some new shoots developed subsequently. Amitrole was less effective than 2,4-D; furthermore it acted more slowly, taking 7 weeks to be fully effective and giving only 95% control as against the 100% kill with 2,4-D salts within a fortnight. This delayed action of amitrole also induced the uninterrupted regrowth of the weed which reached 94%, over the initial stand, compared with only 32-43% for 2,4-D.

Digging ten weeks after the herbicide treatment, helped the weed to re-establish itself; green shoot counts recorded a fortnight later (12 weeks from the start), showed regrowth of 135% in control and 89 to 91% in the herbicide treated plots. Thus the chemical not only suppresses the weed, but also causes its gradual elimination; this was exploited in the next part of the investigation which combined herbicidal and cultural treatment repeatedly.

Second part of the trial This was designed to control the weed by alternate digging and spraying. Only the sodium and amine salts of 2,4-D were used as they are (i) the cheapest in India, (ii) easily available and (iii) well tolerated by cereals as post-emergence sprays. Moreover, cereals not only permit the continued and frequent use of herbicides at regular intervals, but also have a smothering effect on weed growth (Balasubramanian and Rao, 1968).

The data presented in Table 1 suggest, that herbicides cause a spectacular reduction in the number of green shoots. The slight reductions in the other plots (handweeding and no weeding) proved to be illusory as the weed stand exceeded 100% at the end of each stage of the trial in both the treatments.

The advantages of the herbicides in keeping down the weed, could well be seen from a fortnight after spraying up to a period of 10-12 weeks during which time weed control was around 80-95%. It has been reported earlier that herbicides like 2,4-D can keep down the weed for a period of up to 10-12 weeks (Balasubramanian and Rao, 1968 and Narayanan and Meenakshisundaram, 1960), but the effect of chemicals combined with repeated digging (simulating tillage) is now presented for the first time.

A suitable combination of herbicides for post- and pre-emergence application would prove more effective not only for the control and gradual eradication of the weed but also in helping the farmer to grow cotton, the most popular crop of this locality, without the fear of the weed menace.

References

BALASUBRAMANIAN, M. and RAO, SAKHARAM J. (1968) Effects of a few herbicides on the control of Solanum elaeagnifolium Cav. a recent weed in Coimbatore district. PANS (C), 14, 282-289.

NARAYANAN, T.R. and MEENAKSHISUNDARAM, D. (1960) Chemical control of white horse-nettle (Solanum elaeagnifolium Cav.) - a new weed in South India. Proc. [illegible] Sci. Workers' Conf., Coimbatore, 1956, 75-78.

Proc. 10th Br. Weed Control Conf. 1970

SATISFACTORY CONTROL OF OROBANCHE CRENATA IN BROAD BEANS BY SOIL FUMIGATION IN THE U.A.R.

M. K. Zahran
Weed Control Research Section, Ministry of Agriculture, U.A.R.

Summary At six different sites in the U.A.R., during two successive seasons from 1968 to 1970, the effectiveness of dibromochloropropane ('Fumazone' and 'Nemagon') was investigated for the control of Orobanche in broad beans. Very satisfactory control was achieved where the above fumigants were applied at 7-11 lb per feddan (= 1.03 ac) in irrigation water, either at sowing or four weeks later. Control of broomrape resulted in very significantly increased crop yields. Sowing during November is favourable. The addition of nitrogenous fertilizer at 34 lb per feddan to the treated soil following application of the fumigant assisted growth of the crop.

INTRODUCTION

Parasitism by broomrape (Orobanche crenata) causes great reductions in the yield of broad beans (Vicia faba), the most important leguminous crop in the U.A.R.

The longevity of the seeds, their minute size and their enormous populations result in the constant appearance of the parasite throughout the growing period of the host plant. The fact that the parasite does not grow in the absence of the host plants is a further factor contributing to the difficulty of the broomrape problem.

The possible use of soil fumigants as herbicides has been reported before (Crafts & Harvey, 1955 and Dunham et al., 1956). Wilhelm et al. (1957 and 1958) showed that broomrape on tomatoes was satisfactorily controlled by fumigating the soil with methyl bromide under a plastic cover at rates above 0.5-1 lb per 100 ft^2. Dixmeras and Bouchet (1960) noted that metham gave some control of broomrape in flax but its use is not practicable. Zahran (1964) showed that metham ('Vapam') applied as a soil fumigant and sealed in by further watering controlled broomrape in broad beans but the effective rate was found to be as high as 400 lb per feddan.

The outstanding efficiency of soil fumigation by dibromochloropropane at 7-9 lb per feddan against broomrape in broad beans reported by Zahran (1969) encouraged further work. It is the purpose of the present study to report the results of trials undertaken to determine the possible use of this compound for soil fumigation against broomrape in broad bean fields.

METHOD AND MATERIALS

The present work was carried out during two successive seasons from 1968 to 1970 comprising six trials laid down in fields that were infested with broomrape seeds at six different sites in the U.A.R. viz., Giza, Sakha, Sids, Shandaweel, Abnoub and Dircut. At the first four sites treatments were replicated four or five times at random with a plot size of 1/200 feddan. At the other two sites, trials were undertaken as demonstration applications including non-replicated treatments with a plot size of 1/10 feddan. Throughout, broad bean seeds variety Giza 2 were used. Sowing dates fell during November at all sites.

The chemical 1,2-dibromo-3-chloropropane was used as 'Fumazone' 47.6% e.c. or 'Nemagon' 75% e.c. at rates of 7-11 lb a.i. per feddan. The pre-planting treatment, where included, was carried out by spraying the diluted fumigant with a knapsack sprayer with immediate incorporation by hand-hoeing. The application in irrigation water either at sowing or four weeks later was conducted by continuous metering of the fumigant into the irrigation channel.

Data were statistically analysed except where the difference was otherwise perfectly obvious.

RESULTS

At both Giza and Sakha, the crop yield was not measured and only broomrape control was determined. The host plants were removed from the plots at different times and tested for the development of the parasitic plants and nodulation on the roots.

The visual observation indicated that dibromochloropropane at 7 and 9 lb per feddan either at the time of sowing, or four weeks later, resulted in almost complete control of broomrape. Nodulation was found to be affected especially where the application took place four weeks after sowing.

The addition of nitrogenous fertilizer at 34 lb nitrogen per feddan assisted the growth of the host plants and compensated for the influence of the fumigant on nodulation.

Data obtained from Sids trial are presented in Table 1.

The best control of broomrape was obtained when 'Fumazone' was used in the irrigation water. This procedure was greatly superior to both the control and the pre-planting treatment. The rates as well as the times of application did not differ significantly from each other. Beans developed significantly better when the fumigant was applied with the irrigation; the final crop yield followed the same course. The pre-planting (incorporated) treatment appeared to be inferior to the treatment in the irrigation water in all respects.

Results from the Shandaweel trial are shown in Table 2.

It is clear that dibromochloropropane gave very satisfactory control of broomrape and soil fumigation increased the yield of broad beans. There was no significant difference between the chemical treatments and both were significantly better than the control.

The percentage broomrape control and the yield of broad beans in the demonstration applications at Abnoub and Dirout are presented in Table 3.

Clearly, soil fumigation with dibromochloropropane satisfactorily controlled broomrape and increased the crop yield. The higher of the two rates (9 lb/feddan) was the more effective against broomrape and resulted in the greater increase in the yield.

DISCUSSION

Throughout the present investigation, the beneficial effect of soil fumigation was clearly evident. Very satisfactory broomrape control was obtained and significant increases in crop yield were gained. Broomrape seeds may also have been killed by soil fumigation. Ahlgren et al. (1951) reported that because of their volatile nature, soil fumigants are potentially one of the most practicable means for killing weed seeds, however, Ciccarone et al. (1962) pointed out that 'Nemagon' at 2.2-2.6 ml/m^2 appeared merely to delay germination of broomrape.

The best way to use dibromochloropropane is to apply 7-11 lb/feddan in the irrigation water either at sowing or four weeks later. As nodulation of broad bean roots may be affected it seems advisable to add a nitrogenous fertilizer to the previously fumigated soil to assist crop growth and to counteract the chemical effect of the fumigant.

On the basis of the present result, the use of dibromochloropropane should be widely extended.

References

AHLGREN, G.H., KLINGMAN, G.C. and WOLF, D.E. (1951) Principles of Weed Control. John Wiley & Sons, Inc., New York, pp.368.

CICCARONE, A., PIGLIONICA, V. and ELIA, M. (1962) Chemical control of Orobanche. Italia agric., 99, 925-41.

CRAFTS, A.S. and HARVEY, W.A. (1955) Weed control by soil sterilization. Ext. Serv. Circ. Calif. Exp. Stn, 446, 9-10.

DIXMERAS, J. and BOUCHET, J. (1960) A parasite of flax - broomrape. Phytoma, 117, 39-44.

DUNHAM, R.S., NYLUND, R.E., HANSEN, H.L. and JENSEN, E.H. (1956) Cultural and chemical weed control in Minnesota. Agric. Ext. Serv. Ext. Folder Univ. Minnesota, 191, 17.

WILHELM, S., BENSON, L.C. and SAGAN, J.E. (1957) Methyl bromide gives promising control of broomrape. Phytopathology, 47, 537-8.

WILHELM, S., BENSON, L.C. and SAGAN, J.E. (1958) Studies on the control of broomrape on tomatoes. Soil fumigation by methyl bromide is a promising control. Pl. Dis. Reptr, 42, 645-51.

ZAHRAN, M.K. (1964) Further studies on the control of Orobanche on horse bean plant. Ph.D. Thesis, Cairo Univ.

ZAHRAN, M.K. (1969) The solution of broomrape problem. 1st Arabic Conference for Physiological Sciences, 22-27 February, 1969.

Table 1

Effect of 'Fumazone' on broomrape and broad bean plants at Sids

Treatment / Rate (lb/feddan)	Pre-planting 9	Pre-planting 11	At sowing 9	At sowing 11	4 weeks after sowing 9	4 weeks after sowing 11	Control 0	L.S.D. (a)5%	L.S.D. (b)1%
Broomrape								a	b
% Parasitism*	63.3	56.5	9.8	10.9	8.4	4.5	73.1	10.4	14.2
Mean	59.9		10.35		6.45			7.35	10.06
No.of plants/plot	116	133	15	21	12	11	184	40	55
Mean	124.5		18.0		11.5			28.6	39.2
Wt.of plants(g)/plot	1466	1378	193	191	181	155	1580	430	589
Mean	1422		192		168			304	416
Broad bean									
No.of branches/plant	1.5	1.6	1.8	2.1	1.5	1.2	1.8	N.S.	N.S.
Mean	1.55		1.95		1.35			N.S.	N.S.
Wt.of tops(g)/plant	43.5	48.1	96.7	81.6	92.8	64.1	41.2	31.4	43.0
Mean	45.8		89.15		78.45			22.21	30.43
No.of pods/plant	9.1	7.1	16.1	15.9	14.3	11.3	4.8	6.4	8.8
Mean	8.1		16.0		12.8			4.54	6.23
Wt.of pods(g)/plant	43.7	48.2	129.9	121.0	116.6	77.8	32.9	36.7	50.3
Mean	45.94		125.43		97.2			25.97	35.57
Wt.of seeds(g)/plant	25.2	30.0	69.4	67.4	54.8	43.3	20.8	20.4	27.8
Mean	27.6		68.4		47.05			14.45	19.8
Yield (ardab)/feddan**	3.91	3.5	5.35	5.04	4.89	4.47	2.82	0.88	1.16
Mean	3.71		5.2		4.68			0.62	0.85

* % Parasitism = % infested host plants

** Ardab = 341 lb   Feddan = 1.03 ac

Table 2

Effect of dibromochloropropane on broomrape control (%) and broad bean yield (ardab/feddan) at Shandaweel

Treatment	At sowing		4 weeks after sowing	
	% Control	Yield	% Control	Yield
'Fumazone'				
9 lb/feddan	96.5	5.97	99.1	5.54
11 lb/feddan	99.1	6.03	96.7	6.07
'Nemagon'				
9 lb/feddan	96.7	5.90	97.9	5.69
11 lb/feddan	98.1	5.55	97.6	6.18
Control	0	2.40	0	

L.S.D. (5%) for yield = 1.00

Table 3

Effect of dibromochloropropane on broomrape control (%) and broad bean yield (ardab/feddan) at Abnoub and Dirout

Treatment	At Abnoub		At Dirout	
	% Control	Yield	% Control	Yield
'Fumazone'				
7 lb/feddan	75.9	7.63	75.5	5.38
9 lb/feddan	80.3	8.15	82.6	5.48
'Nemagon'				
7 lb/feddan	85.2	7.71	86.9	5.61
9 lb/feddan	84.0	8.02	83.3	5.95
Control	0	5.80	0	4.43

Proc. 10th Br. Weed Control Conf.1970

HERBICIDE DEVELOPMENT IN PEASANT FARMING AREAS

C. Sharman
Group Conservation & Extension Officer, Dept. of
Conservation & Extension, P.O.Box 191, Sinoia, Rhodesia

Summary The increase in the acreage of cash crops grown on peasant farms in Rhodesia has led to a number of problems. One of the greatest is weed control. This paper discusses the initial introduction of a herbicide into these areas with particular reference to the practical problems met in the field.

INTRODUCTION

There are two broad types of African farming in Rhodesia. Farmers cultivating communal land, crop from 3 - 6 ha on a subsistence basis while on farms that are individually owned or leased, 10 - 20 ha of crop are commonly grown. These areas are farmed in a peasant manner in that a proportion of the crops is for domestic use, while the remainder is sold.

Farming systems in peasant farming areas have, in recent years swung away from the traditional maize, groundnut and rapoko (Eleusine corocana) rotations and now include substantial acreages of cotton and burley tobacco. This change has raised problems, one of the greatest being that of weed control. A small number of farmers operate tractors but weeding is normally carried out by hand or with single row ox-drawn cultivators. Particularly in wet years, the labour available cannot cope with the increased acreage under cultivation and while the maize crop is seldom neglected, cotton and burley tobacco often suffer.

A suitable power source is a necessity for the application of herbicides and since cotton is now widely grown, a cotton spray pump, invariably a knapsack sprayer, is available on the majority of farms. Consideration was therefore given to using atrazine on the maize crop which, if successful, would permit labour to concentrate on hand cultivation of the other and more profitable crops.

Simple calculation showed that a single knapsack sprayer with a lance attachment would be satisfactory where only 2-3 ha were concerned, but since many growers have areas of between 6-12 ha of maize some other method had therefore to be found.

A number of factors had to be considered. These were that no more than two days should be spent on herbicide applications, thereby allowing for a daily area of about 3-6 ha to be covered, remembering that the labour must come from within the average family unit of 3 adults and 3 children. However, two farmers might co-operate thereby increasing the labour available. The machinery costs excluding spray-pump or pumps should not exceed $60 (£35 sterling) to keep it within the financial reach of the farmers it was designed to serve. Furthermore, the operation of the equipment had to be relatively simple and capable of being used efficiently by these farmers. Finally, the application of any weedkiller had to comply with the agronomy extension programme and should not conflict with it.

METHODS

Equipment Design

Since they are the most common form of transport in the areas concerned, it was suggested that spray-pumps should be mounted on ox-drawn two-wheel carts with a boom fixed at the rear end. This was found to work very satisfactorily although the variation in pace of the oxen could be a problem, particularly with regard to over applications of herbicide and subsequent residues. Herbicides of short persistence and high crop tolerance would reduce this risk but, in practice to date, the problem has not arisen. The speed of the oxen has proved fairly consistent provided they are changed at mid-day.

One major problem was foreseen in that during turning, the booms would drain out and herbicide would be lost on the headlands resulting in poor cover in the first few metres of the new run. This was effectively and cheaply solved by hinging the vertical straps that hold the boom on the cart. On arrival at the headland the boom would then be turned upwards so that the nozzles lay above the spray liquid in the sprayer.

Hand-held booms were specially constructed to cover 2.7 and 3.6 metre swathe widths and these were estimated to give an output of up to 5 ha per day.

Hand-held lances were also supplied to be used by the smaller grower applying a band cover over the maize rows.

Finally, a conventional tractor-mounted sprayer was to be demonstrated to illustrate the type of unit that could be used if the farmer owned a tractor.

Training and Selection

Since this was a demonstration new to them and the equipment untried, it was decided that farmers who were prepared to co-operate should pay for the herbicide only and not for its application. The equipment which was demonstrated in each area aroused much interest. It was a simple matter to find the 170 ha to be sprayed and the farmers took it on trust that the herbicide would work even although they found it difficult to imagine how this could be.

Farmers who were not credit-worthy were, of course, not selected. It was made clear that this was a pre-emergent weedkiller and that it should only be applied to an early crop. Although this might seem an arbitrary decision, it was considered that morally, a practice that would raise costs should not be demonstrated unless it could also provide a reasonable chance of raising yields. The possibility that the herbicide might be used on a late December planted crop having a very low yield potential was a cause for concern.

Application

The rains in the 1969-70 season occurred a clear three weeks before normal and the timing of the trial was thus upset. Only half the expected area was covered, about 85 ha in all. This was quite sufficient however, and enabled the practical advantages and disadvantages of each unit to be observed.

RESULTS

1. Cotton-sprayer with lance attachment:

The hand-operated lance gave a reasonable band cover over a single row. The lance proved a simple and effective means of applying a good cover to a relatively small area of say four ha or less. However, the problem common to all band applications did arise in that weed infested soil was thrown on to the weed free area while cultivating later in the season.

2. Tractor-mounted sprayer:

Owing to a lack of water bowsers it was found that refilling was a long and tedious business and for this reason, the tractor-operated sprayer was surprisingly inefficient. Furthermore, long runs were uncommon and turning occupied a high proportion of time. Nevertheless, the tractor owners on whose farms the machine worked could see that this fitted in well with their acreages. Where this type of machine is used one can foresee contract use on other farms.

3. Hand-held boom:

Two hand models were tested, one having eight nozzles and the other six spaced 45 cms apart. The weight of the water contained in the boom tended to bend the longer one in the middle and it proved clumsy to operate and difficult to negotiate around obstacles. The six nozzle boom, however, was relatively cheap and easy to operate but heavy to carry and required frequent refilling. The daily output was therefore rather low and operators rested frequently whilst refilling which reduced output still further. Since the output is not likely to be much greater than four ha per day this adaptation is likely to be of more use on smaller farms.

4. Ox-drawn cart with boom:

This unit has the natural advantage over the very tiring hand operated boom in that the weight is carried on wheels and traction is provided by oxen. In view of the refilling problem encountered, which in fact proved to be worse than anticipated, it was decided that a 200 litre drum mounted in the cart would enable the knapsack sprayers to be refilled whilst on the move and this proved to be very successful.

Two men operating two cotton spray-pumps mounted on a simple plank fixed across the cart can achieve 40 p.s.i. pressure within 45 seconds. After moving off one operator can maintain this pressure easily whilst the other operator refills the spray-pumps. A hand-operated diaphragm pump was tested as a means of refilling the sprayers from a 200 litre drum but was found to be inefficient. However, a wing pump with a hose leading to the spray-pumps will probably enable quick refilling and permit one ha to be completed before stopping to refill the 200 litre drum. If the pump is a good one, it can also be used to lift the mixed atrazine from the ground into the mounted drum and eliminate splashing which can be a problem.

Since the atrazine is a wettable powder, the problem of keeping it in suspension is provided for in conventional spraying machines by built-in agitators. This is not the case in the oil drums used in these trials, although the bumping and rocking of the scotch-cart as it moved across the land appeared to keep the atrazine in suspension. Situations can be visualised however, in which settling could occur.

The ox-drawn cart will complete 5-6 ha per day or more relatively easily. It therefore complies with the criteria laid down and can be fully recommended. One can even envisage this equipment being used by owners of tractors as the capital cost is low.

Problems for the future

Thorough cleaning of equipment with a detergent was insisted upon and no damage to other crops was observed. This is seen,however, as a potential problem.

Farmers sometimes have difficulty in achieving the correct fineness of tilth which is essential if herbicides are to be used. This is in many cases due to the fact that only primitive tillage equipment is available.

Refilling is a major obstacle and is likely to remain so since the essentially simple equipment found on peasant farms makes an easy solution unlikely where a spraying technique is used. Although usually higher priced, granular herbicides would appear to have a place in peasant agriculture as simpler techniques of application may be possible.

The major problem however is likely to remain that of when the atrazine should be applied. The farmers do understand the nature of a planting rain and if application is related to a dry-planted crop after or during a planting rain, this problem may not be as considerable as it now seems.

Following the success of this initial scheme, demands for atrazine are likely to exceed the ability of staff to supervise its application. This supervision at this stage is thought to be essential.

Acknowledgements

The writer acknowledges the assistance given in this exercise by commercial organisations and officers of the Departments of Conservation and Extension and of Research and Specialist Services in the Rhodesian Ministry of Agriculture.

Proc. 10th Br. Weed Control Conf. 1970

AN APPROACH TO THE CONTROL OF ROTTBOELLIA EXALTATA IN MAIZE

P.V.M. Richards and P.E.L. Thomas
Weed Research Unit, Department of Research & Specialist Services,
Henderson Research Station, P. Bag 222A, Salisbury, Rhodesia.

Summary Results of maize herbicide experiments done over a three-year period indicate that with the presently-available, pre-emergent, selective herbicides, control of R. exaltata in maize is unlikely. Competition studies have shown that light infestations of R. exaltata seriously reduce maize grain yields. Trifluralin as a pre-plant, soil-incorporated herbicide has been used in maize crop trials at low rates and while control of R. exaltata was achieved, in a season which commenced with cool moist weather, crop damage was recorded, resulting in a significant reduction in grain yield. Results are also reported of effects of applied trifluralin as a band between crop rows.

A systematic approach to the control of R. exaltata in maize is suggested. This includes the rotation of the maize with other crops to which herbicides of the aniline group are selective and measures for prevention of reinfestation. In this latter regard R. exaltata shows a lack of persistence in the soil. The banded application of herbicides of the aniline group in the between-row area of maize is also suggested as an aid to control.

INTRODUCTION

The major food crop grown in Rhodesia is maize and with the use of hybrid cultivars and high standards of agronomic practice, yields have increased markedly over the last decade. The soils in the main maize producing areas are generally heavy-textured, but a large acreage is also grown on sandy soils with clay contents of less than 10%. Chemical weed control is now common practice on many farms and while some 2,4-D is used, reliance is mainly on atrazine, in many cases applied from aircraft. Until 1969 the use of herbicides had been limited to the larger farms but last season atrazine was used by a number of small farmers and peasant producers.

In Rhodesia the weed problem in maize is similar to that of cotton (Richards and van Lindert, 1968). One grass in particular has proved difficult to control with the selective maize herbicides at present available. This grass, Rottboellia exaltata has the capability, similar to that of maize, of hydrolising atrazine and simazine, and many other herbicides show little selectivity between it and maize. In one area of the country Panicum maximum is also proving resistant to maize herbicides but to date no problems have been experienced with other grass species.

R. exaltata is increasing, particularly in rotations in which maize is the most common crop. Populations can be reduced in crops other than maize by using herbicides of the aniline group but they may again increase rapidly under the maize, unless weed removal is complete.

Experiments on maize done by the Weed Research Unit over the last few years have been aimed mainly at the control of triazine-resistant grasses, and R. exaltata in particular. Studies have also been conducted on the biology of R. exaltata and its competitive effects in maize. This paper deals with the results of the investigations over three years into chemical weed control of R. exaltata and of one season's work on competition between maize and R. exaltata. All experiments were carried out on a clay loam soil, low in organic matter, but containing approximately 50% clay.

METHODS

Chemical weed control experiments

While the main objective of these experiments was to study crop-tolerance to the herbicide applied, weed control was measured by counting and weighing surviving weeds. Uniform rates of seed of R. exaltata were sown on all plots prior to the establishment of the experiments. The first trial, reported in this paper (1967/68 season), was designed as a randomised block and a hand-weeded control was compared with various herbicide treatments which were also hand-weeded when and if necessary. In 1968/69 and 1969/70 the design was changed to include 3 subplots within each main plot. Subplot treatments were as follows :

1. No herbicide. Weeds removed, counted and weighed before competing with the crop.
2. Herbicide treatment applied followed by weed removal, counting and weighing at the same time as in No.1 above.
3. Herbicide treatment applied followed by weed removal, counting and weighing at crop harvest.

In all the experiments there were 4 replications of each treatment.

Unless otherwise stated in the tables, the following herbicides were applied pre-emergent :- atrazine, simazine, alachlor(CP50144), fluorodifen, MCPA, ametryne, chlorfenac, while trifluralin was applied pre-planting and soil-incorporated.

Competition Experiments

Four experiments with hybrid maize and R. exaltata were done during the 1969/70 season. The main aim of these experiments was to measure :

1. Effects of timing of weed introduction or removal.
2. Interactions between crop populations, weed populations and nitrogen levels. In this section two experiments were carried out one with and one without irrigation.
3. Effects of crop and weed arrangement and fertilizer placement on growth and yield of maize and R. exaltata.

RESULTS

Chemical weed control experiments

In the 1967/68 maize experiment (Table 1) all plots were handweeded as necessary. Trifluralin at a low rate, was included as a treatment in combination with a rate of atrazine reduced from that normally applied on this soil type. Maize was planted at approximately 4 cm deep in the trials and at this depth of planting, the treatment showed good control of R. exaltata with limited damage to the maize. Unreported work by the Weed Research Unit, has however, indicated that deep germinating monocots were controlled better than shallow germinating monocots by low rates of trifluralin. To confirm this observation, a trifluralin treatment was included on maize planted 8 cm deep. The number of maize plants which survived expressed as a percentage of maize planted is shown in Table 1. This confirms the suspected risks of deep planting on the crop. As the trials were planted at twice the planned final population and thinned to a standard at a later date, deep planting did not result in significantly lower yields. Marked reduction in vigour of R. exaltata was recorded from Treatment 7, a tank-mix of atrazine and simazine, but this result was not reproducible in later work. Broadleaved weeds were well controlled by all treatments except trifluralin + MCPA while fluorodifen did not give satisfactory control of Bidens pilosa.

Table 1

Maize Herbicide Experiment 1967/68. Yields of maize grain and counts of R. exaltata

Herbicide treatment	Rate a.i. kg/ha	Yield of grain kg/ha	Number of survivors R.exaltata per m^2 at 1st weeding	% Maize stand counts: Before thinning to standard	At harvest
1. Atrazine	2.24	6910	38.8	90.4	94.2
2. Trifluralin Atrazine	0.56 1.12	5960	1.4	82.5	89.6
3. Trifluralin MCPA	0.56 2.24	6320	0.8	84.2	89.2
4. Trifluralin Atrazine maize planted at 8 cm depth	0.56 1.12	6140	1.3	54.2	87.1
5. Atrazine	1.12	6970	30.6	90.8	97.9
6. Atrazine Chlorfenac	1.12 0.22	7490	41.3	90.8	99.2
7. Atrazine Simazine	1.12 1.12	6550	38.6	92.1	95.0
8. Atrazine Ametryne	1.12 1.12	6500	40.0	87.9	98.4
9. Fluorodifen	4.48	6950	3.8	90.4	96.7
10. Handweeding only	-	6430	33.3	90.0	99.2
S.E.$\pm$		567		2.6	

The 1968/69 season (Table 2) commenced with a long wet spell and unusually low temperatures. As a result trifluralin proved more phytotoxic to the maize crop than in previous seasons and the final harvest yield of grain where surviving weeds were removed was significantly lower than that of the control. Of particular interest was the effect on final yield of a directed post-emergent herbicide mixture, which efficiently controlled R. exaltata. The counts of R. exaltata recorded in the table were made, however, prior to the application of the mixture (linuron + MSMA - unsuitable for use in maize but effective on R. exaltata). Other treatments which reduced the populations of R. exaltata were incorporated simazine, fluorodifen and a tank mix of atrazine and alachlor. The surviving populations still however competed seriously with the maize as is shown by the grain yield figures. Broadleaved weed control was satisfactory but fluorodifen again failed to control B.pilosa.

Table 2

Maize Herbicide Experiment 1968/69. Yields of maize grain and counts of R. exaltata

Herbicide treatment	Rate a.i. kg/ha	Yield of Grain kg/ha		Numbers of survivors R.exaltata per m^2 at 1st weeding	% Maize stand count at harvest
		Weeded	Not weeded		
1. Atrazine	2.24	13000	9980	19.2	94.9
2. Trifluralin	0.56	11700	9600	0.9	87.1
Atrazine	1.12				
3. Atrazine	1.12	13000	9640	25.3	104.3
Simazine	1.12				
4. Fluorodifen	4.48	14300	9530	15.2	103.1
5. Simazine	2.24	13800	9100	23.3	101.2
6. Simazine, pre-plant incorporated	2.24	12700	8990	13.2	93.4
7. Atrazine	1.12	12500	9370	14.6	100.0
Alachlor	1.68				
8. Atrazine	1.12	12600	9980	22.2	94.1
Prometryne post-emergent, directed	1.12				
9. Atrazine	1.12	13000	9730	26.7	95.7
Linuron post-emergent, directed	1.12				
10. Herbicide mixture post-emergent directed		12500	12500	18.7	92.2
11. Handweeded only		13600	-	21.8	97.9
S.E.± Handweeded only vs other treatment means		564	-	-	3.46

While trifluralin had shown promising selectivity in maize, it was obvious that adverse weather conditions in the early developmental stages of the crop (Table 2) could result in serious crop damage. A treatment was therefore included in the 1969/70 experiment (Table 3) where trifluralin was banded in the 'between row' area leaving a 15 cm untreated strip for the crop row. The planting technique used in this treatment attracted field rats which caused a reduction in stand counts on all three subplots. Trifluralin as a full cover spray did not seriously reduce initial stands of maize and broadleaved weeds were again well controlled except in the case of fluorodifen which failed to control *Acanthospermum hispidum*.

Table 3

Maize Herbicide Experiment 1969/70. Yields of maize grain and counts of R. exaltata

Herbicide treatment	Rate a.i. kg/ha	Yield of grain kg/ha Weeded	Yield of grain kg/ha Not weeded	Numbers of survivors R.exaltata per m² at 1st and only weeding	% Maize stand count at harvest No herbicide	% Maize stand count at harvest herbicide
1. Atrazine	2.24	7890	7050	8.7	95.3	95.7
2. Trifluralin Atrazine	0.56 1.12	8450	8030	1.1	96.1	90.1
3. Trifluralin in 'between row' area Atrazine	0.99 1.12	8500	7800	1.0	90.9	89.2
4. Fluorodifen	4.48	7650	8310	4.1	96.6	96.1
5. Atrazine Alachlor	0.67 1.68	8400	7330	7.7	94.8	97.8
6. Atrazine Paraquat tank mix, post-emergent, directed	1.12	7990	8080	7.8	95.7	91.4
7. Handweeded only		8570	-	7.1	94.9	-
S.E.± Handweeded only vs other treatment means		359	-	-	1.92	-

Competition experiments

In competition studies during the 1969/70 summer season it was shown that R. exaltata sown 2 weeks (or later) after maize emergence did not influence the final crop yield. On the other hand, R. exaltata which grew in maize for the first 8 weeks only of the season did not influence yield while that which competed for 12 weeks or longer from the start significantly reduced maize grain yields, yield per cob, cobs per stem, shelling %, and maize stem diameter. This last effect resulted in more lodging of maize.

As R. exaltata populations increased in maize then grain yields were reduced, the main effect being due to reduction in the number of cobs and average weight of these cobs. The results from an irrigated and non-irrigated experiment are shown in Table 4.

Table 4

Grain yield of irrigated and non-irrigated maize as influenced by R. exaltata population

Number of R. exaltata plants/m²	Grain yield (kg/ha) Irrigated	Grain yield (kg/ha) non-irrigated
0	8440	4856
13	6771	3239
50	5497	2591
142	3228	1393

In a plant arrangement by fertilizer placement experiment the only factor to affect maize grain yield was weed arrangement (Table 5).

Table 5

The effect of weed arrangement and fertilizer placement on maize grain yield (kg/ha)

Weed arrangement	Fertilizer broadcast	Fertilizer placed	Mean
No *R. exaltata*	6885	7531	7208
In row *R. exaltata*	6150	6239	6194
Between row *R. exaltata*	6094	6328	6211
In + between row *R. exaltata*	5771	5392	5581
Mean	6225	6372	6229

There was no significant interaction between weed arrangement and fertilizer placement. However, the trend was for placed fertilizer to favour maize which had between-row *R. exaltata* and for broadcast fertilizer to favour maize with in-row *R. exaltata*. The effect of these treatments on *R. exaltata* are shown in Table 6.

Table 6

R. exaltata numbers and dry matter weights as influenced by weed arrangement and fertilizer placement

Weed arrangement	kg dry weight/ha			Plants/m^2		
	Broadcast	Placed	Mean	Broadcast	Placed	Mean
In row *R. exaltata*	1617	2162	1889	5.9	4.6	5.2
Between row *R. exaltata*	2689	1072	1880	7.2	4.4	5.8
In + between row *R. exaltata*	2794	2408	2601	9.7	8.4	9.1
Mean	2367	1880	2123	7.6	5.8	6.7

Fertilizer placement significantly influenced dry matter weight and plant numbers (p 0.01); dry weight interactions were significant at p 0.01 and weed arrangement effects on dry weight and numbers were significant at the 5% level of probability.

Placed fertilizer reduced between-row dry weights while broadcast fertilizer reduced within-row *R. exaltata* weights.

Table 7 combines the results of chemical weed control experiments with competition experiments and gives a comparison of the yield reductions brought about by various infestations of *R. exaltata*.

Table 7

Comparison of maize grain yields with numbers and weights of surviving *R. exaltata* plants

Experiment	Grain yield in kg/ha		% Yield reduct-	*R. exaltata*	
	R. exaltata absent	*R. exaltata* present		Plants/ m^2	Dry weight kg/ha
Maize, herbicide Expt. 1969/70	8450	8030	5.0	1.0	440
Maize herbicide Expt. 1969/70	7890	7050	10.6	8.2	3000
Maize, *R. exaltata* placement Expt. 1969/70	6885	5771	16.2	9.7	2790
Maize herbicide Expt. 1968/69	13000	9980	24.0	12.4	6500
Maize, *R. exaltata* competition Expt. 1969/70	7870	4335	44.9	35.5	3320

DISCUSSION

In practice, *R. exaltata* in a maize crop is relatively easy to control by mechanical means if the weather is suitable. Seedlings of *R. exaltata* usually emerge before or at the same time as the maize but as the majority of these seedlings emerge from depth, they cannot be removed by shallow cultivation. This shallow cultivation on Rhodesian farms is often done by fast-operating, comparatively light, rotary cultivators and while these machines are very effective against the majority of local weeds if used at the right time, they are ineffective against any plants of *R. exaltata* which germinate from below 1-2 cm depth (about 77%, Thomas, 1970a). *R. exaltata* must therefore be removed by heavier equipment such as tined cultivators operating at a much slower speed. The weed infests only the heavy soil areas of Rhodesia, (Thomas, 1970b) and any prolonged wet weather precludes mechanical cultivation. It is under these circumstances that the weed is most troublesome.

While *R. exaltata* is susceptible to a number of post-emergent herbicides, its rate of growth is only slightly less than that of maize and complete reliance on the use of post-emergent herbicides is therefore risky. Under adverse climatic conditions, means of application can present serious problems.

The results of the various herbicide trials reported in this paper indicate that, with the selective maize-herbicides at present available, acceptable control is unlikely and that the probable solution lies in the systematic approach. This will entail exploiting apparent weaknesses in the biology of the weed. The two main points of attack would be its lack of persistence in the soil in the absence of further seed infestation (Thomas, 1970a) and, because of its annual nature, its susceptibility to herbicides of the aniline group. Rotations of maize with crops to which herbicides of the aniline group may be applied, e.g. cotton, groundnuts and soyabeans reduce infestations drastically. Some attempt has also to be made to facilitate the control of the weed in maize crops and the use of an aniline herbicide in the 'between row' area of maize is now being studied both experimentally and on a field scale.

The use of low rates of trifluralin as a full cover spray has been investigated and provided maize is planted at seed rates higher than normal and not too deep, the results are promising. However, as a general practice this technique cannot be recommended owing to the potential crop damage that may arise in cool wet weather, e.g. in 1968/69 (Table 2).

Minimum tillage techniques may also possibly be exploited to reduce reinfestation of arable areas. Within a rotation, reinfestation is most likely through the maize crop and in this case a non-ploughing technique should minimize seed burial.

Although persistence of R. exaltata seed in the cultivated depth of the soil appears shortlived, cases have been recorded when unusually deep ploughing has exposed further seed which has lain dormant for a number of years. This operation, if necessary, should obviously take place at the start of a systematic attempt to eradicate or reduce R. exaltata.

Other areas of potential reinfestation have also to be considered. R. exaltata does appear in non-arable situations and these areas, if in close proximity to arable areas must be mown although minor movement of seed will take place via wild life (Thomas,1970a) and possibly wind.

Finally in this systematic approach, success also depends upon careful removal of the few surviving plants of R. exaltata as large number of seeds can be produced by a single plant. Schwerzel (1967) reported that up to 4,400 viable seeds were produced by one plant.

Acknowledgements

The assistance of colleagues on the Weed Research Unit at Henderson Research Station is gratefully acknowledged. Thanks are due also to Dr. R.C. Elliott, Officer in Charge, and other members of staff at the Henderson Research Station for their advice and assistance in the preparation of this paper.

References

RICHARDS, P.V.M. and VAN LINDERT, H.J.A. (1968) Weed Control in Cotton Proc. 9th Br. Weed Control Conf. 1968., 2, 701-706

SCHWERZEL, P.J. (1967) Seed production of some common Rhodesian weeds. PANS (C) 13, 215-217

THOMAS, P.E.L. (1970a) A study of the biology of Rottboellia exaltata Linn.F Proc. 10th Br. Weed Control Conf. 1970. In press

THOMAS, P.E.L. (1970b) A survey of the weeds of arable lands in Rhodesia Rhod. agric. J., Bul. No.2542

INFLUENCE OF WEED GROWTH ON COTTON YIELDS AND WEEDING TIME BASED ON EXPERIMENTS AT GALOLE IN EASTERN KENYA

A. H. Druijff and G. J. Kerkhoven
Time and motion expert and agronomist, respectively,
International Land Development Consultants N. V. (ILACO),
P. O. B. 33, Arnhem, the Netherlands

Summary Weed growth varying between 0 and 11 tons fresh weeds reduced yields from 2400 to 170 lb seed-cotton per acre.
Delaying the crucial first weeding from 10 to 30 days increased the labour requirement from 25 to 100 hours and for following weedings from 15 to 50 hours per acre.

INTRODUCTION

Experiments were conducted to study the effects of weed competition on the yield of irrigated cotton in Galole in Eastern Kenya over the period March to July 1968. It was also intended to investigate whether the weeds showed certain growth characteristics from which could be deducted the most effective methods of weed control. This is of vital importance as weeds are one of the major limiting factors in growing cotton.

The first weeds to appear after irrigation and before the rains begin are Cyperus spp. with C. rotundus predominating. After the first rains drought-resistant weeds germinate, such as Aristida, Brachiaria, Chloris, Cynodon, Dactylotenium, Echinochloa, Eleusine, Eragrostis, Setaria and Sporobolus. Later in the season Amaranthus, Malvaceae and Sonchus appear.

The effect of weed competition was clearly illustrated during previous experiments in this area (see Table 1). In considering these figures it must be borne in mind that the weediest plots were never weeded at all.

Table 1

Fresh weight of weeds in tons/acre	Yields of seed-cotton in lb/acre
0	2,400
1.6	2,050
4.0	1,140
6.0	730
8.0	210
11.0	170

In the experiments described in this paper weed competition was only light.

LAYOUT OF EXPERIMENTS

The cotton used in this experiment was Albar 59 240, planted at intervals of 30 cm on ridges 1 m apart on the following dates: 4/3, 12/3, 18/3 and 25/3 1968.

The weeding treatments after each time of planting were:

A. weeding after 1 week and then every 2 weeks
B. weeding after 2 weeks and then every 2 weeks
C. weeding after 4 weeks and then every 3 weeks
D. weeding after 5 weeks and then every 4 weeks.

Mechanical weeding was carried out on some plots with a Dutch hoe. The efficiency of the Dutch hoe compared to the jembe formerly used locally is discussed in detail in another paper also presented at this conference. To determine the times needed for weeding, a time and motion study was conducted giving precise figures not influenced by climate, working pace and workers' rest times.

Prior to each weeding weed growth was measured by the number, weight, height, age and cover of the weeds.

RESULTS

Analysing the relations between the treatments A, B, C and D and the corresponding yields it became evident that there was a decrease in yields (see Table 2) which should be avoided if possible. This Table also includes the total amounts of weeds removed during the experiments.

Table 2

Treatment	Yield in lb/acre	Weeds in tons per acre
A	2,403	0.6
B	2,350	1.2
C	2,287	3.1
D	2,121	4.3

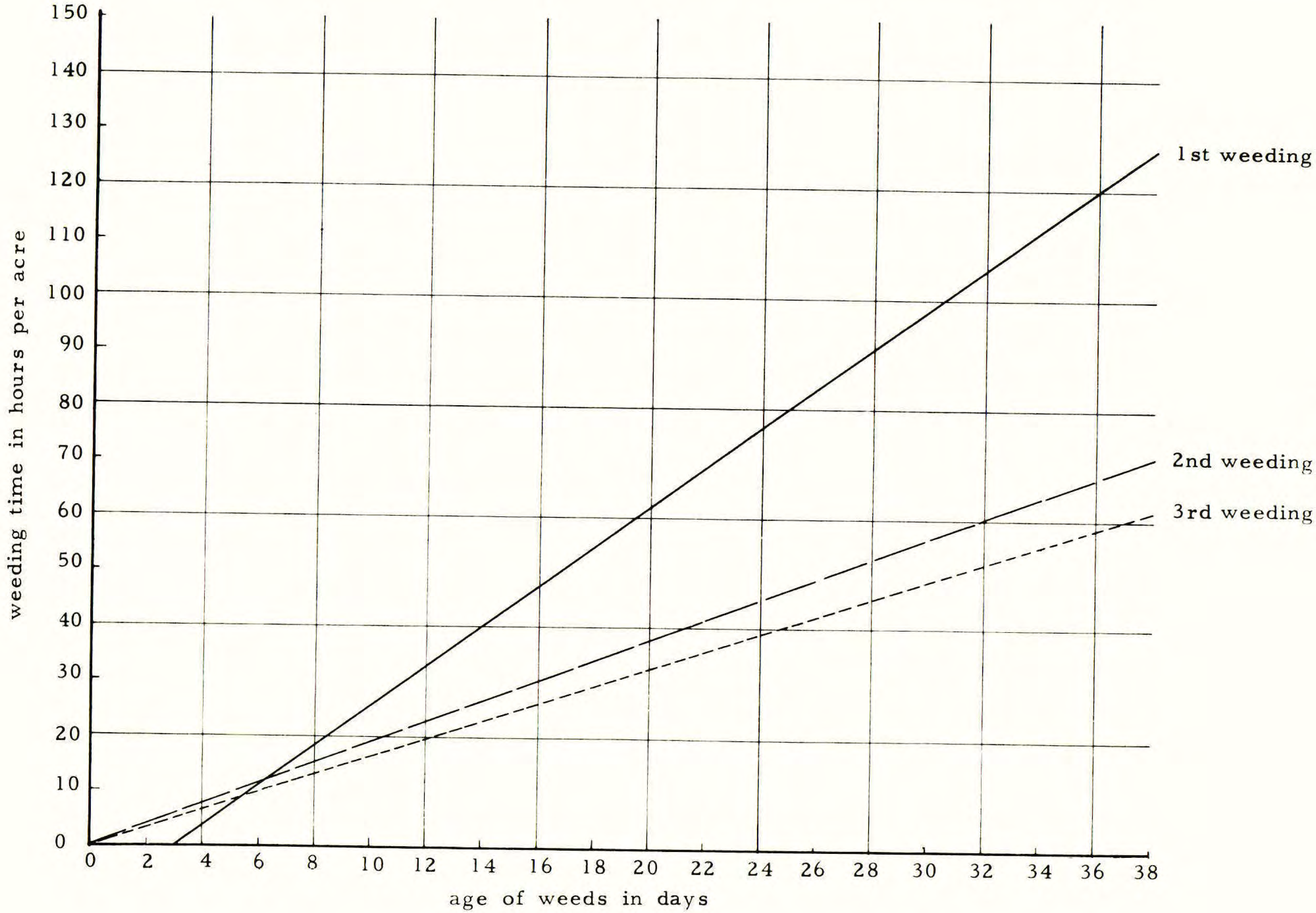
As the weeding operation has as its limiting factor the amount of labour involved it is essential to find a relation connecting the amount of weeds with the labour needed.

Through calculations with a computer it was evident that the best correlation was between weeding time and the age of the weeds, this was fortunate as this was the easiest to organise in the field. It also appeared there was a difference in correlation between the first, second and third weedings as is shown in Graph 1.

Full details of these experiments are described in the Final Report on Studies on Working Methods in the Cultivation of Cotton at Galole.

DISCUSSION

The Graph shows that it is essential to have the first weeding done as soon as possible after planting, when the weeds start emerging, and using all hands available.



150
140
130
120
110
100
90
80
70
60
50
40
30
20
10
0
weeding time in hours per acre
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38
age of weeds in days
1st weeding
2nd weeding
3rd weeding

GRAPH 1

The labour demand for the second weeding does not increase in the same way with the age as during the first weeding (see Graph 1). The labour demand for the third weeding round is still less (Graph 1).

To arrive at the yield of treatment A it is essential to have the weeding rounds at short intervals (a maximum 2 weeks).

The economic aspects of this way of controlling weeds in growing cotton is discussed in another paper also presented during this conference.

References

ILACO (1968) Preliminary report on a study of weed control in cotton plantation at the Galole Pilot Demonstration and Training Project. Unpublished report

ILACO (1969) Final report on studies on working methods in the cultivation of cotton at Galole Unpublished report

ILACO (1970) The economics of hand-weeding vs. chemical weeding in irrigated cotton at Galole in Eastern Kenya. Unpublished report

THE ECONOMICS OF HAND-WEEDING VERSUS CHEMICAL WEEDING IN IRRIGATED COTTON AT GALOLE IN EASTERN KENYA

A. H. Druijff and G. J. Kerkhoven
Time and motion expert and agronomist, respectively,
International Land Development Consultants N. V. (ILACO),
P. O. B. 33, Arnhem, the Netherlands

Summary The socio-economic costs of some five hand-weedings in Eastern Kenya is 2.50 shillings (tools only), the private economic costs with additional labour is 10 shillings, and with entirely hired labour 41 shillings and with 1 lb diuron-80% 35 shillings (half of which foreign exchange) per acre.
Weed control with diuron requires some additional spot-weeding and special precautions to prevent a rapid increase of nutgrass.

INTRODUCTION

Due to the unemployment prevailing at Galole, two different methods are possible in calculating the costs of labour needed for weeding. From a socio-economic point of view it can be argued that the labour costs in unemployment situations are nearly zero. From a private economic point the labour costs are those which the farmer has, when hiring additional labourers from outside his family.

Both methods have been applied in calculating the profitability of hand-weeding versus chemical weeding in section 4.

CONDITIONS IN GALOLE

The Galole Irrigation Scheme comprises about 1200 acres. The greater part of it is allocated to local tenants in 4-acre plots. The management of the scheme looks after the tillage, supply of irrigation water and control of insects. The tenants are responsible for planting, fertilizing, weeding and harvesting of the cotton.

A time and motion study showed that the tenants mostly worked 6 days a week and more than 8 hours a day, especially those who lived in compounds near the scheme. Based on these observations the number of working hours a week was fixed at 50. Other observations have shown that a tenant who is helped by his family produces about 1.6 times as much, equivalent to 80 manhours a week.

Up till a few years ago all the weeding was done with a 'jembe', a heavy hoe with a narrow blade. Recently the more efficient and lighter Dutch hoe was introduced and has almost completely replaced the jembe, except for heavily infested fields.

LABOUR DEMAND IN WEEDING

Comparison of the efficiency of the locally used jembe and the Dutch hoe showed that under dry conditions of the soil production using the Dutch hoe was on an average 20.5 per cent higher and under moist conditions rose to 39.5 per cent. Only when the weeds were very tall the advantages of the Dutch hoe are lost. This condition was not considered in this paper as it only occurs under bad management.

A further improvement might be achieved by using a hoe with a horizontal blade that is sharpened on both sides enabling the farmer to use the tool with a reciprocating horizontal movement.

Only figures based on work with the Dutch hoe were used in the calculations mentioned in this paper. From these it became apparent that the amount of weeds removed from the plots decreased steadily, until after about 9 weeks it amounted to less than 100 kg fresh weight per acre. This tallies with the fact that cotton closes over in 10-12 weeks after planting and after 9 weeks no more weeding was done because of the negligible weed growth.

From our other paper presented at this conference it will be seen that the first weeding has to be conducted as soon as possible after weed emergence, which is a few days after the first irrigation. The first weeding tends to lag behind because weed growth at this time is the most vigorous and all emerges at about the same time.

At the start of the second weeding, however, part of the field has been weeded recently and is consequently comparatively clean. It is therefore essential that weeding be carried out in a systematic way, e.g. starting at one side of the field and working to the other.

From Table 1 the demand of labour during the period of weeding can be seen; it is assumed that the tenant works on his own without the help of his family. The first weeding was fixed for 10th day after irrigation. The manhours needed for weeding one acre can be read off Graph 1 in our other paper.

Table 1

Number of weeding	Interval or age of weeds	Manhours available	Manhours needed for 4 acres	Balance of manhours
1st	10 days	10/7 x 50 = 71	4 x 22 = 88	- 17
2nd	14 days	14/7 x 50 = 100	4 x 26 = 104	- 4
3rd	14 days	14/7 x 50 = 100	4 x 22 = 88	+ 12
4th	14 days	14/7 x 50 = 100	4 x 22 = 88	+ 12
5th	14 days	14/7 x 50 = 100	4 x 22 = 88	+ 12
	66 days	471	456	+ 15

For want of accurate figures for the 4th and 5th weeding the figures of the 3rd weeding were repeated. In cases where the tenant has the help of his family at his disposal there is no problem for then there are 10/7 x 80 = 114 manhours available for the first weeding.

COST OF HAND-WEEDING VERSUS CHEMICAL WEEDING

Socio-economic appraisal

The costs of hand-weeding are the cost of labour by the farmer's family and the cost of tools.

The cost of labour is determined by the employment situation. Given the high unemployment in Galole, engaging farm labour for weeding does not mean that a productive activity will be stopped elsewhere in the economy. In other words, the socio-economic labour costs are zero.

For purposes of calculation it is assumed that the costs of tools are 2.50 sh. per acre.

The cost of chemical weeding is comprised of the following items: purchase price of the chemical, cost of transport to the field and application costs (these being wages, cost of machines and supervision).

Under Galole conditions the following breakdown of costs per acre was arrived at in spraying diuron with knapsack sprayers that were filled from containers on a trailer behind a tractor:

diuron (0.8 lb/acre)	20 sh.	
wages (skilled labour)	7 sh.	
machines	8 sh.	
total	35 sh.	per acre (more than half of it is foreign exchange).

The conclusion must be that from a socio-economic point of view hand-weeding is much more profitable than chemical weeding.

Private economic appraisal

All the labour for hand-weeding being supplied by the farmer and his family, his costs are only the tools 2.50 sh. per acre (assuming that the leisure time of the farmer is abundant).

The costs for the farmer of chemical weeding are also:

diuron (0.8 lb/acre)	20 sh.	
wages (skilled labour)	7 sh.	
machines	8 sh.	
total	35 sh.	per acre

A farmer not helped by his family will have to hire labour at 3 sh. a day or 36 cts an hour which will cost him (17 + 4) x 0.36 = 7.56 sh. for 4 acres or 1.89 sh. per acre (see Table 1, 'balance of manhours'). This private economic calculation results in the same conclusion as before.

Moreover, the following point should be taken into account. If chemicals are used it must be remembered that it is virtually impossible to apply one herbicide that will control the whole range of weeds. This means that after prolonged use of such a chemical the resistant weeds will become dominant. Consequently, in practice more than one chemical must be applied or hand-weeding must be conducted in addition to herbicide applications. Furthermore, considerations should always include the possible risk of damage to crops due to mistakes in applying herbicides and unfavourable weather conditions afterwards.

References

ILACO (1969) Final report on studies on working methods in the cultivation of cotton at Galole. Unpublished report.

ILACO (1970) Influence of weed growth on cotton yield and weeding time based on experiments at Galole in Eastern Kenya. Unpublished report.

Proc. 10th Br. Weed Control Conf.1970

EFFICIENCY AND SELECTIVITY OF HERBICIDES IN RICE PRODUCTION

J.K. Verma and V.S. Mani
Division of Agronomy, Indian Agricultural Research Institute, New Delhi

Summary. Field experiments were conducted to study the efficiency and selectivity of individual and combined applications of herbicides in transplanted rice (Variety: Taichung Native-1). A post-emergence spray of propanil 2 kg a.i./ha controlled annual weeds particularly barnyardgrass (Echinochloa colonum). A negative correlation was observed between the dry matter accumulation of monocot weeds and grain yield of the crop. There was a substantial improvement in dry matter production, mineral nutrition and final grain and straw yield of the crop resulting from the chemical spray. The best chemical treatment increased the grain yield by 14.1 and 24.2 quintals per hectare over manual weeding and the unweeded check respectively. Combining either MCPA or manual weeding with propanil (Stam F-34) did not give any advantage over the application of the latter alone. A granular formulation of nitrofen was more selective and effected better control of monocot weeds than the liquid formulation.

INTRODUCTION

Transplanting of rice seedlings is a practice that is adopted in rice growing areas with assured irrigation. The discontinuous submergence of rice fields promotes a rank growth of monocot weeds such as barnyardgrass and sedges.

The benefit derived from weed control is determined to a great extent by the time it is applied in the field. The adoption of cultural methods of weed control in a very close spaced crop such as rice which is under frequent submergence during its early growth is difficult. On the other hand the chemical control of weeds in this situation is easier and allows large areas to be treated quite in time long before weed growth assumes menacing proportions in the growing crop.

The objectives of the present investigations are: (1) to study the relative efficiency of chemical and physical methods in regard to weed control, (2) to assess the selectivity of herbicides in rice, (3) to broaden the spectrum of weed control by combination of herbicides and (4) to explore the possibility of reducing the cost of chemical treatment by combining herbicides with and without manual weeding.

METHOD AND MATERIALS

The experiments which were conducted for two consecutive seasons (1966 and 1967) in different fields were laid out in a randomised blocks design with the following treatments replicated four-fold.

	Treatment	Kg a.i./ha	Notation employed	Year of application
1)	Propanil (Stam F-34)	2	S	Both years
2)	Propanil (Rogue)	2	R	Both years
3)	MCPA	1	M	Both years
4)	Nitrofen liquid	1	T	Both years
5)	Nitrofen granular	7	TG	1967
6)	Glenbar*	2	G	1966
7)	Weeding once	-	W	Both years
8)	Rotary weeder	-	Wr	Both years
9)	Propanil+MCPA	1+½	SM	Both years
10)	Propanil+rotary weeder	1	SWr	1966
11)	Propanil+weeding	1	SW	Both years
12)	Weeding+propanil	1	WS	1967
13)	Propanil+weeding	1	RW	Both years
14)	MCPA+weeding	½	MW	Both years
15)	Nitrofen+weeding	1	TW	Both years
16)	No treatment	-	C	Both years

*Glenbar = O-S-dimethyl tetrachlorothioterepthalate

Observations on crop related to dry matter production, straw and grain yield and its components. The chemical composition (per cent N,P and K) was determined of plant samples and grain at maturity. Observations on weeds included periodic population counts, dry matter accumulation and chemical composition.

RESULTS

Crop data are presented in Tables 1 and 2 and weed data in Tables 3 and 4.

Table 1 (Expt. 1966)

TRT	GY*	DMC*	NRC*	TRT	GY	DMC	NRC
S	80.5	168.5	147.2	SM	69.8	151.3	128.6
R	75.3	169.8	140.7	SWr	76.0	153.5	137.2
M	66.5	149.0	130.0	SW	76.4	147.9	131.2
T	53.8	127.8	104.9	RW	74.2	161.7	132.3
G	55.5	129.5	116.4	MW	68.8	141.4	131.3
W	65.0	162.0	130.8	TW	52.4	131.9	114.5
Wr	63.2	146.2	130.2	C	54.2	146.2	121.6
L.S.D.5%	9.2	16.2	12.5	L.S.D.5%	9.2	16.2	12.5

Table 2 (Expt. 1967)

TRT	GY	DMC	NRC	TRT	GY	DMC	NRC
S	81.2	167.7	141.8	SM	75.9	161.9	137.3
R	76.5	167.8	135.7	SW	79.0	175.0	140.3
M	68.2	159.2	133.5	WS	83.7	166.7	149.5
T	64.5	152.0	125.6	RW	77.6	170.8	137.1
TG	72.5	166.5	137.3	MW	71.6	163.8	140.2
W	68.4	159.4	133.7	TW	60.7	153.7	127.3
Wr	68.8	157.2	134.5	C	59.1	144.6	120.1
L.S.D.5%	4.6	8.5	8.8	L.S.D.5%	4.6	8.5	8.8

Table 3 (Expt. 1966)

TRT	**DW.M	DW.D	WE.M	WE.D	TRT	DW.M	DW.D	WE.M	WE.D
S	0.32	8.00	99.6	83.4	SM	0.60	0.67	99.3	98.5
R	1.50	9.00	98.2	81.4	SWr	2.12	5.28	97.5	89.2
M	29.30	0.56	65.4	98.8	SW	3.20	1.10	96.2	97.7
T	25.00	17.50	65.3	63.8	RW	3.50	1.56	95.6	96.7
G	64.06	43.00	24.2	11.1	MW	13.40	0.12	84.1	99.7
W	31.00	15.80	63.3	67.3	TW	32.44	18.50	61.6	61.8
Wr	30.00	19.00	64.5	60.7	C	84.50	48.40	--	--
L.S.D.5%	7.96	6.76	--	--	L.S.D.5%	7.96	6.76	--	--

Table 4 (Expt. 1967)

TRT	DW.M	DW.D	WE.M	WE.D	TRT	DW.M	DW.D	WE.M	WE.D
S	0.64	11.42	99.2	82.2	SM	0.30	2.34	99.6	96.3
R	2.90	11.51	96.4	82.1	SW	2.10	30.80	97.4	52.0
M	24.60	1.20	69.9	98.1	WS	1.92	8.20	97.6	87.2
T	26.50	16.40	67.6	74.4	RW	3.10	36.32	96.2	43.5
TG	7.30	17.30	91.1	72.9	MW	31.20	1.70	61.8	97.3
W	43.10	23.10	47.2	64.0	TW	23.00	26.77	71.8	58.3
Wr	40.00	17.90	51.0	72.1	C	81.70	64.19	--	--
L.S.D.5%	6.82	6.80	--	--	L.S.D.5%	6.82	6.80	--	--

Tables 1 and 2

* GY: grain yield in quintals per hectare - q/ha (1 q = 100 kg);
DMC: dry matter crop (q/ha);
NRC: nitrogen removal by crop (kg N/ha)

Tables 3 and 4

**DW.M: mean dry weight monocot weeds in grams in 1 sq.m, 10 weeks after transplantation;
DW.D: mean dry weight dicot weeds in grams in 1 sq.m, 10 weeks after transplantation;
WE.M and WE.D: weed control efficiency (per cent) of monocot and dicot weeds respectively.

$$WE = \frac{DM.C - DM.T}{DMC} \times 100$$ where

WE: weed control efficiency in per cent
DM.C: dry matter under control
DM.T: dry matter under treatment

Tables 1 and 2

Propanil (S) gave the best grain yield in both the seasons (Av. 80.8 q/ha) with a yield increase of 14.1 and 24.2 quintals per hectare over weeding and the unweeded check respectively.

The dry matter production of the crop was increased by 7.3 q/ha over weeding and 22.6 q/ha over no-weeding. The crop removed 144.5 kg N/ha registering an increase of 23.7 kg N/ha as compared to the untreated check.

Tables 3 and 4

The weed control efficiency per cent worked out to 99.6 and 83.4 for monocot and dicot weeds respectively with propanil (S) in 1966. The corresponding values in 1967 were 99.2 and 82.2.

Combining MCPA or manual weeding with propanil (S) - (SM, SW) did not improve the WE.M.

In 1967, the WE.M and WE.D for nitrofen (granular) were 91.1 and 72.9. The corresponding values for nitrofen (liquid) were 67.6 and 74.4. The granular formulation improved the WE.M but not the WE.D.

The data on correlation between dry weight of weeds and grain yield of the crop are presented in Table 5 and on the economics of the treatments in Table 6.

Table 5

Coefficients of correlation (r) and regression (b) between weed weight and grain yield

	1966			1967		
CC(r)	DW.AW	DW.M	DW.D	DW.AW	DW.M	DW.D
S_1	-0.67**	-0.72**	-0.42	-0.60**	-0.84**	-0.36
S_2	-0.69**	-0.87**	-0.43	-0.68**	-0.75**	-0.36
S_3	-0.61**	-0.68**	-0.38	-0.56**	-0.74**	-0.33
RC(b)						
S_1	-0.27	-0.43	N.S.	-0.15	-0.27	N.S.
S_2	-0.21	-0.36	N.S.	-0.12	-0.23	N.S.
S_3	-0.13	-0.23	N.S.	-0.09	-0.17	N.S.

Table 6

Economics of treatments

TRT	Grain yield (q/ha) 1966	1967	Money value of additional produce (Rs.) 1966	1967	Cost of treatment (Rs.)	Net profit over control(Rs./ha) 1966	1967
S	80.5	81.2	1052.00	1016.00	145.00	903.00	871.60
M	66.6	68.2	496.00	418.00	52.00	444.00	366.00
W	65.0	68.4	432.00	427.80	30.00	402.00	397.80
SM	69.8	75.9	624.00	772.80	98.50	573.50	674.30
SW	76.4	79.0	888.00	915.40	100.00	785.00	815.40
C	54.2	59.1	--	--	--	--	--

Table 5

CC(r): correlation coefficient;
RC(b): regression coefficient;
DW.AW, DW.M, DW.D: dry weight of all weeds, monocots and dicots respectively;
S1, S2, S3: samples collected 7, 10, 13 weeks after start of the experiment.

Table 6

Rate of rough rice:	Rs. 40.00 and Rs. 46.00 per quintal in 1966 and 1967 respectively
Price of Stam F-34:	Rs. 40.00 per litre
Price of MCPA	: Rs. 10.80 per litre
Hand-weeding	: 15 men/ha at Rs. 2.50 per day
Spraying	: 10 men/ha at Rs. 2.50 per day

Table 5

In both the seasons a highly significant negative correlation existed between the dry weight of monocot weeds and grain yield.

Table 6

The highest net returns accrued in both the seasons from a post-emergence spray with propanil (S) at kg a.i./ha. Even though the cost of this chemical treatment was nearly five times higher than hand-weeding, the profit from the former was more than twice as great as the latter.

DISCUSSION

Propanil alone versus a combination of propanil and weeding (S vs SW): S and SW did not differ in respect of weed growth or grain yield. The dry matter production of rice was significantly more under S in one season only. The conclusion that emerged from this was that no advantage resulted from a manual weeding. Even though the efficiency of control of dicot weeds was much improved by a weeding operation, the crop did not derive any advantage because the dominant monocots were as effectively controlled by S alone.

Propanil (S) alone versus a combination of propanil and MCPA (S vs SM): SM proved more effective against dicot weeds, but it did not differ significantly from S in control of monocots. Although SM controlled dicot weeds better, grain production was significantly less than S. In explaining the reduced yield with SM two factors should be borne in mind: (i) the lower dosage or propanil in SM and (ii) the inclusion of MCPA. As monocot weed growth was affected equally by the two treatments, the significantly lower grain production in SM in both the seasons indicated that MCPA antagonised the beneficial effects of propanil.

Propanil formulations (S vs R): These two formulations of propanil were equally effective in controlling monocot and dicot weeds. The dry matter production of the crop also did not differ between these two. Several workers including Smith (1961) and Nester (1969) secured promising results with propanil in controlling weeds belonging to both grasses and broad leaved category in rice.

The grain yield under Stam F-34 was significantly superior to that of Rogue in one season only (1967). It thus appeared that Stam F-34 had a slight edge over Rogue in grain production in Taichung Native-1. Better response of rice to Stam F-34 was also reported by Sajo (1965) who compared three formulations of propanil, namely, Stam F-34 (35% DPA), Rogue (45%) and Surcorpur (25%). The relative efficiency of these formulations against Echinochloa crusgalli was 85, 51 and 75 per cent resulting into corresponding yield increases.

Nitrofen granular versus liquid (TG vs T): The grain yield, dry matter production and nitrogen uptake were significantly more with TG. TG effected a significant reduction in the dry matter accumulation of monocot weeds. As TG did not differ from the weeding treatment (W) in respect of grain yield, dry matter production and nitrogen uptake and as it was significantly superior in arresting the dry matter accumulation in monocot weed growth as compared to both W and T it appeared that the granular formulation of nitrofen was more selective on the crop besides securing an efficient control of monocot weed growth.

The liquid formulation was applied as a post-emergence spray and the rice foliage received some spray whereas the granular formulation did not contact foliage during application since it was deposited directly on the soil. It was further diluted by mixing with sand for facilitating uniform distribution. The active principle that was slowly released appeared to have controlled emerging weed seedlings but never attained the threshold limits to cause crop phytotoxicity. Root injury was further prevented by dilution in water and low penetration into the soil.

References

NESTER, R.P. (1969) Barnyardgrass competition and control in rice. Rice J., 72, (2), 12-14.

SAJO, Z. (1965) Chemical weed control experiments with DPA in rice. Kieserl. Kozl. Ser. A., 58, (1), 23-45 (c.f. Weed Abstr. 49 Vol. 17).

SMITH, R.J. (1961) 3,4-dichloropropionanilide for control of barnyardgrass in rice. Weeds, 9, 318-22.

Proc. 10th Br. Weed Control Conf. 1970

CHLORAMBEN AND FIVE NEWER HERBICIDES FOR WEED CONTROL IN TRANSPLANTED RICE*

S.R. Obien and D.L. Plucknett
College of Tropical Agriculture, University of Hawaii, Honolulu, Hawaii, U.S.A.
L.C. Burrill
International Plant Protection Center, Oregon State University,
Corvallis, Oregon, U.S.A.

Summary Chloramben was very effective for selective weed control in transplanted rice. Both granular and emulsifiable concentrate (e.c.) forms were effective, even when the e.c. materials were applied in the irrigation water. Little injury to rice occurred with rates as high as 6 lb per acre. Satisfactory weed control was obtained with pre-emergence or early post-emergence applications, but not when post-emergence applications were made later than 8 days after transplanting. Chloramben, CP 53619 (N-butoxymethyl-2-chloro-2',6'-diethylacetanilide) and RP 17623 (2-tert butyl-1,4,2',4'-dichloro-5'-isopropyloxyphenyl 1,3,4-oxadiazolin-5-one) applied pre-emergence provided adequate control of grass, sedge and broadleaved weeds. Pronamide controlled grasses and broadleaved weeds but was less effective on sedges.

INTRODUCTION

Developments in the last 10 years have contributed significantly to the progress of weed control in rice. At present many effective and economically feasible herbicides are recommended for use in rice. However, the variety of weeds and variability of conditions and/or cultural management often reduce the probability of success in the use of these compounds. For this reason, it is necessary to find herbicides which are more selective and effective at various growth stages of rice; this is done by (a) screening new herbicides to isolate selective compounds that may be further developed, and (b) re-examining old herbicides that have been cleared for other crops to find better means of using them in rice.

In the latter part of 1969 and early 1970, chloramben and several new herbicides were tested on transplanted and direct-seeded rice. Chloramben appeared promising in transplanted rice and it was decided to conduct further studies to compare it with some new herbicides selected from our screening experiments or found sufficiently selective in rice by other workers.

METHOD AND MATERIALS

The field experiments were conducted in the spring and summer of 1970 at the Wailua Paddy Crop Substation of the Kauai Branch Station on the island of Kauai.

* Published with the approval of the Director of the Hawaii Agricultural Experiment Station as Journal Series No. 1260.

The soil is a montmorillonite-kaolinite mixture with high content of organic matter (8 to 14 percent) and a pH range of 4.9 to 5.5. The annual rainfall is 40 to 50 in.

Experiment 1 was designed to compare the effects of granular chloramben with some newer herbicides on the yield of rice (IR8) and Experiments 2 and 3 to determine the response of rice and weeds to various rates of granular chloramben applied at different stages of growth. In general, 20 to 25 day-old seedlings raised in seed-beds were transplanted in plots separated by levees to minimize herbicide loss or plot contamination through water movement. Seeds of Echinochloa crus-galli were broadcast (about 8 g per plot) at planting time to ensure uniform weed stand. The experimental details are shown in Table 1.

Experiment 1. Rice (variety IR8) was transplanted at 2 to 3 seedlings per hill. The herbicides tested are listed in Table 2. Chloramben and VCS 438 (2-(3',4'-dichlorophenyl)-4-methyl-3,5-diketo-1,2,4-oxadiazole), both in granular forms, were broadcast at 3 days, and pronamide, CP 53619, and RP 17623 at 5 days when the weeds had just emerged. Propanil and fluorodifen were applied at the 2-leaf stage (11 days) of Echinochloa. Propanil was included among the treatments to serve as a basis for comparison. Because of poor performance, propanil and fluorodifen were reapplied 11 days after the first application (22 days after planting). Similarly, VCS 438 performed very poorly and the plots were retreated with propanil at 3 lb/ac, not with VCS 438 itself because this compound has poor post-emergence activity.

Data taken included percent weed control (subjective rating), weed population and relative growth of weeds and rice at 21 days, and the grain yield at harvest (123 days).

Experiments 2 and 3. The objectives of these experiments were: (i) to determine the tolerant stage of rice and weeds to increasing rates of chloramben, and (ii) to compare the effectiveness of granular and e.c. formulations of chloramben. The e.c. formulation was applied (a) as spray, and (b) injected in the irrigation water', to find out if method of application would influence selectivity. The general procedures were the same as in Experiment 1 (Table 1), except that in Experiment 3 the variety Caloro was used because of earlier maturity during the summer months.

RESULTS

Experiment 1. Chloramben and three new herbicides: CP 53619, pronamide and RP 17623, gave adequate weed control with minimum toxicity to rice (Table 2). On the other hand, fluorodifen, propanil, and VCS 438 were not sufficiently active on the weeds at the rate and time they were applied. A second application of the same rates of fluorodifen and propanil, and an application of propanil to plots initially treated with VCS 438 did not control weeds well enough to prevent competition with the crop.

Table 2 shows the degree of weed control and injury to rice at 21 days after transplanting and yields at harvest. There was a dense and uniform stand of Echinochloa, a medium stand of sedges (predominantly Cyperus difformis and a few Scirpus junccides), and only very irregular stands of broadleaved weeds. The effect on rice was, attributed mainly to Echinochloa, hence detailed data on density and growth for that weed were taken at 21 days (Table 2). A population of less than one weed/m^2 was rated as nil and was assumed to be inconsequential, as compared with the control plots with weed populations of 170 Echinochloa/m^2.

The benefit from good weed control was reflected in the grain yield (Table 2); treatments which gave excellent weed control also resulted in good yields. Rice treated with chloramben, CP 53619, pronamide, and RP 17623 had computed yields of more than 6900 lb/ac each; however, CP 53619 plot yields were highest, exceeding 7000 lb/ac.

Table 1

Summary of materials and methods in herbicide experiments; Kauai, 1970

Item	Experiment 1	Experiment 2	Experiment 3
Rice variety	IR8	IR8	Caloro*
Plot size	5.9 x 10 ft ($5.25\ m^2$)	5.9 x 14 ft ($7.43\ m^2$)	5 x 10 ft ($4.5\ m^2$)
Planting distance	10 x 10 in. (7 rows)	10 x 10 in. (7 rows)	10 x 10 in. (7 rows)
Date planted	March 13, 1970	April 6, 1970	June 30, 1970
Date treated	March 16, 18, 24 April 4	April 8, 14, 18	July 3, 10, 20
Date rated	April 3, 1970 (21 days)	May 11, 1970 (35 days)	July 23, 1970 (23 days)
Date harvested	July 14, 1970 Grain yield data taken	No grain yield data	September 23, 1970 Sample data only (not reported); rice stand and weed control taken

* Caloro matures earlier than IR8 during the summer months.

Experiments 2 and 3. Because the use of chloramben as a selective herbicide in transplanted rice had never been reported previously, the tolerance of rice to various dosages and the susceptible stages of weeds were also determined. In Experiment 1, 3 lb/ac was shown to be an excellent pre-emergence treatment for *Echinochloa*, although the data on sedges and broadleaved weeds were not conclusive, because the populations were low and not uniform. In our screening trials, 2 lb/ac gave reasonable weed control but a few weeds survived, especially sedges, in those plots with poor water management or when the weeds had just emerged at the time of treatment. The rates and times of application are presented in Tables 3 and 4. The granular and e.c. formulations were compared at 3 lb/ac.

In Experiment 2, the weed population was low and not uniform; *Echinochloa* sown at planting time did not germinate uniformly, and there were few broadleaved weeds. However, the data (Table 3) revealed the following important points: (a) chloramben injury to rice was negligible and varied very little from 2 to 4 lb/ac, (b) the critical application time for effective weed control was after planting but not later than 8 days (or at the early 1-2 leaf stage of *Echinochloa*), and (c) there was no measurable difference between the granular and e.c. formulations. These observations were verified in Experiment 3 where the population of *Echinochloa* and sedge was dense and uniform throughout the test plots.

Since there was no significant toxicity of chloramben at 4 lb/ac to rice in Experiment 2, 6 lb/ac was also tried in Experiment 3. Table 4 shows the degree of injury to rice and extent of weed control at 23 days, and rice stand and weed control at 86 days (harvest time). Rice stand is a subjective rating of the number of productive tillers compared with the weeded control. The weed control data taken at maturity represented the residual activity of the treatments as well as the extent of competition between *Echinochloa*, sedges (mainly *Cyperus difformis* and *Scirpus juncoides*) and rice. It will be noted that the weed control data at 23 days were taken just 3 days after the last application of chloramben, 20 DAT (days after

Table 2

Experiment 1. Effects of chloramben and other herbicides on rice (IR8) and weeds 21 days after planting; Wailua Substation, Kauai, 1970

Herbicide	lb/ac	Effect on rice: Tillers per hill*	Effect on rice: Percent injury	Effect on rice: Mean yield lb/ac	Effect on weeds: Effect on Echinochloa**: No. per 1 m^2	Effect on weeds: Effect on Echinochloa**: Tiller per plant	Effect on weeds: Effect on Echinochloa**: Length of shoot (cm)	Effect on weeds: Percent control of: Sedges	Effect on weeds: Percent control of: Broadleaves
Chloramben (gram.)	3.0	7.5	nil	6960	nil	nil	nil	100	100
Cr 53619 (e.c.)	1.5	8.5	nil	7300	nil	nil	nil	100	100
Pronamide (w.p.)	1.5	8.2	nil	6930	nil	nil	nil	67	100
RP 17623 (e.c.)	1.0	6.5	3.3	6620	nil	nil	nil	100	100
Fluorodifen (e.c.)	4.0†	7.4	38.3	5620	117	1.7	17.5	100	100
Propanil (e.c.)	3.0††	8.0	1.3	5720	150	1.2	14.5	73	73
VCS 438 (gran.)	1.0††	7.2	2.3	6000	133	2.7	19.7	100	100
Control (weeded)	-	9.1	0	6420	nil	nil	nil	100	100
Control (unweeded)	-	8.5	0	4920	170	2.9	21.0	0	0

* Average of 5 hills per plot. Percent injury to rice and percent control of weeds were all subjective ratings.

** Number of weeds per 1 m^2 was based on 5 samples (25 cm x 25 cm each) from each plot, while tiller counts and length of shoot were based on the total number of samples taken.

† Retreated with same rate 22 days after planting or 11 days after the first application

†† Retreated with propanil 3 lb/ac 22 days after planting

Table 3

Experiment 2. Effect of different rates and time of application of chloramben rice injury and weed control. Wailua Substation, Kauai, 1970

Chloramben lb/ac	Time of application (DAT)*	Injury to rice (percent)	Weed control (percent)	
			Grass	Sedge
2 gran.	2	3.3	100	93
3 gran.	2	6.6	100	100
4 gran.	2	5.0	100	100
2 gran.	8	5.0	81	100
3 gran.	8	5.0	100	83
4 gran.	8	7.3	100	100
2 gran.	12	2.0	18	20
3 gran.	12	1.6	40	53
4 gran.	12	2.3	37	60
3 (e.c.)	2 (Applied as spray)	1.6	100	100
3 (e.c.)	2 (Applied through irrigation water)	3.3	93	95

* DAT = days after transplanting. The emulsifiable concentrate (e.c.) formulation applied as spray and through the irrigation water was also included to compare it with the granular form.

transplanting). Although these data reflect only the extent of injury to the weeds (not percent kill), the results agree very closely with the data at 86 days.

Results obtained in Experiment 3 (Table 4) confirmed the observations in Experiment 2. Injury to rice increased as the rate of chloramben increased; however, rice also became more tolerant of the herbicide with time. The degree of weed control also followed the same trend as that shown for rice, but the weeds were more seriously affected. Adequate grass control was obtained with all rates applied at 3 DAT. In general, there was no benefit from rates higher than 3 lb/ac when application was made before weed emergence. However, grass control was best at 6 lb/ac when Echinochloa was at 2-3 leaf stage, although the sedges were still inadequately controlled. Chloramben was ineffective when applied post-emergence to sedges.

DISCUSSION AND CONCLUSIONS

Chloramben has never been used successfully in the past for weed control in rice. It is a good pre-emergence compound (which explains its toxicity to direct-seeded rice in our screening trials), on the other hand, it has little effect as a post-emergence treatment (which is why it is not toxic to transplanted rice). When high rates were used, rice displayed an 'onion leaf' symptom, similar to that caused by 2,4-D; at high rates there was stem bending. Symptoms in Echinochloa included: stem bending or twisting at the base, root growth inhibition or stubby root formation at the base, and 'onion leaf'.

Table 4

Experiment 3. Effects of different rates and time of application of chloramben on rice (Caloro) and on weed control. Wailua Substation, Kauai, 1970

Chloramben lb/ac	Time of Application (Days after transplanting)	Effect at 23 days				Effect at 86 days (maturity)			
		Injury to rice (%)	Weed control (%)			Rice stand (%)	Weed control (%)		
			Grass	Sedge	Broadleaved		Grass	Sedge	Broadleaved
2 gran.	3	5	93	77	90	98	96	92	98
3 gran.	3	10	95	80	100	98	94	93	100
4 gran.	3	23	100	87	98	100	98	95	98
6 gran.	3	27	100	87	100	100	100	93	100
3 e.c.	3 (Applied as spray)	10	100	90	97	96	96	95	95
3 e.c.	3 (Applied through irrigation water)	10	100	92	100	95	98	95	98
2 gran.	10 (2-3 leaf)	5	60	37	43	33	30	16	13
3 gran.	10 "	10	80	37	67	50	56	46	10
4 gran.	10 "	10	83	63	82	60	63	60	63
6 gran.	10 "	10	92	53	88	85	80	70	70
2 gran.	20 (4 + leaf)	nil	47	40	27	43	23	26	43
3 gran.	20 "	nil	33	47	27	40	10	10	86
4 gran.	20 "	5	37	57	27	72	30	33	93
6 gran.	20 "	10	30	53	27	53	33	46	93
Control (weeded)		0	95	95	90	98	100	100	100
Control (unweeded)		0	0	0	0	18	0	0	0

The sedges were more resistant when chloramben was applied post-emergence. Rice tolerated rates up to 6 lb/ac, but there was no clear benefit from using more than 2 or 3 lb/ac as long as chloramben was applied before the weeds had emerged and provided a good water level was maintained. Also, granular and e.c. formulations performed equally well as pre-emergence treatments. The e.c. applied either as a spray application or in the irrigation water was effective and caused little effect on rice.

Chloramben, CP 53619, and RP 17623 applied pre-emergence provided adequate control of grass, sedge, and broadleaved weeds. Pronamide also adequately controlled grass and broadleaved weeds but was rather ineffective on sedges. Rice tolerated rates of chloramben up to 6 lb/ac; weed control was adequate when the compound was applied pre-emergence and early post-emergence but not later than 8 DAT.

Acknowledgments

The authors gratefully acknowledge the financial support of the International Plant Protection Center of Oregon State University and the U.S. Agency for International Development (AID). The technical help of the following staff of the Kauai Branch Station and the University of Hawaii is likewise deeply appreciated: Dr. Ramon S. de la Peña, Messrs. Rodolfo Escalada, Dimyati Nangju, Gordon Shibao, and Humphrey Ezumah.

Proc. 10th Br. Weed Control Conf. 1970

ATRAZINE AND AMETRYNE FOR GRASS WEED CONTROL IN BRITISH FORESTRY

R. M. Brown
Forestry Commission Research Station, Alice Holt, Farnham, Surrey

Summary. In trials from 1967 to 1970 atrazine provided a good kill of a range of fine and soft perennial grasses (e.g. Agrostis spp.) at 2-4 lb a.i./ac applied from February to May, control persisting for most of the growing season. Coarser grasses (e.g. Deschampsia caespitosa (L)Beauv.) and non - graminaceous species were not well controlled at these rates, and some tended to spread in plots where atrazine had provided control of other weeds. Limited trials with ametryne suggested that it was less effective than atrazine.

All coniferous species appeared to tolerate overall sprays of atrazine at rates up to 4 lb a.i./ac without serious damage. Some signs of atrazine damage were seen however, and the tolerance of crop species requires more study.

Generally, the results suggest that atrazine should be a very useful herbicide for controlling predominantly grass weeds in British forestry.

INTRODUCTION

Paraquat, and to a lesser extent dalapon and chlorthiamid, are commonly used herbicides for controlling grass and herbaceous broadleaved weeds in British forestry. All involve problems of avoiding crop damage, either during application or because of herbicide residues. Paraquat and dalapon have the further disadvantage that weed control tends to be non-persistent.

Reports from America (e.g. Newton 1964) of the successful use of atrazine for forest weed control in climatic conditions not too dissimilar from our own, suggested that it may overcome some of these disadvantages.

This paper reports the results of subsequent trials, from 1967 to 1970, and gives provisional recommendations for the use of atrazine for controlling grass weeds in British forestry.

METHODS AND MATERIALS

(a) General

Sites: All sites were in the south or south-east of England. For the exact locations see brief description of each series of trials below. All were below 500 ft a.s.l., unexposed, with level or nearly level topography. Rainfalls ranged between 25 and 45 in. per annum. Soil types varied from free draining acidic brown earths (e.g. Thetford Forest) to gleyed soils (e.g. Friston Forest).

Generally, the former were on light, sandy soils and the latter on loamy clays or clays. Accumulation of decomposing organic matter at the soil surface was negligible (generally less than ½ in.) and mechanical analysis of some of the sites suggested that organic matter of the uppermost soil horizons was between 5 and 10%.

All sites except two (at Neroche Forest) were cleared of trees (generally scrub hardwoods) from one to three years prior to the experiment. Grass weeds dominated the weed flora, and were well established at the time of spraying. Broad-leaved herbaceous and woody weeds were also present in varying frequencies from site to site. The major grass species are referred to in the Results section; other weeds are only mentioned where they have been important.

Experiments: Except where otherwise mentioned both herbicides were used as wettable powders; atrazine as a 50% w.p. and ametryne as a 65% w.p. Wettable powders and water soluble herbicides were applied in water at a rate of from 30 to 50 gal/ac using knapsack sprayers at low pressure. All applications were post planting.

Each plot contained between 15 and 25 trees of each species in a single row (some sites had two species). Where one species only was planted this was normally at 6 ft spacing in the row, but where two species were present the spacing was generally 3 ft. The spray or granules in all trials except the first (1967) were applied to a 3 ft wide strip along the row of trees, the trees being centrally placed in this treated strip. All plots were surrounded by a 6 ft buffer.

All plots were hand-weeded as necessary to normal forest standards. Except for the 1967 trial the time taken on these weedings was recorded and used as a comparative measure of the effectiveness of the weed control. Other assessments of weed control were % live cover by major weed types (grass, herbaceous broadleaves and woody weeds) or major weed species.

Assessments on the crop species were beginning and end of season height, health (scoring systems) and scores of any symptoms which appeared during the course of an experiment.

There were three or four replications of a randomised block design in all experiments.

(b) Further details of each series of trials

(i) 1967 preliminary trial

Location and crop species:- Orlestone Forest, Kent. Corsican pine planted in Spring 1964.

Experiment: Atrazine and ametryne were applied at 0, 5, 10 or 15 lb/ac to circular patches one yd^2 in area round each tree on the 8th and 9th June, 1967, the tree being protected from the spray by the use of an 'Arbogard Mk. II'. Treatments were replicated four times.

(ii) 1968 trials

Location and crop species:- Friston Forest, Sussex; Corsican pine and Western hemlock. Thetford Forest, Norfolk; Corsican pine only. All planting was done in the early spring of 1968.

Experiment: Atrazine and ametryne at 1½ and 2½ lb/ac, and paraquat at 1 and 2 lb/ac were applied at three dates during April, June and October 1968. A hand-weeded control was also included. Treatments were replicated three times. Trees were protected from the spray by polythene bags.

At Thetford, after complete failure to produce any signs of weed control with the April application, the rates of atrazine and ametryne were doubled to 2½ and 5 lb/ac for the June and October applications.

(iii) 1969 trials

Location and crop species (the number in brackets indicates the spring in which planting took place):- Forest of Dean, Gloucestershire; Corsican pine (69) and Grand fir (69). Friston Forest, Sussex; Corsican pine (67) and Norway spruce (69). Hursley Forest, Hampshire; Douglas fir (68) and Western hemlock (69). Neroche Forest, Somerset; Sitka spruce (69). Thetford Forest, Norfolk; Corsican pine (69) and Scots pine (69).

Experiment: Atrazine at 2, 3 and 4 lb/ac, and paraquat at 1 lb/ac were applied at three dates: March, April/May and June 1969. A hand-weeded control was included, and treatments were replicated four times.

In 1970, all herbicide plots were re-treated, all atrazine plots at 3 lb/ac and paraquat plots at 1 lb/ac in early May 1970. At the Forest of Dean, because of poor results in the first year, the experiment was modified and repeated on the same site in 1970. Atrazine rates were adjusted to 3, 4½ and 6 lb/ac applied in March, April and May.

(iv) 1970 trials

Location and crop species (the number in brackets again indicates the spring in which they were planted):- Bere Forest, Hampshire; Corsican pine (69) and Norway spruce (70). Friston Forest, Sussex; Corsican pine (68) and Western hemlock (70). Neroche Forest, Somerset; Sitka spruce (70) and Douglas fir (70). Thetford Forest, Norfolk; Corsican pine (70) and Scots pine (70).

Experiment: Atrazine at 2 and 4 lb/ac was applied as either a 50% w.p. or a 4% granule. Two paraquat or two chlorthiamid plots at 1 lb/ac or 4 lb/ac respectively were included for comparison. All herbicide treatments were applied at three dates, either February, March/April or April/May. A hand-weeded control was included and treatments were replicated four times.

RESULTS

(a) Weed Control

In the preliminary trial in 1967, 5, 10 and 15 lb/ac of both atrazine and ametryne gave excellent control of grasses, the live cover of treated areas being only 12 to 21% against 78% of the 0 lb/ac (control) areas in October 1967. Most of the cover was bracken, bramble and herbaceous broadleaves, which had begun to invade the treated patches. The grasses Holcus lanatus L. and Agrostis stolonifera L. were virtually eradicated from the patches. The lack of any noticeable difference in weed control between rates suggested that both the 10 and 15 lb/ac rates must have been far higher than necessary.

Weed control from the 1968 trials, which involved much lower rates of both atrazine and ametryne, was generally much poorer, except for the April date of application at Friston. The total time spent on weeding the plots was the best measure of this (Table 1). October treated plots are not included in this table as the herbicides could have little effect until the following year; in fact, October applications of both atrazine and ametryne had very little effect in the following year.

Table 1

Mean weeding time per 20 yd^2 plot at Friston during 1968 (minutes)

Rate a.i. per acre

Date of application	Atrazine $1\frac{1}{4}$	Atrazine $2\frac{1}{2}$	Ametryne $1\frac{1}{4}$	Ametryne $2\frac{1}{2}$	Paraquat 1	Paraquat 2	Control -
April	1.6	0.7	3.1	3.4	2.8	3.0	8.8
June	2.2	0.9	2.8	3.1	0	0	

Weed control at Thetford was very poor, even following June and October applications when the rates of both atrazine and ametryne had been doubled to $2\frac{1}{2}$ and 5 lb/ac. It was noted, however, that at the time of the April applications very little target vegetation was present on the plots (this was the only experiment in which this happened) and subsequent experiments have suggested that Holcus mollis L., which was dominant on this site, may be moderately resistant.

Results from the 1967 and 1968 experiments suggested that rates of atrazine should be somewhere between $2\frac{1}{2}$ and 5 lb/ac, and that applications in the first half of the growing season provided better control than applications in the second half. There seemed little point in continuing with ametryne because the control it provided was rather poorer than that provided by atrazine.

Weed control in the five experiments carried out in 1969 varies both between sites and within sites, but was generally quite good. The major factor producing the variation appeared to be grass species dominating the site, whilst the presence of woody weeds (e.g. bramble) was also important.

Table 2

Mean percentage live cover of grass weeds in 1969 experiments - Autumn 1969

Forest	Control	Paraquat M	Paraquat A/M	Paraquat J	Atrazine 2 lb M	Atrazine 2 lb A/M	Atrazine 2 lb J	Atrazine 3 lb M	Atrazine 3 lb A/M	Atrazine 3 lb J	Atrazine 4 lb M	Atrazine 4 lb A/M	Atrazine 4 lb J
Friston	80	20	30	15	0	0	75	0	5	55	0	0	20
Neroche	95	80	75	60	50	60	80	25	30	70	30	0	70
Thetford	100	24	37	19	47	24	38	48	11	21	24	41	13

Table 2 gives results for three sites where grass species were well controlled, especially by rates of 3 and 4 lb in March or April/May. At Thetford, there seemed little consistent difference in dates or rates.

Agrostis stolonifera (Friston and Neroche), A. tenuis Sibth, (Neroche), Anthoxanthum odoratum L. (Friston), Deschampsia flexuosa (L.) Trin. (Friston) and Holcus lanatus (all three sites) were very well controlled by the best treatments;

Arrhenatherum elatius (L.) J & C Presl. (Neroche) was moderately controlled, but Dactylis glomerata L. (Neroche) was poorly controlled, being only partially checked after application, and recovering quickly enough to be a troublesome weed before the end of the season.

At Friston (and also at Thetford - though the data is not given here) the grass control was appreciably better than the weeding times indicate. At Friston, Rubus fruticosus L. invaded plots very much in proportion to the degree of grass control. At Thetford, Urtica urens L. did likewise.

At Hursley Forest, variation in resistance to atrazine amongst the grasses and other vegetation completely masked any effect atrazine had on end of season % live cover, although mid-season observations showed control by March and April applications at 3 and 4 lb/ac was good. Table 3 shows how different components of the weed flora were altered in extent by the treatments.

Table 3

Difference in amount of live cover provided by various components between beginning and end of season assessments - Hursley 1969 (Expressed as % change on beginning of season live cover)

Paraquat 1 lb a.i.			Atrazine 2 lb a.i.			Atrazine 4 lb a.i.		
H + A	D	O	H + A	D	O	H + A	D	O
-23%	-3%	+57%	-38%	0%	+87%	-49%	-19%	+143%

H + A = Holcus lanatus + Anthoxanthum odoratum; D = Deschampsia caespitosa
O = others (mainly bramble and bracken).

At the Forest of Dean, neither applications of atrazine or paraquat appeared to have much effect on a site of nearly pure Holcus mollis.

The retreatment of all the 1969 experiments in 1970 (see Methods and Materials) generally confirmed the above results except at the Forest of Dean, where the retreatment at rates 50% higher than in 1969 seemed to be giving moderate to excellent control of Holcus mollis.

The object of the 1970 series was to confirm some of the findings in earlier trials, to test slightly earlier applications (useful in forestry) and to test granular atrazine. It has not been possible to collate all the data from these experiments in time for this paper, but the general weed control picture seems similar in experiments where assessments are available (Table 4).

Granular atrazine generally gave much poorer control than the wettable powder, although, where the proportion of susceptible grasses was high, control was satisfactory at earlier application dates. There was little to choose between the dates of application for the wettable powder.

Agrostis spp., Holcus lanatus and Alopecurus pratensis L. were well controlled wherever they occurred, even by 2 lb/ac of atrazine. Arrhenatherum elatius was satisfactorily controlled at 4 lb/ac. Dactylis glomerata and Deschampsia caespitosa (L.) Beauv. were again only poorly controlled, the former largely accounting for the rather higher % live cover in August 1970 at Neroche Forest.

Table 4

Mean percentage live cover of grass weeds - August 1970

Forest	Month	Control	Paraquat	Chlorthiamid	Atrazine wettable powder 2 lb	Atrazine wettable powder 4 lb	Atrazine granules 2 lb	Atrazine granules 4 lb
Bere	Feb.	94		6	19	2	18	17
	March			7	19	2	37	35
	April			9	31	7	61	41
Friston	Feb.	60	5		5	0	15	0
	April		13		20	0	35	5
	May		3		40	0	70	80
Neroche	Feb.	100	100		80	75	90	60
	March		100		80	60	90	80
	April		80		75	40	100	100

Note: Live cover at Neroche included weeds other than grass weeds, but these were very few.

At Bere Forest, Rubus fruticosus L. invaded treated plots, and again illustrated how some of the benefits of good grass control can be lost.

(b) Effects on tree crop

The preliminary trial in 1967 did not give rise to noticeable damage to the tree crop following applications of atrazine and ametryne up to 15 lb/ac. Crop trees were 3 years old, well established, and assessments of tree height were not taken. Thus, although failure to produce noticeable damage was interesting, it had to be treated with caution.

In the 1968 series analysis of the health scores showed that atrazine had caused no significant reduction in health compared with the control in either experiment. At Friston, a significant reduction in crop health at the end of 1968 on some paraquat treatments was attributed to the herbicide dripping onto the tree from the polythene bags upon their removal after spraying.

A number of significant differences in height growth occurred at Friston, both at the end of the first and second seasons. Table 5 gives the heights at the end of 1969, and shows that both Western hemlock and Corsican pine grew significantly better ($P = 0.05$) on plots treated with atrazine in April than on plots treated with atrazine in June or plots which were hand-weeded. Western hemlock on plots treated with atrazine in April also grew significantly better ($P = 0.05$) than on plots treated with atrazine in October.

This result seemed only explicable in terms of reduced weed competition (note similar trends on paraquat plots).

Table 5

Mean heights (cm) at the end of 1969 - Friston Forest. (Mean of 2 rates for atrazine and paraquat - heights adjusted for variations at the beginning of 1968 season

Species	Control	Paraquat Apr.	Paraquat June	Paraquat Oct.	Atrazine Apr.	Atrazine June	Atrazine Oct.	S.E.
Western hemlock	52.4	71.4	59.0	58.8	78.7	56.4	53.5	7.1
Corsican pine	35.2	30.5	42.0	34.4	45.1	35.3	39.1	3.4

In the 1969 series, heights at the end of the first season showed a number of significant differences (Table 6).

Table 6

Adjusted mean heights (cm) at the end of 1969 - 1969 Experiments

Site	Species	Control	Atrazine 2 lb			Atrazine 3 lb			Atrazine 4 lb			S.E.
			M	A	J	M	A	J	M	A	J	
Hursley	Western hemlock	48.4	47.9	50.5	42.0	49.3	46.9	41.8	48.0	43.0	37.3	2.2
Neroche	Sitka spruce	48.5	51.8	50.0	48.8	53.4	51.8	49.1	50.6	49.7	50.0	0.9
Thetford	Corsican pine	14.5	12.6	12.4	13.6	13.1	12.7	12.7	10.4	12.7	14.3	0.8
	Scots pine	18.1	17.7	15.9	18.4	17.4	18.2	18.8	15.0	17.2	15.9	0.9

There were a number of indications that on plots where atrazine had provided good control of weeds (usually March and April applications) crop growth was superior to those plots where weed control was poor (generally June applications).

Some treatments showed significantly (P = 0.05) poorer growth than control (Western hemlock @ 4 lb in June, Hursley; Corsican pine and Scots pine @ 4 lb in March, Thetford). Whether this was due to weed competition or atrazine damage is not clear. There were, however, few typical symptoms of atrazine damage ('scorched' or stunted leaves) at Hursley and Theford Forests where these differences occurred.

On the other hand, Sitka spruce at Neroche grew significantly better following applications of 2 lb/ac atrazine in March and 3 lb/ac of atrazine in March and April. Scores of leaf colour in August 1969 showed that the trees on all atrazine plots were greener than control plots, and there was every other indication that this was a genuine response to reduced weed competition. Typical atrazine damage was observed at Neroche, particularly on plots receiving 4 lb/ac atrazine in March, and the fact that trees on treatment of 4 lb/ac of atrazine did not grow more than control suggests that atrazine is capable of depressing crop growth.

At the Forest of Dean and Friston Forest there were no significant differences in height. At the Forest of Dean June applications of atrazine appeared to reduce survival both of Corsican pine and Grand fir, but since no visible symptoms of herbicide damage were seen and there was no difference between rates, it seems probable that this reduced survival was due to weed competition. At Friston, control plots of Norway spruce were markedly yellower than all herbicide plots, although there were no significant height differences.

Not all the 1970 experiments could be assessed and analysed in time for this paper, but Table 7 presents the height data for those that were. Generally, height differences are small, but there are three cases of significantly (P = 0.05) greater heights occurring on herbicide treatments than on controls, and these are all on atrazine treatments (Western hemlock at Friston - atrazine in February; Sitka spruce at Neroche - atrazine in February and March).

In the experiments assessed for crop health, there were no significant reductions in health compared with the control. However, at Neroche, symptoms of atrazine damage appeared on both crop species (needle browning). This was mainly present on plots receiving 4 lb/ac atrazine as a wettable powder, and was more severe on the Douglas fir than on Sitka spruce.

Table 7

Mean heights (cm) at August 1970 - 1970 Series

Site	Species	Control	Paraquat(P)/Chlorthiamid(C) Feb.	March/Apr.	Apr./May	Atrazine (w.p.only) Feb.	March/Apr.	Apr/May	S.E.
Bere (C)	Corsican pine	34.3	35.2	32.1	32.7	34.7	32.5	38.1	not yet analysed
	Norway spruce	28.1	27.2	28.9	28.8	28.1	31.3	29.8	
Friston(P)	Corsican pine	64.0	57.0	57.2	47.9	57.0	60.0	56.0	3.5
	Western hemlock	20.5	21.1	19.0	19.9	24.9	23.3	20.6	1.1
Neroche(P)	Sitka spruce	32.0	31.8	33.4	31.9	35.7	35.1	33.3	1.0
	Douglas fir	30.0	30.0	29.9	31.4	30.7	32.0	29.8	1.3

(Note: Heights for atrazine treatments are the mean of two rates)

DISCUSSION

Control of grass weeds in these trials has generally been good at rates of atrazine between 3 and 5 lb/ac, applied from February to May. The results from these trials have been adequate to define the application times and the rates of atrazine (w.p.) required for adequate grass weed control in forest situations.

The effectiveness of atrazine against grasses clearly varies greatly with the species. The very good and persistent control of both fine and soft grasses should make atrazine an attractive proposition for forest weed control, but the scope for its use in forestry would be considerably extended if techniques could be evolved of improving its efficiency against coarse grasses, particularly _Deschampsia caespitosa_ which is a common grass weed.

The poor control provided by granular atrazine suggests (not unexpectedly) that foliar absorption of the herbicide by grass weeds was necessary to provide adequate control. However, granular herbicides are very attractive to foresters because they avoid the cost and organisation difficulties of getting water to inaccessible areas. It seems worth while testing granular atrazine at slightly higher rates, and at the earlier application dates.

There have been references in the literature (Erdmann 1967 and Newton 1967) to poor control with atrazine resulting from dry weather following application. Observations throughout these trials suggest that this has not been an important factor in this country. Poor control from June onwards has not been related to dry weather (in fact some excellent control was obtained in 1970 when April and May applications were followed by extremely long periods of drought) but seemingly to maturing grasses acquiring resistance.

The tolerance to overall sprays of atrazine of the wide range of coniferous species tested means that applications can be made quickly and cheaply with simple spray machinery. The degree of tolerance to atrazine of various conifers requires more testing in a range of soil types and weather conditions before confident limits can be drawn. However, the results do suggest that little crop damage should result from applications of atrazine up to 3 - 4 lb/ac.

There have been a number of instances of improved crop growth on atrazine treated plots. There is reason to believe that these are genuine responses to reduced weed competition, although some form of response to small quantities of atrazine in the soil cannot be ruled out (Gast & Grob 1964). Improved colour (greener) observed in some species in these trials support both hypotheses.

References

ERDMANN, G.G. (1967). Chemical weed control increases survival and growth in hardwood plantations. U.S. For. Serv. Res. Note Nc - 34.

GAST, A. and GROB, J. (1964). Triazines in top fruit and viticulture. Proc. 7th Brit. Weed Cont. Conf. 217 - 226.

NEWTON, M. (1964). Chemical weed control in conifer plantations. Res. Progr. Rep. Western Weed Conf. 42 - 3. (School of For., Oregon State Univ. Corvallis).

NEWTON, M. (1967). Control of grasses and other vegetation in plantations. Symposium proc: Herbicides and vegetation management in forests, ranges and noncrop lands, 1967 - School of For. Oregon State Univ. Corvallis).

Proc. 10th Br. Weed Control Conf. 1970

USE OF TERBACIL AND OTHER HERBICIDES ON SOME ORNAMENTAL SHRUBS

James C. Kelly

Kinsealy Research Centre, Dublin. 5.

Summary Good results were obtained with terbacil, atrazine and dichlobenil in a range of nursery stocks. Terbacil at 0.5 and 1.0 lb/ac controlled a wide range of weed species without any adverse effect on Chamaecyparis lawsoniana, Olearia and Ligustrum. These doses caused a slight growth check to cuttings of Rosa rugosa and R. canina but the effect was transient. Atrazine gave similar weed control but caused no damage to any species. Dichlobenil at 5.0, 7.5 and 10.0 lb/ac controlled a dense infestation of Agropyron repens without damage to eight cultivars of Chamaecyparis lawsoniana. These herbicides appear promising adjuncts to the use of simazine for the control of weeds in nursery stocks.

INTRODUCTION

For some time simazine has proved satisfactory for the control of a range of annual weeds in many species of nursery stock. However, perennial weeds, especially Agropyron repens, and some species of annual weeds continue to be a problem in nurseries. This paper describes the effects of simazine, atrazine, lenacil, terbacil and dichlobenil on Agropyron repens and annual weeds in a number of shrubs in nursery beds.

METHOD AND MATERIALS

The trials at Kinsealy were on a medium loam soil containing 25.6% clay and 6.9% organic matter. At another trial site (St. Anne's, Dublin) the soil is a heavy clay loam containing 29.2% clay and 3.7% organic matter. The trials were laid out in a randomised block design or on a fully randomised basis. The granular formulation of dichlobenil was applied by hand. All doses of chemicals are given as lb/ac a.i. The treatments were applied in January 1970 and some were repeated in the following July. The genera concerned were Ligustrum, Rosa, Olearia and Chamaecyparis.

RESULTS

Experiment 1

The plants treated in this experiment were two-year-old Chamaecyparis lawsoniana 'Pottenii', about 12 in. high. Plot size was 27 ft^2. Planting date was 28 October 1969 and terbacil and simazine were applied on 27 January 1970. On 29 July all plots were hand weeded and the herbicide treatments were repeated on the same plots. The rainfall during the week prior to the January application was 13.2 mm and during the week after spraying 16.6 mm. The corresponding figures in July were 32.2 mm and 15.0 mm. Treatments and results are shown in Table 1.

No damage was visible in the crop. Capsella bursa-pastoris was controlled by all herbicide treatments. Stellaria media was controlled by all doses of herbicides except by the January application of simazine at 1.0 lb/ac where little control was evident on the date of the weed count 18 July. The high dose of both herbicides was needed to control Veronica spp. and Senecio vulgaris. Though both terbacil and simazine apparently checked the growth of Agropyron repens, it should be noted that the initial infestation with this weed was low and plants were small. The rainfall in May, June and July was 10.9 mm, 27.2 mm and 54.5 mm respectively. Due to these dry conditions the conifers grew slowly. No differences in height were recorded between the plants in the different treatments.

Table 1

Effect of two herbicides on weed growth in Chamaecyparis lawsoniana

Treatment lb/ac		Date applied 1970	Total weed count (27 ft^2)	% weed control (mean of 3 replicates)				
				Agropyron repens	Stellaria media	Capsella bursa-pastoris	Veronica spp.	Senecio vulgaris
Terbacil	0.5	27/1	40	74	70	100	30	27
"	0.5	29/7	-	92	99	100	100	99
"	1.0	27/1	17	87	80	100	70	77
"	1.0	29/7	-	98	100	100	100	100
Simazine	1.0	27/1	58	74	7	81	20	11
"	1.0	29/7	-	85	99	100	100	99
"	2.0	27/1	15	84	100	100	70	77
"	2.0	29/7	-	100	100	100	100	100
Control		untreated	104					

The herbicides were repeated on the same plots in July to observe their effects on the crop and weeds during the growing season. The ground was moist at the time of this second application. Heavy rain was recorded during the weeks after spraying, 67.3 mm being recorded in August and 61.7 mm in September. No adverse effect on the crop had been recorded by early October.

Experiment 2

Hardwood cuttings of Rosa rugosa and Rosa canina were planted in the open ground in December 1969 at St. Anne's, Dublin. Tables 2 and 3 show the degree of weed control on the 15 July and 10 September 1970 and the height attained by the cuttings during the season. On 29 July a second treatment of the herbicides was made at the same rates. Plot size in Rosa rugosa was 4.5 yd^2 and in Rosa canina 4.0 yd^2.

Table 2

Effect of four herbicides on weed growth in Rosa rugosa cuttings

Treatment lb/ac		Date applied 1970	Total weed count (4.5 yd^2)	% weed control (mean of 3 replicates)			Average height of cuttings (in.)	
				Senecio vulgaris	Lamium purpureum	Polygonum aviculare	15/7/'70	10/9/'70
Simazine	1.0	23/1	32	92	45	25	16	29
"	1.0	29/7	-	96	99	92	-	-
"	2.0	23/1	16	97	90	75	14	22
"	2.0	29/7	-	100	100	90	-	-
Atrazine	0.5	28/1	74	48	25	0	14	23
"	0.5	29/7	-	89	80	60	-	-
"	1.0	28/1	6	98	80	100	16	24
"	1.0	29/7	-	100	100	90	-	-
Terbacil	0.5	28/1	24	95	95	55	14	18
"	0.5	29/7	-	100	100	100	-	-
"	1.0	28/1	5	93	100	95	16	21
"	1.0	29/7	-	89	100	100	-	-
Lenacil	2.0	28/1	35	83	40	40	14	19
"	2.0	29/7	-	100	100	80	-	-
"	4.0	28/1	3	93	100	100	15	20
"	4.0	29/7	-	100	100	90	-	-
Control		untreated	114				11	15

No symptoms of leaf damage were evident in the cuttings except a slight yellowing on the leaves at the higher rate of terbacil. However, the plants thus affected soon grew out of the condition.

Table 3

Effect of four herbicides on weed growth in Rosa canina cuttings

Treatment lb/ac		Date applied 1970	Total weed count ($4.0\ yd^2$)	% weed control (mean of 3 replicates)		Average height of cuttings (in.)	
				Sisymbrium alliaria	Senecio vulgaris	15/7/'70	10/9/'70
Simazine	1.0	28/1	32	64	79	10	16
"	1.0	29/7	-	100	100	-	-
"	2.0	28/1	12	93	91	9	21
"	2.0	29/7	-	100	99	-	-
Atrazine	0.5	28/1	7	97	94	8	20
"	0.5	29/7	-	100	98	-	-
"	1.0	28/1	4	95	100	9	22
"	1.0	29/7	-	100	100	-	-
Terbacil	0.5	28/1	16	98	81	8	16
"	0.5	29/7	-	100	100	-	-
"	1.0	28/1	9	98	100	8	14
"	1.0	29/7	-	100	100	-	-
Lenacil	2.0	28/1	22	85	88	8	14
"	2.0	29/7	-	100	100	-	-
"	4.0	28/1	32	39	94	9	15
"	4.0	29/7	-	88	100	-	-
Control	untreated		185			7	11

All treatments gave good weed control except the lower doses of simazine and lenacil which were not effective in controlling Sisymbrium alliaria. Some retardation in growth was evident in plants treated with the higher dose of terbacil, and both doses of lenacil.

Experiment 3

Several herbicides (Table 4) were applied to two-year-old transplanted bushes and to established bushes of Olearia traversii. The date of spraying was 29 January 1970. The plot size was $24\ ft^2$.

Table 4

Effect of four herbicides on weed growth in Olearia traversii

Treatment lb/ac		Total weed count ($24\ ft^2$)	% weed control (mean of 3 replicates)		
			Polygonum aviculare	Polygonum persicaria	Senecio vulgaris
Simazine	0.75	25	79	100	100
"	1.5	11	94	96	100
Terbacil	0.25	40	80	88	78
"	0.5	12	91	99	95
Atrazine	0.5	45	86	96	100
Lenacil	2.0	29	90	85	95
Control	untreated	245			

Both doses of simazine and terbacil at 0.5 lb/ac gave good control of weeds. There was no noticeable damage to the plants at the end of the season, the treated plants being slightly more vigorous than those on the control plots. The established bushes were not visibly affected by the herbicides.

Experiment 4

A trial on the use of dichlobenil was carried out on eight cultivars of Chamacyparis lawsoniana. These were one-year-old plants grown from cuttings and planted into nursery beds at Kinsealy in October 1969. The herbicide was applied on 26 January 1970. A peat mulch of 0.5 to 1.0 in. was applied to some of the treated plots immediately after the application of the herbicide to examine the effect of the mulch on reducing volatilization. Table 5 shows the treatments and the results obtained.

Table 5

Effect of dichlobenil on weed growth in Chamaecyparis

Treatment lb/ac		Total weed count (30 yd^2)	% weed control			
			Agropyron repens	Papaver rhoeas	Polygonum aviculare	Capsella bursa-pastoris
Dichlobenil	5.0	80	96	98	55	50
" + peat	5.0	90	96	100	97	67
"	7.5	56	97	100	86	50
" + peat	7.5	60	97	100	87	92
"	10.0	80	95	94	83	52
" + peat	10.0	49	98	100	88	85
Control untreated		c. 1,000				

The dry season limited growth of the conifers and little difference in plant heights resulted from the respective treatments. All herbicide treatments gave good control of Agropyron repens but the peat mulch did not increase the effectiveness of the herbicide under the conditions of this experiment.

Experiment 5

A trial was carried out in July to observe whether herbicides could be applied to newly planted rooted cuttings of Chamaecyparis and Juniperus. These cuttings were transferred from frames to the open ground at Kinsealy on 17 July 1970 and were sprayed with terbacil at 0.5 and 1.0 lb/ac on the same day. There was no plant injury and both doses gave good control of annual weeds.

DISCUSSION

The soil at Kinsealy has high organic matter and clay contents and the doses used may not be as satisfactory on lighter soil types.

On the site where dichlobenil was used the soil was heavily infested with Agropyron repens and all doses gave very good control. In some cases, results with dichlobenil have been inconsistent, due to rapid volatilization but no obvious benefit accrued from the use of a peat mulch in this experiment.

No definite results on the effects of terbacil on Agropyron repens were obtained from these trials due to the sparsity of this weed in the experimental areas. Terbacil, however, is known to be highly effective against perennial grasses and it is noteworthy that it had no phytotoxic effects on any of the shrub species used in these experiments. It appears, therefore, that terbacil could be a useful herbicide in nurseries in view of the increasing prevalence of Agropyron repens resulting from the continued use of simazine.

The tolerance shown by the shrubs to atrazine is interesting as this herbicide is more effective than simazine under dry weather conditions and where weed seedlings are already established. It is also noteworthy that atrazine at 1.0 lb/ac gave good control of Polygonum aviculare as this weed is also becoming more prevalent following the increasing use of simazine and lenacil.

Although lenacil caused no damage to any shrub it does not appear to have any advantage over simazine, atrazine or terbacil in view of its high cost per acre and inadequate control of weeds.

A very wide range of annual and perennial weeds are currently found in shrub nurseries, due to the varying systems of crop production and plant age at the time of sale. In these circumstances there is need for the continued testing of new herbicides in nursery stocks and for the re-evaluation of established herbicides to prevent the build-up of resistant species as a result of weed control systems based on a narrow range of herbicides.

Acknowledgements

Thanks are due to Mr. J. O'Donovan and Mr. R. Rusk for technical assistance and to the Parks Department, Dublin Corporation for providing sites for Experiments 2 and 3.

Proc. 10th Br. Weed Control Conf. 1970

TRIALS TO INVESTIGATE THE CROP TOLERANCE OF TOP FRUIT TO DICHLOBENIL.

D.H. Spencer-Jones and D. Wilson
Mi-dox Limited, Smarden, Kent.

Summary Field trials with dichlobenil were laid down in 1966. Initially a 50% w.p. was used, this being replaced by a 7.5% granular formulation in 1967. Further trials with the latter were commenced in 1968. The results indicate that the maximum dose (19.5 lb/ac) used in these trials was tolerated by young apples and established apples and pears without adverse effect on yield, tree girth or extension growth after two and four consecutive years of treatment.

INTRODUCTION.

Trials results on bush fruit with dichlobenil granules were reported (1968). These showed blackcurrants and gooseberries to be tolerant to dichlobenil at 30 lb/ac. The current series of trials was laid down in 1966 and 1968 to investigate the effect of annual spring applications of dichlobenil at rates from 6.75 to 19.5 lb/ac (non incorporated) on young and established top fruit (4 apple, 1 pear). To cover soil and climatic variations sites were selected on a geographical basis. See Table 1.

Table 1

Trial No.	Location	Crop	Variety	Soil	1st year of Treatment.
1	Hereford	Est. apple	Cox/Lambourne	Coarse sandy clay loam.	1968
2	Sussex	Est. apple	Cox/Egremont	Clay loam	1968
3	Sussex	Young apple	Cox	Fine sandy clay loam	1966
4	Sussex	Young apple	Cox/Egremont	Fine sandy clay loam	1966
5	Hereford	Est. pear	Conference	Loamy coarse sand	1966

METHODS AND MATERIALS.

Dichlobenil as 50% w.p. was applied in 1966 to trials 3, 4 and 5, the year of planting on the apple trials. This formulation was superceded in 1967 by 7.5% granules which were used from then on. Two further trials (established apple) were commenced in 1968. Application was made as a 6ft band excepting trial 2 on which application was in tree squares (4 x 4 yds).

All trials were randomised block design with five replicates (trials 1 and 2) and four replicates (trials 3, 4 and 5). Plot size varied with site availability and the type of information required i.e. large plots in trials 1 and 2 where yields were recorded. 7.5% chlorthiamid granules were included in trials 1 and 2 as a comparative standard. Control plots on all trials were treated with paraquat as and when necessary. Details of treatments and plot size are shown in Table 2.

Table 2

Trial treatments - lbs. per applied acre.

Trial No.	Plot size No. of trees.	Dichlobenil							Chlorthiamid
1	8 - 12				10.125	14.25		19.5	10.125
2	7 - 8				10.125	14.25		19.5	10.125
3	4		8.25	9.75				19.5	
4	2	6.75	8.25	9.75			16.5		
5	4		8.25		10.125			19.5	

Yield per plot per variety was recorded on trials 1 and 2. On trials 1 and 2 (established apple) and on trial 5 (established pear), tree girth measurements were recorded annually, commencing the winter before the first treatment. Total extension growth and shoot numbers per tree were recorded annually on trials 3 and 4 (young apples), these in 1969 being replaced by girth measurements (trial 4 only) owing to rapidity of growth on this site.

Crop appearance was assessed visually over the period of the trials. On trials 1 and 2 a specific assessment for leaf margin chlorosis was made at harvest in 1969 for each tree, using the undermentioned scale.

0 = Nil
1 = Up to 30% leaves exhibiting marginal chlorosis
2 = 30 - 80% " " " "
3 = 81 - 100% " " " "
4 = As for 3 above but including interveinal yellowing
5 = As for 4 above but with marginal necrosis.

RESULTS.

I **Yields.**

Table 3

Annual yields - expressed as % of control

Treatment		Cox Trial 1 1968	Cox Trial 1 1969	Cox Trial 2 1968	Cox Trial 2 1969	Lambourne Trial 1 1968	Lambourne Trial 1 1969	Egremont. Trial 2 1968	Egremont. Trial 2 1969
Dichlobenil	10.125	101.7	104.5	104.8	94.6	111.9	90.7	122.4	104.8
"	14.25	94.7	111.3	104.8	106.5	84.2	102.5	123.6	111.0**
"	19.5	98.8	108.5	135.7*	102.2	104.9	129.8	118.2	89.3
Chlorthiamid	10.125	95.3	113.6	115.1	90.2	98.0	115.5	111.5	102.3

*Sig. greater than control and dichlobenil at 10.125 and 14.25 P= 0.01, and all treatments P= 0.05.

**Sig. greater than dichlobenil at 19.5 P= 0.05.

Table 4

Total yield - expressed as % of control

Treatment		Cox Trial 1	Cox Trial 2	Lambourne Trial 1	Egremont Trial 2	Mean
Dichlobenil	10.125	103.1	99.7	101.3	113.6	104.4
"	14.25	102.5	105.6	93.3	117.3	104.7
"	19.5	103.6	118.9	117.3	103.7	110.9
Chlorthiamid	10.125	104.4	102.6	106.7	106.9	105.1

Results (Table 3) show:-

1. Yields were not adversely affected by increasing rates of dichlobenil or by chlorthiamid at 10.125 lb/ac.

2. A significant increase on variety Cox was achieved in trial 2 in 1968 at 19.5 lb/ac over all other treatments at the 5% level.

3. A significant increase on variety Egremont in 1969 was achieved at 14.25 lb/ac at the 5% level but only when compared with treatment at the highest rate.

4. In both years, with the major exception of trial 1 (1968) most treatments resulted in increased yields over control though not achieving statistical significance. This trend becomes more apparent when considering the combined yields over the two seasons (Table 4), in respect of which no statistical data is presented.

II Tree girth increments

Table 5

Increment - expressed as % of control

Treatment		Cox Trial 1 1968	Cox Trial 1 1969	Cox Trial 2 1968	Cox Trial 2 1969	Lambourne Trial 1 1968	Lambourne Trial 1 1969	Egremont Trial 2 1968	Egremont Trial 2 1969	Pears Trial 5 1968	Pears Trial 5 1969
Dichlobenil	8.25	-	-	-	-	-	-	-	-	105.1	87.3
"	10.125	117.2	100.8	107.2	94.0	102.4	56.1	106.5	101.7	102.5	103.3
"	14.25	96.1	115.2	103.0	99.1	111.5	101.9	116.3	128.3***	-	-
"	19.5	88.3	100.0	102.1	102.8*	90.1	109.3	100.0	100.6	101.9	87.3
Chlorthiamid	10.125	104.7	106.4	119.6	84.7**	124.0	61.7	119.6	90.8	-	-

* Sig. greater than chlorthiamid P= 0.05
** Sig. less than control P= 0.1
*** Sig. greater than all treatments P= 0.05

The results in Table 5 show:-

1. Girth increments have not been adversely affected by dichlobenil at any rate or by chlorthiamid at 10.125 lb/ac, with the exception of trial 2, 1969, where on Cox, chlorthiamid resulted in a reduction in girth and dichlobenil at 19.5 lb/ac resulted in an increase over chlorthiamid but not over control.

2. In the same year and on the same trial, dichlobenil on Egremont at 14.25 lb/ac increased girth increment.

III Extension growth.

Table 6

Total extension growth - expressed as % of control

Treatment		Trial 3 1967/69 Ext. growth	Trial 3 1967/69 No. of shoots	Trial 4 1967/68 Ext. growth	Trial 4 1967/68 No. of shoots	Trial 4 1969 Tree girth.
Dichlobenil	6.75	-	-	155	149	105
"	8.25	110	115	166	171	109
"	9.75	78	92	187	179	114
"	16.5	-	-	143	160	105
"	19.5	118	118	-	-	-

The results in Table 6 show:-

Extension growth in terms of total growth, and numbers of new shoots, and tree girth, were not adversely affected by dichlobenil at any rate.

These results however do not achieve statistical significance.

IV Leaf margin chlorosis.

Table 7

Leaf margin chlorosis assessment expressed as mean score per tree. 1969.

Treatment		Cox Trial 1	Cox Trial 2	Lambourne Trial 1	Egremont Trial 2	Mean
Control		0	0	0	0	0
Dichlobenil	10.125	0.43	0.48	0.06	0.18	0.29
"	14.25	0.62	0.93	0.22	0.92	0.67
"	19.5	1.43	1.89	0.80	1.56	1.42
Chlorthiamid	10.125	1.10	0.86	0.81	0.20	0.74

DISCUSSION

In that the aim of these trials is to investigate any long term effect to the tree of annual applications of dichlobenil, no weed data is presented, all doses on all sites having resulted in clean weed free strips. On one site however, a severe infestation of Convolvulus arvensis has virtually been eradicated after four seasons at 16.5 lb/ac and very severely suppressed at 8.25 lb/ac.

Sandford (1964) reported symptoms of leaf margin chlorosis following treatment with chlorthiamid at rates up to 16 lb/ac. Crop yields were not affected. As chlorthiamid, under field conditions, is broken down into dichlobenil, a visual assessment for leaf margin chlorosis was made each season. Apart from a tendency to be more severe as the dose increased, the extent to which these symptoms occurred varied and followed no particular pattern.

More precise assessments were started in 1969, but as the method used is qualitative rather than quantitative, the results have not been analysed statistically. It is thus only possible to discuss trends from the data presented in Table 7. These indicate:-

a) The degree to which leaf margin chlorosis occurs increases with increasing dose.

b) At 10.125 lb/ac, leaf margin chlorosis was more severe after chlorthiamid than after dichlobenil treatment.

Despite the presence of leaf margin chlorosis, the results of these trials to date indicate that young apples and established pears tolerated four annual applications and established apples two annual applications of dichlobenil at rates up to 19.5 lb/ac without any adverse effect on yield, girth increment or extension growth. With one exception similar results were obtained from chlorthiamid at 10.125 lb/ac.

IV Leaf margin chlorosis.

Table 7

Leaf margin chlorosis assessment expressed as mean score per tree (1969)

Treatment		Cox Trial 1	Cox Trial 2	Lambourne Trial 1	Egremont Trial 2	Mean
Control		0	0	0	0	0
Dichlobenil	10.125	0.43	0.48	0.06	0.18	0.29
"	14.25	0.62	0.93	0.22	0.92	0.67
"	19.5	1.43	1.89	0.80	1.56	1.42
Chlorthiamid	10.125	1.10	0.86	0.81	0.20	0.74

DISCUSSION

In that the aim of these trials is to investigate any long term effect to the tree of annual applications of dichlobenil, no weed data is presented, all doses on all sites having resulted in clean weed free strips. On one site however, a severe infestation of Convolvulus arvensis has virtually been eradicated after four seasons at 16.5 lb/ac and very severely suppressed at 8.25 lb/ac.

Sandford (1964) reported symptoms of leaf margin chlorosis following treatment with chlorthiamid at rates up to 16 lb/ac. Crop yields were not affected. As chlorthiamid, under field conditions, is broken down into dichlobenil, a visual assessment for leaf margin chlorosis was made each season for all treatments. Apart from a tendency to be more severe as the dose increased, the extent to which these symptoms occurred varied and followed no particular pattern.

More precise assessments were started in 1969, but as the method used is qualitative rather than quantitative, the results have not been analysed statistically. It is thus only possible to discuss trends from the data presented in Table 7. These indicate:-

a) The degree to which leaf margin chlorosis occurs increases with increasing dose.

b) At 10.125 lb/ac, leaf margin chlorosis was more severe after chlorthiamid than after dichlobenil treatment.

Despite the presence of leaf margin chlorosis, the results of these trials to date indicate that young apples and established pears tolerated four annual applications and established apples two annual applications of dichlobenil at rates up to 19.5 lb/ac without any adverse effect on yield, girth increment or extension growth. With one exception similar results were obtained from chlorthiamid at 10.125 lb/ac.

References

SPENCER-JONES, D.H. and WILSON, D. (1968) Trials to investigate the herbicidal efficacy of dichlobenil in bush fruit with special reference to the control of Agropyron repens. Proc. Br. Weed Control Conf., II, 907 - 915.

SANDFORD, H. (1964) The use of 2,6 - dichlorothiobenzamide (W.L. 5792) in top and soft fruit. Proc. Br. Weed Control Conf., I, 208 - 216.

THE RESPONSE OF APPLES, PEARS AND PLUMS TO GROWTH - REGULATOR HERBICIDES APPLIED TO THE SOIL

J. G. Davison and D. V. Clay
ARC Weed Research Organization, Begbroke Hill, Sandy Lane, Yarnton, Oxford

Summary 2,4-D and 2,4,5-T at doses up to 12 lb/ac applied to the soil in July or September had no apparent effect on apples (cv. Lord Lambourne, Cox, Worcester and Bramley) and plum (cv. Pershore Yellow Egg).

2,4-D applied between July and September under pears (cv. Williams and Conference) caused severe formative effects on leaves, death of shoot tips and bud dormancy the year after treatment. Leaves on suckers and flowers were also affected. Degree of injury was not apparently related to timing of application; the lowest dose causing injury was 3.2 lb/ac. Painting of the base of the stems of the pears with 2,4-D caused similar effects to soil treatment. There was some evidence that 2,4-D persisted into the year following treatment.

2,4,5-T caused less injury to pears than 2,4-D at the same doses; shoot apices were killed and bud dormancy induced but there were no formative effects on leaves. MCPA caused least injury, the effects being of the same type as those caused by 2,4,5-T. All three herbicides caused injury to the cultivar Conference in the form of leaf epinasty and shoot dieback within a month of treatment when applied in July 1969.

The cultivar Conference was more susceptible to injury from these herbicides than was the cultivar Williams.

INTRODUCTION

Growth-regulator herbicides are commonly used for the control of perennial broad leaved weeds around tree bases in orchards. While the effects of spraying these herbicides on to shoots of fruit trees have been evaluated (Luckwill and Campbell, 1956; Ivens and Clay, 1966; Clay and Ivens, 1968), until this year there has been little published work on the possible hazards to these crops from uptake of the herbicides from the soil. Robinson (1960) found no crop damage resulted from treatments with up to 8 lb/ac 2,4,5-T and 5 lb/ac 2,4-D to soil around the base of established apple trees, although 2,4,5-T did cause damage when sprayed on to the bark of rootstocks. There have been a number of reports from growers and advisory officers of damage to pear trees for which growth-regulator herbicides were thought to be responsible (Commercial Grower, 1969). Goddrie (1970) working in the Netherlands found that 2,4-D and dicamba could give injury to pears by root uptake and that cultivar, dose of herbicide and soil type all influenced the occurrence and severity of injury.

The present work was undertaken to determine the possibility of injury resulting from tree base treatments with the commonly used growth-regulator herbicides. They were tested at different doses and different application dates through the growing season on several cultivars of apples and pears and one cultivar of plum and the effects were assessed over 1 or 2 years.

METHOD AND MATERIALS

The experiments were carried out at Begbroke Hill on fruit trees planted in a sandy loam soil overlying a calcareous gravel to a depth of 3 ft. Details of the cultivars used in the experiments, planting dates and tree spacings are detailed below. All the trees were planted as maidens.

Cultivar	Code	Rootstock	Spacing(ft)	Planting date
Apple				
Lord Lambourne	L	M VII	6 x 6	January 1965
Worcester Pearmain	W	M VII	6 x 6	" "
Coxs Orange Pippin	C	M VII	12 x 12	" "
Bramleys Seedling	B	M II, MM 106	6(one row)	March 1967
Pears				
Conference	PC	Quince A	6 x 6	March 1966
Williams Bon Chretien	PW	Quince A	6 x 6	" "
Plum				
Pershore Yellow Egg	P	Myrobalan	9 x 9	" "

The trees received dressings of compound fertilizer each spring up to 1967; subsequently, as growth was very vigorous only a spring soil dressing of magnesium sulphate was given each year. Weed control was maintained with applications of simazine at 2 lb/ac each spring (1 lb/ac under plums) and spot treatments with paraquat as necessary; no soil cultivations were carried out. A programme of pesticide applications and winter pruning was maintained each year.

The experiments were carried out on trees which had already been used for testing the effects of growth-regulator herbicides to the shoots. Only single shoots on each tree had been used and the effects were generally localised and short-lived: there were no signs of continuing effects of earlier treatments on the trees at the commencement of the experiments.

The experiments were laid out on a randomised block design with three blocks. Within each block there was one tree per chemical treatment and generally four untreated trees.

The herbicides applied in 1968 were 2,4-D (iso-octyl ester formulation 500 g/l a.e.) and 2,4,5-T (iso-octyl ester formulation 480 g/l a.e.); both were applied at 1.2, 3.6 and 10.8 lb/ac on 29/6/68 and 12/9/68 to apples (Lord Lambourne) and pears (Williams). The 1969 treatments are set out in Table 1.

As no symptoms of herbicide injury had been observed on the Lord Lambourne apple trees treated in 1968, the trees were treated again in July or September 1969. The trees received the same treatments except that those receiving the lowest doses of 2,4-D and 2,4,5-T in 1968 were used for the MCPA treatments in 1969.

The treatments to the soil were made to an area 4 ft x 4 ft under the trees with the trunk central. For the 1968 treatments the trunk base and the ground for 1½ in. out from the stem were covered with aluminium foil. As there appeared little risk of herbicide getting on the stem and it was shown that response to stem and soil treatments did not differ the foil was not used in 1969. To avoid any chance of drift of spray onto foliage the herbicides were applied at a high volume rate (240 gal/ac) from a watering can fitted with a medium rose. The soil was weed free at the time of treatment but there was often an extensive moss cover present on the soil.

Table 1

Herbicide treatments, application dates and cultivars treated in 1969

Herbicide	Formulation	Dose (lb/ac	Application dates	Cultivars treated Apple		Pear		Plum
2,4-D	iso-octyl ester 500 g/l a.e.	4	31/7	L W	C B	PW	PC	P
			26/8			PW		
			26/9	L W	C B	PW	PC	P
		12	31/7	L W	C B	PW	PC	P
			26/8			PW		
			29/9	L W	C B	PW	PC	P
2,4,5-T	iso-octyl ester, 480 g/l a.e.	4	31/7	L W			PC	
			26/9	L W	C B	PW	PC	P
		12	31/7	L W		PW	PC	
			26/8			PW		
			26/9	L W	C B	PW	PC	P
MCPA	potassium salt, 250 g/l a.e.	4	31/7	L W			PC	
			26/9	L W			PC	
		12	31/7	L W			PC	
			26/9	L W			PC	

At the first application date a herbicide volatility test was carried out to detect any movement of herbicide vapour from the solution being applied or later from the soil surface, which might give rise to foliar symptoms on the trees. Dwarf bean plants at the unifoliate leaf stage growing in 3½ in. pots, were placed at ground level and on stakes 2½ ft and 5½ ft above ground level at six points throughout the treated area. One batch of plants was placed in position just before treatment of the soil commenced and removed when the treatments were completed; they were replaced by a second batch of plants which was kept in position for a period of 2 days. After removal the beans were grown on in the glasshouse to observe the development of any symptoms of herbicide injury.

Assessments

Records were made of the growth stage of the crop and of soil surface and moisture conditions at each treatment date. Observations were made on the trees at intervals after treatment: the severity of any symptoms of leaf and shoot injury was estimated visually. Measurements of tree-girth were made in the winter of each year, the yearly increment in girth giving an index of tree growth during the previous year (Moore, 1966). The yield of fruit per tree on the apple cultivars Cox, Lambourne and Worcester was taken in 1970.

Table 2

The effect of soil applications of growth regulator herbicides to Williams pears in 1968

Treatment Chemical	Dose (lb/ac)	Application Date	Dormant shoot score*	Assessments 19/6/69 %Normal leaves	8/9/69 %Normal leaves	3/7/70 %Normal leaves	Girth increase° 1968-1970
2,4-D	1.6	28/6/68	0	98	99	100	99
	3.2	"	0	98	100	100	106
	10.6	"	x	40	95	100	82
2,4-D	1.6	12/9/68	0	97	99	100	101
	3.2	"	x	18	90	98	78
	10.6	"	xxx	1	82	89	43
2,4,5-T	1.6	28/6/68	0	100	100	100	109
	3.2	"	0	100	100	100	103
	10.6	"	0	100	100	99	97
2,4,5-T	1.6	12/9/68	0	100	100	100	92
	3.2	"	0	99	100	100	107
	10.6	"	x	64	97	100	89
Control 1			0	100	100	100	104
" 2			0	99	100	100	109
" 3			0	99	99	100	86
" 4			0	100	100	100	101

+ %Normal leaves - Estimated number of leaves not showing formative effects as % of the number of leaves present on control trees.

* Dormant shoot score x 15-30% shoot tips dormant, xx 35-65%, xxx 70-100%

o Girth increase. Expressed as % of mean value for control trees.

RESULTS

No symptoms of herbicide injury were seen in any of the beans used in the volatility test indicating that there was no significant movement of herbicide vapour from the treated plots during and after the applications.

Leaf and shoot growth, flowers and fruit formation on the Lord Lambourne apples treated in 1968 was normal in the year following treatment. Similarly the treatments on the three apple cultivars and Pershore plum in 1969 had no noticeable effect. Measurements of increase in trunk girth over the period of the experiment also showed no differences due to treatments, and the yield of fruit from the treated trees in the cultivars Cox, Lambourne and Worcester in 1970 was good and comparable to that from untreated trees.

The effects of the treatments on pears are shown in Tables 2 and 3. Where injury symptoms occurred in the season of treatment (Table 3) they took the form of leaf epinasty and bending and dieback of the shoot tips. Injury in subsequent seasons took the form of dormancy of buds on shoots with all chemicals and with 2,4-D, continuing dieback of shoots and formative effects (distinctive distortion and restriction of leaf development) on expanding leaves. With the highest rate of 2,4-D, symptoms occurred on new leaves well into the summer (i.e. not only on those initiated in the buds the previous year); these symptoms were also seen in the second growing season after treatment. In the same treatments formative effects also occurred in the season following treatment on the flowers, in the form of puckering of the petals and fusing of styles, and on some leaves on suckers arising from the tree bases.

Table 3

The effect of soil applications of growth regulator herbicides to Williams and Conference pears in 1969

Treatment	Dose (lb/ac)	Application date	8/9/69 Shoot injury score*		2/7/70 %Normal leaves		%Shoots dormant	
			Will.	Conf.	Will.	Con.	Will.	Conf.
2,4-D	4	31/7/69	0	0	93	75	0	0
"	12	"	0	3.3	45	43	22	33
"	4	26/8/69	0	-	60	-	7	-
"	12	"	0	-	43	-	32	-
"	4	26/9/69	0	0	100	100	0	0
"	12	"	0	0	99	100	5	0
2,4,5-T	4	31/7/69	-	0	-	100	-	0
"	12	"	0	4.3	100	96	2	22
"	12	26/8/69	0	-	100	-	2	-
"	4	26/9/69	0	0	100	100	0	0
"	12	"	0	0	100	100	0	0
MCPA	4	31/7/69	-	0	-	100	-	0
"	12	"	-	4.7	-	98	-	2
"	4	26/9/69	-	0	-	100	-	0
"	12	"	-	0	-	100	-	0

*Shoot injury score - 0, normal; 1, slight leaf epinasty; 2, severe leaf epinasty;
3, very severe epinasty and stem reddening;
4, apex of shoots bending, some dead;
5, majority of shoots dead.

The results indicate that 2,4-D was more damaging to pears than 2,4,5-T or MCPA but that 2,4,5-T and MCPA can cause leaf injury and shoot tip death in the season of treatment. There were no consistent effects of the timing of the treatments. 2,4-D on Williams gave most injury when applied late in the season in 1968 whereas the earlier treatments in 1969 resulted in damage and the September treatments were safe.

Conference was more severely damaged by the treatments than Williams; injury occurred in summer following July treatment and symptoms the following season were more severe.

DISCUSSION

The results of the test for herbicide volatility carried out at the first treatment date suggest that this factor was unlikely to have been a cause of any toxicity to the trees in this experiment in spite of the fact that ester formulations of 2,4-D and 2,4,5-T were used. It is not known what effect differences in formulations have on the penetration and persistence of these herbicides in the soil.

The results presented in Tables 2 and 3 show the considerable tolerance of the apple and plum cultivars that were tested to soil applications of growth-regulator herbicides including 2,4-D. The fact that the same treatments caused damage to pears when applied at the same doses and times suggest that the herbicides are in contact with the roots, but that they either do not enter the tree tissues or else are quickly broken down once they enter. The rapid de-toxification of 2,4-D by many apple cultivars, particularly those related to Cox's Orange Pippin, has been clearly demonstrated although other cultivars such as Bramley like pears are less able to de-toxify 2,4-D (Luckwill and Lloyd-Jones, 1960; Clay and Ivens, 1968). The tolerance of apples (cv. Lord Lambourne) to 2,4-D and 2,4,5-T was also demonstrated in that when the basal 12 in. of the trunks were painted with solutions of these herbicides at concentrations of up to 3700 ppm at the same time as the soil treatments there were no effects on the trees. In a weed control experiment in the same plantation of Lord Lambourne apples, treatments with up to 4 lb/ac of either 2,4-D, 2,4,5-T or MCPB at high volume were applied to the soil under the trees twice in 1968 and twice in 1969 between early June and late September with no later indication of damage to the trees.

The finding that pears are susceptible to injury from soil application of growth-regulator herbicides agrees with the results of work in the Netherlands (Goddrie, 1970). The greater susceptibility of pears to injury from 2,4-D and 2,4,5-T compared with apples was further demonstrated in that application of 2,4-D and 2,4,5-T to the basal 12 in. of the trunk of cultivar Williams in September 1968 at doses up to 3700 ppm caused comparable effects to the soil treatments with these herbicides made at the same time. 2,4-D appears to be considerably more toxic to pears than MCPA or 2,4,5-T although high doses of these herbicides did cause shoot death shortly after treatment on one cultivar. These results and the continuing effect of 2,4-D in subsequent seasons closely parallels the effects of shoot applications of these herbicides (Clay and Ivens, 1968). With the September 1968 2,4-D treatments at 10.6 lb/ac the number of leaves on new shoots showing growth regulator herbicide effects in 1969 varied but was often of the order of 15 to 20. This was more than the total number of leaf initials likely to have been present in the apical buds at the time of treatment and suggests that 2,4-D itself is persisting and causing these effects the year after treatment. It was also observed on the new shoots produced in 1969 that the severity of symptoms on successive leaves frequently decreased and then increased again, two or three leaves in the transition zone showing slight or no formative effects. This again points to 2,4-D being moved to the shoot apices in the growing season following treatment.

The comparison of effects on the two pear cultivars confirm the finding of Goddrie (1970) that pears show differential varietal susceptibility; in this case Conference appears more susceptible to injury than Williams.

There was a clear difference in the response of the pears according to the dose applied and no injury was found from applications at the nominal commercial doses.

The lack of any correlation between timing of application and incidence of injury also agrees with the results of Goddrie (1970). Examination of rainfall data for the periods before and after the treatment dates does not suggest a direct influence of rainfall pattern on toxicity. The degree to which the herbicides penetrated into the soil is unknown.

The results of these experiments suggest that there should be no risk to apples from any of the growth regulator herbicides tested when used commercially even if the soil is sprayed. The related chemicals mecoprop, dichlorprop and MCPB should also be safe since their effects on apple shoots have been shown to be similar in type and intermediate in severity between MCPA and 2,4,5-T (Clay and Ivens, 1968).

On pears the spraying of stems and bare soil under trees with 2,4-D could lead to injury as could over-dosing when treating weed infestations under trees. MCPA and 2,4,5-T appear much safer for use under this crop.

Acknowledgements

The help of Messrs. A. H. Marks and Company Ltd., and Boots Pure Drug Company Ltd., in supplying the chemicals used in these experiments is gratefully acknowledged. Thanks are due to the members of the Horticulture Section of the Weed Research Organization for assistance with the experimental work.

References

CLAY, D. V. and IVENS, G. W. (1968) The response of apples, pears and plums to shoot applications of growth-regulator herbicides. Proc. 9th Br. Weed Control Conf. 939-946.

COMMERCIAL GROWER (1969) Suffolk pears show weedkiller damage. Comml. Grow., 3831, 837.

GODDRIE, P. D. (1970) [The influence of auxin-type growth regulators on pears] Jvensl. Proefstn Fruitteelt Valle Grond, 1969, 101-113.

IVENS, G. W. and CLAY, D. V. (1966) The effect of growth-regulator herbicides on fruit trees - a progress report on experiments with apples. Proc. 8th Br. Weed Control Conf. 103 - 109.

LUCKWILL, L. C. and CAMPBELL, A. I. (1956) The tolerance of fruit crops to certain selective and pre-emergance herbicides. Proc. 3rd Br. Weed Control Conf. 539-542.

LUCKWILL, L. C. and LLOYD-JONES, C. P. (1960) Metabolism of growth regulators II Decarboxylation of 2,4-dichlorophenoxyacetic acid in leaves of apple and strawberry. Ann. appl. Biol., 48, 626-636.

MOORE, C. S. (1966) The relationship of increment in trunk girth with shoot growth in apple trees. Rep. E. Malling Res. Stn. 1965, 115 - 119.

ROBINSON, D. W. (1960) Results of trials with herbicides in fruit crops. Rep. Hort. Centr., Loughgall, 1960, 1 - 15.

Proc. 10th Br. Weed Control Conf. 1970

THE CONTROL OF CONVOLVULUS ARVENSIS AND CALYSTEGIA SEPIUM IN ORCHARDS AND VINEYARDS WITH 2-TERTIOBUTYL-4-(2,4-DICHLORO-5-ISOPROPYLOXYPHENYL)-(4H)-1,3,4-OXADIAZOLINE-5-ONE

L. Burgaud, J. Deloraine, M. Guillot, M. Riottot
Société des Usines Chimiques Rhône-Poulenc

Summary In orchards and vineyards of several areas of France, 2-tertiobutyl-4-(2,4-dichloro-5-isopropyloxyphenyl)-(4H)-1,3,4-oxadiazoline-5-one (17,623 RP) has controlled *Convolvulus arvensis*, and *Calystegia sepium*, applied pre-emergence at 4 kg/ha or post emergence at 2 kg/ha. Treatment must be repeated for several years for complete eradication of *Convolvulus arvensis* and *Calystegia sepium*. On grape vines, RP17,623 is not phytotoxic through root absorption; however spray drift on young leaves should be avoided. No phytotoxic symptoms have been detected on apple or pear trees.

INTRODUCTION

In order to avoid weed competition, French vine and fruit-growers used to cultivate orchards and vineyards. For several years, persistent herbicides have been used at the end of winter, to avoid cultivations, however, they are generally ineffective against *Convolvulus arvensis* and *Calystegia sepium*, which may develop completely covering the soil.

2-tertiobutyl-4-(2,4-dichloro-5-isopropyloxyphenyl)-(4H)-1,3,4-oxadiazoline-5-one (17,623 RP) is a new herbicide (Burgaud (1969).) with the unique property of controlling *C. arvensis* and *C. sepium* both pre and post-emergence (Burgaud et al (1969) and Amphoux et al (1969).) and of being practically non-phytotoxic to vines when applied to the soil. (Julliard et Ancel (1967 & 1969) Burgaud et al (1969).)

We have studied dose and time of treatment and we have examined the possible influence of successive yearly treatments on *Convolvulus arvensis*, *Calystegia sepium* growth.

METHOD AND MATERIALS

17,623 RP was used as an emulsifiable concentrate containing 400 g/l a.i. in 1968, as a wettable powder containing 30% a.i. in 1969 and as an emulsifiable concentrate containing 250 g/l a.i. in 1970.

In order to aid *C. arvensis* and *C. sepium* growth, each site was sprayed with simazine at 3 kg/ha in February-March each year. Aminotriazole at 3 kg/ha, sprayed post-emergence of *C. arvensis* and *C. sepium* was used as the standard treatment. Every experiment was carried out with at least 4 replications.

In vineyards, 6 to 15 vine plants were included in each plot; plant density, generally high, varied from 4000 to 10,000 vine plants per hectare. Grape vine varieties have differed from area to area:

- Chenin and Groslot at Dampierre, Coutures, St-Saturnin (49*)
- Chardonnay at St-Bris-le-Vineux and La Chapelle-Vaupelteigne (89*)
- Gamay at Marcilly and Breuil (69*)
- Cinsault at Nîmes (30*)

In orchards, 5 to 12 trees were included in each plot; plant density varied from 1000 to 1600 trees per hectare. The varieties were as follows:

apple: Golden Delicious at Emerainville (77*), Curis (69*) and Charbonnière (69*) Starking Delicious at Lissieux (69*).

pear: Passe-crassane at Lissieux (69*) and Maclas (42*), Alexandrine Douillard and Packam's Triumph at Charbonnière (69*)

The spray volume was 1000 l/ha; the sprayed area covered 1 metre on either side of the plant row. Plot area varied from 15 to 30 m^2, i.e. 2 x 7.5 to 15 m.

Pre-emergence treatments were applied during dormancy, between February 15 and April 1; treatments applied post-emergence of C. arvensis and C. sepium were carried out from May 15 to the end of June.

Efficacy was evaluated by the C. arvensis and C. sepium growth: C. arvensis and C. sepium soil coverage was expressed as a percentage. Assessments were made in May-June, July and September 1970. In May-June, they were carried out just before post-emergence treatments.

RESULTS

The percentage coverage for all trials is presented in table 1 and 2. Table 1 deals with pre-emergence applications and control, and table 2 with post-emergence and aminotriazole treatments; percentages for each site are on corresponding lines in tables 1 and 2 and since they belong to the same trial, they may be compared.

Assessments, made in 1970, may be related to one application (1970) or two (1969-70) or three (1968-1969-1970). In table 2, percentages calculated in May-June for one application (1970) are really control data and are indicated by an asterisk.

DISCUSSION

Comparing table 1 and 2, there is good evidence that post-emergence treatments are generally more effective than pre-emergence applications. The best results were obtained post-emergence at 2 kg/ha and pre-emergence at 4 kg/ha. If May-June assessments are considered, i.e. before post-emergence treatments (table 2), the persistence of 17,623 RP is evident at 4 kg/ha from the 2nd year, also after 3 years at 2 kg/ha. Such results are partly due to the persistence of 17,623 RP in soils (Desmoras et al (1970).).

In the Dampierre trial, where it was possible to compare data after 1,2 and 3 years, the statistical analysis was carried out on the percentages of coverage, transformed into arc $\sin\sqrt{x}$. The "treatment" sum of squares was partitioned into 7 independent comparisons corresponding to the 7 degrees of freedom as indicated in

* Code number of the French Department

table 3. Such analysis, for July 1970 assessments, leads to the following interpretations;

Post-emergence treatments give results which are significantly different as compared to pre-emergence treatments (relation 3).

When studying dose, relations 4 and 6 (quadratic) are not significant, but relations 5 and 7 linear are significant; since the coefficients of the orthogonal comparison are valid for dose in arithmetical progression, the complete set of relations 4, 5, 6 and 7 shows that transformed percentages of soil coverage are inversely proportional to the logarithm of the doses. Corresponding regression lines have been drawn (fig 1).

Figure 1 shows the influence of dose, of times of spraying and of number of years of treatment. It should be noticed that there is no significant interaction between years and treatments in this trial.

Although the results of the Dampierre trial should not be generalised, it is useful to note that the Nîmes trial, subjected to the same statistical analysis for July assessments, gives identical conclusions, although the interaction year x treatment is significant.

In the Lissieux and St-Saturnin trials, efficacy is considerably less satisfactory. In both trials Calystegia sepium was present: it grows and climbs up very rapidly, and so the possible spray period is reduced; it differs from Convolvulus arvensis which creeps on the ground and may be sprayed on leaf and stem or be effected by direct contact from the sprayed soil surface when it has not been controlled pre-emergence.

In all cases it is necessary to spray carefully in order to get even spray coverage on the soil: high volume applications (with a minimum of 1000 l/ha are preferred.

Soil preparation is an important factor during the first year of treatment: reduced efficacy has been noted on cloddy soils with a high clay content or on stony soils.

Climatic conditions after treatment may affect the efficacy: rainy or wet conditions enhance the absorption of 17,623 RP, and a dry period decreases its activity.

In orchards, no symptom of phytotoxicity was ever detected. On vines, 17,623 RP is not phytotoxic through root absorption (Julliard et Ancel (1967-1969).) but spray drift on leaves caused heavy scorch. The product is not translocated in the plant but young leaves may be killed. To prevent this, it is necessary to avoid treatment at the first flush of growth and spraying is therefore only recommended pre-emergence of the Convolvulus arvensis and Calystegia sepium while the vines are dormant or later post-emergence when the vines have abundant less sensitive foliage.

Table 1

Percentage coverage of bindweed after yearly application of 17 623 RP, pre-emergence

Site	Length of Trials / Time of Assessment	17 623 RP 1 kg/ha May June	1 kg/ha July	1 kg/ha Sept.	2 kg/ha May June	2 kg/ha July	2 kg/ha Sept.	4 kg/ha May June	4 kg/ha July	4 kg/ha Sept.	Control May June	Control July	Control Sept.
VINES													
Dampierre (49) (1)	3 years	33	54	21	16	36	15	2	3	2	39	58	25
	2 years	41	67	31	22	44	36	6	22	9	43	64	40
	1 year	42	57	35	42	55	57	23	25	15	59	59	47
Coutures (49)	3 years	26	50	39	17	26	20	1	3	2	39	54	28
St Saturnin (49)	2 years	16	51	31	16	62	24	2	13	10	69	82	57
St Bris-le-Vineux (89)	2 years	13	10	11	8	9	8	1	2	1	57	54	53
La Chapelle-Vaupelteigne (89)	3 years	26	22	16	3	4	15	0	0	0	69	79	60
Marcilly (69)	2 years	-	-	-	55	59	62	12	17	40	(2)	(2)	(2)
Breuil (69)	1 year	-	-	-	3	18	25	1	6	6	21	61	(2)
Nîmes (30)	3 years	6	67	(3)	2	28	(3)	0	1	(3)	58	82	(3)
	2 years	6	71	(3)	5	53	(3)	0	5	(3)	58	89	(3)
	1 year	25	73	(3)	7	62	(3)	2	18	(3)	56	80	(3)
ORCHARDS													
Emerainville (77)	3 years	-	-	-	55	80	85	2	3	4	95	97	96
	2 years	-	-	-	82	96	96	6	9	10	95	97	96
Charbonnière (69)	3 years	-	-	-	15	28	-	12	24	-	(2)	(2)	(2)
	2 years	-	-	-	16	31	-	10	24	-	(2)	(2)	(2)
Lissieux (69)	2 years	22	25	55	29	33	62	13	17	40	(2)	(2)	(2)
Curis (69)	1 year	-	-	-	2	11	19	0	3	10	17	45	45
Maclas (42)	1 year	-	-	-	1	40	51	0	20	36	20	67	72

(1) : (49) = code number of the French Department

(2) : the control was hoed

(3) : missing value: the soil was cultivated by error

Table 2

Percentage coverage of bindweed after yearly application of 17 623 RP, post-emergence

Site	Length of Trials / Time of Assessment	17 623 RP 1 kg/ha May June	July	Sept.	2 kg/ha May June	July	Sept.	4 kg/ha May June	July	Sept.	Aminotriazole 3 kg/ha May June	July	Sept.
VINES													
Dampierre (49) (1)	3 years	37	16	15	34	3	6	6	0	0	19	8	4
	2 years	24	18	17	41	11	13	2	0	0	29	41	7
	1 year	59*	34	40	45*	9	19	48*	2	5	41	21	19
Coutures (49)	3 years	10	0	0	11	1	0	5	0	0	33	17	19
St Saturnin (49)	2 years	9	12	10	19	4	6	14	2	3	41	30	39
St Bris-le-Vineux (89)	2 years	35	38	0	16	15	0	12	10	0	52	62	19
La Chapelle-Vaupelteigne (89)	3 years	9	14	0	6	7	0	5	2	0	36	44	6
Marcilly (69)	2 years	-	-	-	28	15	45	3	5	10	72	82	70
Breuil (69)	1 year	-	-	-	16*	2	7	14*	1	3	19(2)	10	14
Nîmes (30)	3 years	9	4	(3)	7	3	(3)	3	0	(3)	35	10	(3)
	2 years	8	15	(3)	12	5	(3)	7	0	(3)	35	17	(3)
	1 year	12*	6	(3)	13*	3	(3)	17*	1	(3)	39	19	(3)
ORCHARDS													
Emerainville (77)	3 years	-	-	-	4	0	8	7	0	0	90	60	45
Charbonnière (69)	2 years	-	-	-	3	0	0	4	0	0	86	55	42
	3 years	-	-	-	(4)	6	54	(4)	4	42	(4)	42	72
	2 years	-	-	-	-	-	-	-	-	-	-	-	-
Lissieux - (69)	2 years	-	-	-	(4)	6	54	(4)	4	42	(4)	42	72
Curis (69)	1 year	-	-	-	-	-	-	-	-	-	-	-	-
Maclas (42)	1 year	-	-	-	17	4	16	19*	1	5	19	55	59

(1) : (49) Code number of the French Department
(2) : 2 treatments at 1 month interval
(3) : missing value : the soil was cultivated by error
(4) : treatment of bindweed during emergence

Table 3

Partitioning of the "treatments" of sum of squares
Orthogonal comparisons
Dampierre trial

	17 623 RP Pre-emergence 1 kg/ha	2 kg/ha	4 kg/ha	Post-emergence 1 kg/ha	2 kg/ha	4kg/ha	Amino-triazole 3 kg/ha	Control
Relation 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	- 7
2	+ 1	+ 1	+ 1	+ 1	+ 1	+ 1	- 6	0
3	+ 1	+ 1	+ 1	- 1	- 1	- 1	0	0
4	+ 1	- 2	+ 1	0	0	0	0	0
5	+ 1	0	- 1	0	0	0	0	0
6	0	0	0	+ 1	- 2	+ 1	0	0
7	0	0	0	+ 1	0	- 1	0	0

Reference

AMPHOUX, M., AGULHON, R., and VERGNES, A. La lutte contre quelques plantes vivaces dans le vignoble méridional. 5th Conf. COLUMA - 924 (1969)

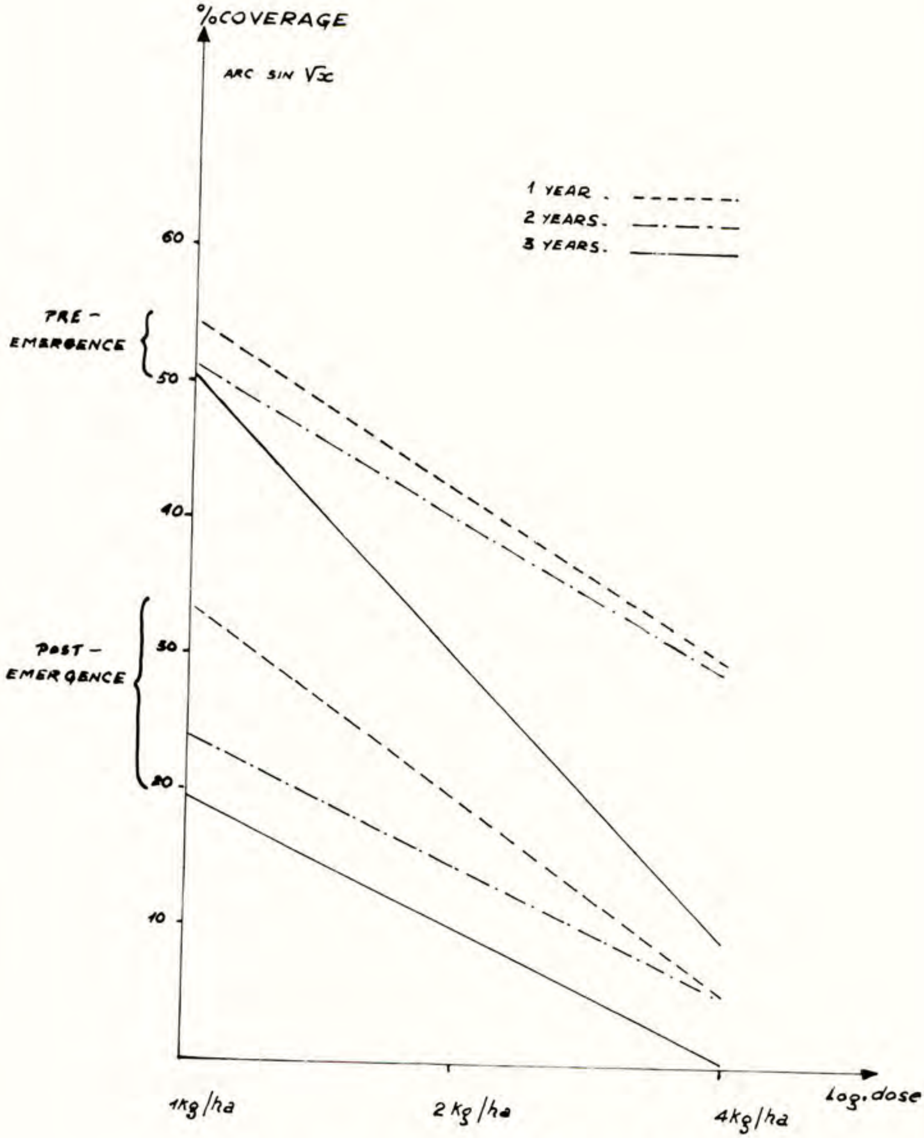
BURGAUD, L., DELORAINE, J., DESMORAS, J., GUILLOT, M., PETRINKO, P., RIOTTOT, M., Etude de l'activité et de la sélectivité en plein champ d'un nouvel herbicide: la tertiobutyl-2-(dichloro-2,4-isopropyloxy-5 phényl)-4 oxo-5 oxadiazoline-1, 3,4. 3rd Symp. Eur. Weed Res. Coun. - 201 (1969)

MESMORAS, J., LAUTENT, M., PETRINKO, P. and VUYS, M. Etude de la persistance et de la migration dans le sol du 17623 RP. C.r. VIIth int. Congr. Plant Prot. Paris (1970) (under press).

JULLIARD, B. et ANCEL, J. Essais préliminaires d'herbicides pour le désherbage de la vigne. 4th Comg. COLUMA - 609 (1967)

JULLIARD, B., et ANCEL, J. Premières évaluations de la phytotoxicité de quelques herbicides pour la vigne. 5th Conf. COLUMA - 884 (1969)

LANGE, A.H., FISCHER, B.B. and LIDER, L. The results of 1969, a grape herbicide screening trial. Res. Progr. Rep. west Soc. Weed Sci. - 40 (1970)



% COVERAGE VS. DOSE RATES

Fig. 1 – DAMPIERRE. ASSESSMENT OF JULY 23, 1970

Proc. 10th Br. Weed Control Conf. 1970

THE DEVELOPMENT OF TERBACIL AND BROMACIL FOR THE CONTROL OF AGROPYRON REPENS AND OTHER WEEDS IN SOME FRUIT CROPS

C Myram & J D Forrest
Bayer Agrochem Ltd, Bury St Edmunds, Suffolk

Summary In replicated trials in apple orchards, terbacil gave commercially acceptable control of *Agropyron repens*, *Agrostis* spp., other grasses and some broad-leaved weeds at 2.4 lb per acre. This result was supported by grower usage trials. Nineteen apple varieties tolerated terbacil at rates of 2.4 lb to 8 lb per acre. A similar range of trials showed that bromacil at 2.8 lb controlled almost the same species of weeds in cane fruit without any adverse effect on the crop.

INTRODUCTION

The aim of the development programme was to study the effect of terbacil and bromacil particularly on rhizomatous grass weeds, and to establish the tolerance of apples and cane fruit respectively to the two materials.

The work was initiated at Rowhill Experimental Farm with terbacil in 1966 following reports of its activity and selectivity from the United States of America. (Hilton *et al*. (1964), Hoffman *et al*. (1964), Hill *et al*. (1965).) This was followed in 1967 and 1968 by small plot replicated trials, and in 1968 grower strip trials, in Eastern, Southern and Western England. Bromacil has been used as a non-selective herbicide but was found to show selectivity on raspberries at the Scottish Horticultural Research Institute. (Waister (1966).) Further work on this aspect has been carried out by Lawson (1968). Replicated trials were commenced in 1967 by ourselves and continued in 1968. These were carried out in Scotland, Eastern, Western and Southern England on raspberries, blackberries and loganberries.

METHOD AND MATERIALS

Terbacil was used as an 80% wettable powder formulated as Du Pont Herbicide 732 (Sinbar).

Bromacil was used as an 80% wettable powder formulated as Du Pont Herbicide 976 (Hyvar X).

Applications on the small plot trials were made with standard knapsack sprayers as a band, a tree base or an overall treatment. Plot sizes, number of replicates and soil type are given in Tables 1 and 4. The grower usage trials were applied by growers' normal equipment, either as a band or overall treatment and plot size was at least one acre. Application dates of terbacil on apples ranged from early February to mid-June and with bromacil on cane fruit from February to May.

All control plots were untreated and unweeded.

Assessments

1 Weed assessment. Trials were assessed by using a visual scoring system, 0 = no control and 10 = 100%.

2 Soil analysis. Representative samples from the top 2 in of soil were taken from each site. A mechanical analysis was subsequently carried out using the Bouyoucos hydrometer method. The soil was then classified on the basis of sand, silt and clay content. (Pizer et al (1957).) Organic mater contents were determined using the dichromate titration technique.

3 Crop tolerance. Yield assessments were carried out on a fruit per tree or per plot basis. In one instance on apples the fruit was graded into sizes. Apart from yield data crops were observed or scored for any adverse effect on leaf or vigour. In one trial on apples the fruit of six varieties was graded for eye, stalk and side russet, 0 = no russet to 3 = severe russet. The formula of Townsend and Heuberger (Unterstenhöfer (1963).) was applied to the resulsts obtained:-

$$P = \frac{(\text{sum of } n \times v)}{3 \times N} \times 100$$

where P = degree of russeting, N = total number of fruits assessed per plot, n = number of fruits recorded in each grade and v = grade.

RESULTS

The results are reported below in two sections - 1 terbacil and 2 bromacil.

1 Terbacil - apples

1.1 Weed Control. From 1966 - 1969 over 50 trials have been carried out and results from a selection of these is given in Tables 1 and 2. Results are shown from trials where Agropyron repens infestation was heavy.

Table 1

Small plot trials - control of Agropyron repens

Terbacil/ac	1	2	3	4	5	6	7	8
1.6 lb	9.7	5.7	7.7	5.3	10	9.0	10	10
2.4 lb	7.3	9.3	-	-	-	-	10	-
3.2 lb	10.0	-	9.3	9.7	10	10.0	10	10
4.8 lb	9.3	9.3	-	-	10	-	-	-
Control	0	0	0	0	0	0	0	0
Weeks after treatment	18	11	22	22	23	19	35	30
Soil type	L	L	SCL	CSL	CSL	CL	ZyL	ZyL
Plot size yd^2	30	32	40	40	24	24	12	8
No. of replicates	3	3	3	3	2	1	5	3

These results suggested that terbacil was promising at a rate of 2.4 lb/ac on Agropyron repens and therefore a series of grower trials was planned in 1968.

Table 2

Grower Trials 1968 - total weed control score from 13 different sites

Terbacil/ac	1	2	3	4	5	6	7	8	9	10	11	12	13	Mean
2.4 lb	9.5	9.5	7.5	7	9	9.5	4*	7.5	8.5	7.5	8.5	9	7.5	8.0
Weeks after treatment	31	30	29	28	29	14	25	25	23	21	14	33	19	
Soil type	SL	SL	CSL	FSL	Org ZyC	L	ZyL	SL	FSL	FSL	CS	LCS	LS	

*Trial mulched with manure before application.

In Table 2 eleven of these trials showed 100% control of Agropyron repens and one trial 100% control of Agrostis stolonifera. Sample digs nine months after treatment showed that all rhizomes had been killed with 2.4 lb/ac of terbacil.

It was observed that terbacil was slow acting and leaf dieback took several weeks.

Weeds other than Agropyron repens and Agrostis stolonifera found to have been well controlled by terbacil at 2.4 lb/ac were:-

Agrostis tenuis, Artemisia vulgaris, Bromus sterilis, Chenopodium album, Dactylis glomerata, Epilobium spp., Festuca spp., Hordeum murinium, Lamium purpureum, Lolium perenne, Medicago arabica, Poa annua, Poa pratensis, Poa trivialis, Polygonum aviculare, Polygonum persicaria, Sonchus arvensis, Sonchus oleraceus, Solanum dulcamara, Stellaria media, Tripleurospermum maritimum ssp. inodorum.

The following perennial weeds were found to be moderately susceptible:

Anthriscus sylvestris, Rumex crispus, Rumex obtusifolius, and Torilis spp. whereas Calystegia spp., Cirsium spp. and Veronica spp. were moderately resistant. Senecio vulgaris was initially well controlled but reinfestation did occur. The following weeds were found to be resistant: Convolvulus arvensis, Equisetum spp., Ranunculus repens, Taraxacum officinale, Urtica dioica. However, in some cases, particularly with Urtica dioica, vigour was markedly reduced.

1.2 Crop tolerance. Following early work showing the effectiveness of terbacil on weed control repeated high annual doses were used to study crop tolerance. The varieties Cox's Orange Pippin, Worcester Pearmain and Crispin were treated in replicated trials annually for a period of three years at 4.8 lb/ac without any visible effect. Cox's Orange Pippin treated with 8.0 lb/ac in two successive years also showed no visible effect. From other replicated and grower trials the following varieties established for at least 4 years were found to tolerate at least 2.4 lb/ac of terbacil:

Blenheim Orange, Bramleys Seedling, Discovery, Egremont Russet, George Cave, Grenadier, James Grieve, Jonathan, King of the Pippins, Lanes Prince Albert, Laxtons Fortune, Laxtons Superb, Lord Lambourne, Red Ellison, Scarlet Pimpernel and Tydemans Early Worcester.

In one trial on a shallow soil overlying chalk transient interveinal chlorosis occurred at 3.2 and 6.4 lb/ac of terbacil on Cox's Orange Pippin, Laxtons Superb and James Grieve on approximately 4% of the foliage.

Two yield trials carried out on Cox's Orange Pippin at rates up to 6.4 lb/ac showed no significant yield difference at $P = 0.05$.

Fruit quality is especially important in apples and the results of a russet assessment on six varieties on E.M. II stock, planted in 1951 on a loam soil, are given in Table 3.

Table 3

Russet assessments 1967

	Lanes Prince Albert			Worcester Pearmain			Cox's Orange Pippin		
	a	b	c	a	b	c	a	b	c
(1)	27.3	1.5	7.9	66.7	0	4.8	70.6	41.5	50.6
(2)	24.5	3.6	3.4	70.0	0.1	5.3	73.5	42.1	56.7
(3)	26.4	1.3	5.0	70.1	0	3.9	77.8	63.0	66.7

	Laxtons Superb			James Grieve			Tydemans Early Worcester		
	a	b	c	a	b	c	a	b	c
(1)	70.5	5.5	20.8	57.4	7.3	38.4	52.3	1.0	6.6
(2)	67.7	4.8	15.7	65.7	4.5	30.4	50.2	1.9	6.9
(3)	68.8	7.1	19.1	61.6	5.6	28.7	54.7	1.4	12.9

(1) Terbacil 3.2 lb
(2) Terbacil 6.4 lb
(3) Control

(a) = Degree of stalk russeting
(b) = Degree of eye russeting
(c) = Degree of side russeting

From this it is evident that there was no effect on fruit finish.

2 Bromacil - cane fruit

During 1967 and '68 an intensive trials programme was carried out; 6 replicated and 19 grower trials on raspberries: 6 replicated and 6 grower trials on blackberries and loganberries. The replicated trials were designed to establish the optimum rate of bromacil for *Agropyron repens* control and crop tolerance.

2.1 Weed control. In Table 4 resulsts are given of trials where *Agropyron repens* was the dominant weed species.

Table 4

Small plot trials - control of Agropyron repens

Bromacil/ac	1	2	3	4	5	6	7(a)	7(b)
1.0 lb	7.7	-	3.7	8.6	-	7.8	7.6	4.7
1.6 lb	-	7.0	-	-	-	-	9.6	7.5
2.0 lb	10.0	8.0	5.0	8.5	9.8	7.2	10.0	8.5
2.8 lb	10.0	-	7.1	8.5	-	8.6	10.0	9.4
3.2 lb	-	8.6	-	-	-	-	-	-
4.0 lb	10.0	-	7.7	9.4	-	8.3	-	-
Control	0	0	0	0	0	0	0	0
Weeks after treatment	24	10	10	7	7	15	11	45
Soil type	L	SL	L	L	L	L	ZyL	ZyL
Plot size yd^2	20	16	18	9	72	12	12	14
No. of replicates	3	4	4	3	1	4	4	3

In trial 1 good control of Agrostis stolonifera was also noted.

In trial 7 a further assessment was carried out after 45 weeks and the results are seen in column (b).

From these results it was considered that a rate of 2 - 2.8 lb/ac would give an economic control. Consequently grower trials were initiated in the following year to examine bromacil at 2 and 2.8 lb/ac under practical field conditions.

The results of Scottish grower trials on raspberries are given in Table 5.

Table 5

Grower trials in Scotland 1968 - total weed control score from different sites

Bromacil /ac	1	2	3	4	5	6	7	8	9	10	11
2 lb	9.0	8.0	6.0	8.0	-	-	-	-	-	-	-
2.8 lb	-	-	-	-	8.0	5.0	9.5	9.0	9.0	9.5	8.0
Weeks after treatment	21	19	19	22	22	19	19	17	19	18	20
Soil type	SL	LCS	SL	CSL	CSL	CSL	SL	SL	LCS	SL	LCS

Agropyron repens was controlled by 2.8 lb/ac of bromacil but the full effect was not apparent for four weeks or more. By the autumn the lower rates of 2lb/ac also showed good control.

However, where dense established Agropyron repens was present the higher rate was more effective. At site 6 the dominant weeds were dicotyledonous annuals and perennials with no Agropyron repens and poor control particularly of Rumex acetosa and Stachys palustris was exhibited.

Results from trials in England which included raspberries, blackberries and loganberries showed a similar trend and the following weed susceptibilities were established:-

Susceptible weeds: Agropyron repens, Agrostis spp.

Moderately susceptible: Cirsium arvense, Chamaenerion angustifolium, Epilobium hirsutum, Urtica dioica, Rumex spp., Mentha spp..

Moderately resistant: Tussilago farfara, Calystegia spp., Heracleum sphondylium.

Resistant weeds: Convolvulus arvensis, Ranunculus repens, Equisetum spp., Potentilla spp., Torilis spp..

2.2 Crop tolerance. It was necessary to establish whether or not bromacil had any adverse effect on cane fruit and results of cane growth and yield assessments are given in Tables 6 and 7.

Table 6

Raspberry cane assessments following treatment in previous year

Bromacil/ac	Mean no. of canes per plot - January 1968		% at tipping height - January 1968		Mean no. of canes per plot - May 1968		Ft of fruiting cane - May 1968	
	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2	Site 1	Site 2
2.0 lb	963	178	31.5	64.1	143	131	931	649
2.8 lb	-	178	-	70.3	-	143	-	705
3.2 lb	978				141	-	919	-
4.0 lb	-	192	31.5	73.4	-	162	-	789
Control	599	127	26.9	54.4	113	103	700	478
Plot size yd^2	16	18	16	18	16	18	16	18
No. of replicates	4	3	4	3	4	3	4	3

Where application was delayed until after sucker emergence, transient yellowing was recorded. This condition soon passed and subsequent growth was normal.

Table 7

Yield results 1967 and 1968

Bromacil/ac	Mean wt of fruit per cane in lb			Mean wt of fruit per plot in lb			
	1	2	3	1*	2*	4	5
2.0 lb	0.22	0.31	0.21	60.5	161.5	63.0	4.7
2.8 lb	-	0.34	0.18	-	160.5	57.4	4.6
3.2 lb	0.29	-	-	60.0		-	-
4.0 lb	-	0.36	-	-	189.0	43.0	4.8
Control	0.27	0.29	0.16	56.8	109.5	55.0	5.1
No. of pickings	6	5	1	6	4	4	2
P = 0.01	NS	NS	NS	NS	78.9	NS	NS
Plot size yd^2	16	18	14	16	18	14	9

* Treated for two successive years. In trial 2 bromacil at 4 lb/ac was increased to 5.6 lb/ac in the 2nd year. Trials 1 - 4 on raspberries and trial 5 was on laganberries.

The replicated trials covered the main varieties and the grower usage trials covered a wider range. From all these trials it has been established that when applied at 2.8 lb bromacil is safe to use on the following:

(a) Raspberries: Malling Promise, Malling Jewel, Malling Exploit, Malling Enterprise, Malling M, Norfolk Giant, American September, Burnett Holm, Lloyd George.

(b) Loganberries: LY 59

(c) Blackberries: Himalayan Giant, Bedford Giant, Oregon Thornless.

In tests carried out by the Fruit & Vegetable Preservation Research Association and by the British Food Manufacturing Industries Research Association no taints were detected when the fruit from bromacil treated raspberries was quick frozen, canned or jammed.

DISCUSSION

1 Terbacil - Apples

The trials showed that terbacil was active against Agropyron repens and Agrostis stolonifera and that at 2.4 lb/ac an acceptable level of control (in most cases 100%) was achieved. A range of other weed species were also controlled.

Terbacil was safe to use at this rate on nineteen varieties of established apples on soil types ranging from coarse sands to clay loams.

Where Agropyron repens or Agrostis spp. are the dominant weeds in apple orchards, terbacil at 2.4 lb/ac as a tree base, band or overall application will give, in most cases, complete control. Further applications of terbacil may be required subsequently where application has been uneven or where there is encroachment from untreated areas.

Resistant weeds such as Convolvulus arvensis and Ranunculus repens may colonise treated areas and treatment with growth regulator herbicides may be required. Lower rates of terbacil are at present being investigated for the control of probelm annual weeds such as Polygonum spp. and Atriplex patula.

2 Bromacil - Cane fruit

Agropyron repens is a serious weed in cane fruit and the results of the above trials showed that good control can be obtained with a rate of 2.8 lb/ac of bromacil. At this rate bromacil was well tolerated by all varieties of cane fruit on which it was used in the main growing areas of England and Scotland. Lower rates of bromacil could be used for the control of difficult annual weeds such as Polygonum spp. and Atriplex spp.

Bromacil was introduced commercially in 1969 and field results have been satisfactory, particularly on Agropyron repens, resulting in increased crop vigour.

Bromacil is therefore a useful material to include in a herbicide programme in cane fruit under a minimal or no cultivation regime and by controlling Agropyron repens may help to prolong the like of a plantation.

Acknowledgements

The authors would like to thank for their assistance, D.A.Allison of the Du Pont Company (UK) Ltd., the processors and farmers who provided trials sites and the various members of Bayer Agrochem Ltd (then Baywood Chemicals Ltd) in conducting the trials.

References

HILL, G. D. Jr., BINGEMAN, C.W. & WOOD, M.B. (1965) New substituted uracil herbicides. Proc Eur. Weed Res Coun. 2nd Symp. New Herbicides

HILTON, J.L., MONACO, T.J., MORELAND, D.E. & GENTNER, W.A. (1964) Mode of action of substituted uracil herbicides. Weeds 12, 129-131.

HOFFMAN, C.E., McGAHER, J.W., & SWEETSER, P.B. (1964) Effect of substituted uracil herbicides on photosynthesis. Nature Lond., 202 No. 4932, 577-578.

LAWSON, H.M & WAISTER, P.D. (1968) An evaluation of four herbicides for routine weed control in a minimal cultivation management programme for raspberries. Proc. 9th Br. Weed Control Conf. 2 916-921

PIZER, N.H. & DEWIS, J.W. (1957) Assessment of the texture of mineral soils. Revised 1957. Soil chem Dep, Minist agric., Fish Fd, natn. agric. advis. Serv. east. Reg.

UNTERSTENHOFER, G. (1963) The basic principles of crop protection field trials. Pflanzenschutz-Nachrichten 'Bayer', 16, (3), 156.

WAISTER, P.D. (1966) Crops research. Rep. Scott. hort. Res. Inst. 13 18-19

Proc. 10th Br. Weed Control Conf. 1970

EXPERIMENTS ON THE CONTROL OF PERENNIAL WEEDS IN ESTABLISHED RASPBERRY PLANTATIONS

H. M. Lawson
Scottish Horticultural Research Institute, Invergowrie, Dundee
T. G. Rubens
East of Scotland College of Agriculture, Edinburgh

Summary Four herbicides were applied in early spring before cane emergence for the control of perennial weeds, mainly couch grass, in three mature raspberry plantations. Bromacil and terbacil sprayed at 2lb a.i./ac had little effect on weeds at two sites where soil conditions were dry before and after treatment, but at a third site with moist soil conditions they gave excellent weed control. Chlorthiamid and dichlobenil applied as granules at 8.25 and 10lb a.i./ac respectively rapidly killed couch grass foliage at all three sites regardless of weather, but re-growth began in late summer and had increased considerably by the end of the year. At two of the sites the amount of cane tied in for fruiting the next season was significantly greater on plots treated with herbicides than on untreated plots, illustrating the degree of weed competition from which the crop was suffering. On most plots the level of infestation had again become limiting to cane production by the beginning of the second season.

INTRODUCTION

Perennial weeds have become increasingly important in raspberry plantations as the use of simazine has become more widespread and the availability of labour for hand-hoeing along the rows has declined. Many commercial growers practise a system which combines band application of simazine along the rows with rotavation of the alleys for weeds and sucker control. Resistant weeds and unwanted suckers in the rows are removed by hand-hoe as and when labour is available. At its best this management system works efficiently, but too often the rows become choked with perennial weeds which the grower has neither time nor labour to remove at regular intervals throughout the season. The three experiments reported in this paper were carried out to assess the effect of single applications of four herbicides on weeds and canes in commercial plantations grown under this type of management system.

METHODS AND MATERIALS

Experiments were carried out at three sites, each of which had a previous history of annual applications of simazine along the rows. In each case, six replicates of five treatments were laid out in a randomised block design. Plots consisted of single rows with treatments applied to a one-foot band on each side of the row. Cane rows were 6 ft apart and the alleys between the treated row bands were rotavated for weed and sucker control. Herbicide treatments were as follows, the dosage rates chosen being those suggested by the manufacturers as appropriate for the control of couch grass (Agropyron repens).

The granular formulations were diluted with sand and applied by hand. Bromacil and terbacil were applied by 'Mistifier' knapsack sprayer using a single nozzle delivering 80 gal. water/treated acre.

Treatment	Dose lb a.i./ac	Formulation
A Chlorthiamid	8.25	7½% granule
B Dichlobenil	10.00	7½% granule
C Bromacil	2.00	80% wettable powder
D Terbacil	2.00	80% wettable powder
E Untreated control		

Applications were made in early April just before the normal time of emergence of new cane. All rows had already been treated with simazine for control of annual weeds.

No cane thinning was carried out by the farmers during the growing season. Canes growing between the stools were dug out in late autumn and a certain amount of perennial weed growth was removed at this time. It was not possible to record yields of fruit from the experiments and the effects of treatment on the crop were assessed by recording numbers and lengths of fruiting cane tied in during the next winter. No visible evidence of adverse effect of herbicide treatment on the yield or quality of fruit was noted at any site. The level of infestation of couch grass and buttercup (Ranunculus repens) was scored on a 0-10 basis (0 = no weeds, 10 = the whole length of plot row densely infested). Because of the considerable natural variation in both the cane and the weed populations in these commercial plantations the results of measurements taken since treatment are presented as adjusted means after covariance on similar records taken before the experiments commenced.

RESULTS

Expt. 1

Location - Pitreuchie, Forfar. Plot length - 10 yd. of row.

Cultivar	- Malling Promise, planted April 1965.
Weed stand	- Couch grass, varying in density.
Soil type	- % sand 68.7; % silt 14.3; % clay 13.3; % loss on ignition 7.5.
Date of application	- April 4, 1967
Weather	- Dry at application. Little or no rain for nearly three weeks thereafter.

Weed control. Chlorthiamid and dichlobenil had killed a high proportion of grass weed foliage within a few weeks of treatment, while the other two herbicides produced some slight discolouration of the foliage and reduction in vigour compared with the untreated control. This is illustrated by weed assessments taken 7 weeks after treatment (Table 1). From late summer onwards substantial re-growth of couch grass took place on plots treated with dichlobenil and chlorthiamid while the infestation on plots treated with bromacil and terbacil remained unchanged until the end of the year. The infestation on untreated plots increased during 1967 and again during 1968. By the end of the second season, the levels of infestation on all treated plots had again increased substantially but with the exception of those treated with dichlobenil they were still significantly lower than that on the untreated plots.

Table 1.

Experiment 1 Records taken after treatment on April 4 1967 (Adjusted means)

Treatments	Couch infestation 0-10 May 1967	Dec. 1967	Nov. 1968	Total cane length tied in (ft per plot) April 1968	Relative	April 1969	Relative
Chlorthiamid	2.2***	4.2	6.5**	195**	134	217	116
Dichlobenil	1.7***	6.5	8.4	210***	144	232	124
Bromacil	4.1*	4.8	7.1*	197**	135	188	100
Terbacil	5.1	4.7	6.5**	215***	148	230	122
Untreated	6.1	7.3	8.4	146	100	188	100
S.E./mean ±	0.6	0.8	0.4	10		20	

* / ** / *** = significantly different from the untreated control at the 5% / 1% / 0.1% level

Crop reaction. Dichlobenil and chlorthiamid caused stunting of the new canes which emerged within a week or two of treatment, the symptoms being considerably more severe on plots treated with dichlobenil. This effect had been largely outgrown by the end of the season and no significant differences in height of cane selected for tying in were found. Bromacil and terbacil had no visible adverse effect on cane growth. Records taken in spring 1968 showed that a significantly greater total length of cane had been tied in on all herbicide-treated plots than on untreated plots (Table 1). Similar records taken on canes tied in for fruiting in 1969 showed that more cane had been tied in on three of the herbicide treatments than on the control treatment but the differences were too small to be statistically significant at the 5% level.

Expt. 2

Location	-	Balgillo, Broughty Ferry.
Plot length	-	18 yd of row.
Cultivar	-	Malling Promise, planted April 1962.
Weed Stand	-	Mixed perennial weeds, mainly couch grass and buttercup.
Soil type	-	% sand 54.7; % silt 21.8; % clay 20.0; % loss on ignition 7.0.
Date of application	-	April 4, 1967
Weather	-	Dry at application. Little or no rain for nearly three weeks thereafter.

Weed Control. Chlorthiamid and dichlobenil again killed a high proportion of the grass weed foliage within a few weeks of treatment (Table 2) while bromacil and terbacil had no visible effect, apart from slight yellowing of the leaves. The first two herbicides also caused some initial check in the vigour of buttercup but this weed spread to fill much of the gap left by the grass weed foliage. The other two herbicides had no visible effect on this or any other broad-leaved weed. Amongst the other perennial species whose top growth was killed within a few weeks on plots treated with the granular herbicides were *Tussilago farfara*, *Cirsium arvense*, *Rumex* spp. and *Taraxacum officinalis*. Resistant species included *Heracleum sphondylium*, *Torilis japonica* and *Potentilla anserina*. As a result, plots treated with dichlobenil and chlorthiamid ended the year very much freer from weeds than all other plots. Those treated with bromacil or terbacil could not be distinguished from the untreated control plots. Assessments made in April 1968 (Table 2) showed that the level of infestation of couch grass was still significantly lower on plots originally treated with the granular herbicides although considerable recovery by the weed had taken place. The levels of infestation of buttercup were not significantly different.

Crop reaction. Both chlorthiamid and dichlobenil caused some initial stunting of canes emerging in 1967. This effect was outgrown by the end of the season. The other two herbicides had no visible effect on cane growth. Unfortunately, the farmer took out the posts and wire during the winter and abandoned the crop, and it was only possible to record the total numbers of canes produced per plot during 1967 (Table 2). Plots treated with dichlobenil had produced significantly more canes than the untreated plots. Treatment with chlorthiamid showed a small but non-significant increase, while plots treated with bromacil and terbacil were no better than the control plots. The tallest canes were to be found on plots treated with the granular herbicides, and, in fact, much of the new cane on the other treatments had only just managed to grow above the weed canopy. The tangle of weeds and canes growing between the stools made impossible any estimate of the numbers of canes suitable for tying in for fruiting on the weedy plots.

Table 2

Experiment 2. Records taken after treatment on April 4 1967
(Adjusted means)

Treatments	Couch infestation 0-10 June 1967	Couch infestation 0-10 April 1968	Buttercup infestation 0-10 June 1967	Buttercup infestation 0-10 April 1968	Total cane numbers produced in 1967	Relative
Chlorthiamid	1.2***	2.5*	1.9	3.3	430	112
Dichlobenil	0.3***	1.8**	3.2	2.1	464*	121
Bromacil	5.1	5.6	3.9	2.4	357	93
Terbacil	4.2	4.3	3.9	3.7	366	95
Untreated	4.2	5.1	3.7	2.4	385	100
S.E./mean ±	0.5	0.7	0.7	0.6	26	

* = significantly different from the untreated control at the 5% level
** = significantly different from the untreated control at the 1% level
*** = significantly different from the untreated control at the 0.1% level

Expt. 3

Location - Pitreuchie, Forfar.
Plot length - 10 yd. of row.
Cultivar - Malling Jewel, planted April 1965.
Weed Stand - Couch grass of variable density.
Soil type - % sand 65.0; % silt 17.0; % clay 14.6; % loss on ignition 6.8.
Date of application - April 2, 1968.
Weather - Application was followed by a light snow cover which lay for several days. Rainfall during the next few weeks was sufficient to ensure adequate soil penetration by the herbicides.

Weed control. Chlorthiamid and dichlobenil killed most of the couch foliage within a few weeks of treatment while on plots treated with bromacil and terbacil the foliage slowly turned yellow and died over a period of several months. By mid-September, plots treated with bromacil and terbacil were still virtually free of weeds, while some degree of re-growth had occurred on plots treated with the granular herbicides (Table 3). Assessment in July 1969 showed that plots treated with bromacil and terbacil were still very clean and by late May 1970, the level of weed infestation on plots treated with bromacil and terbacil was still significantly lower than that on untreated plots. Plots treated with chlorthiamid or dichlobenil were still less badly infested than the untreated plots in July 1969, but by April 1970 were indistinguishable from the control treatment.

Crop reaction. Both chlorthiamid and dichlobenil caused some initial stunting of cane emerging in 1968. Dichlobenil produced the more severe symptoms. No differences were found, however, in the height of canes tied in for fruiting in 1969. Bromacil and terbacil had no visible effect on cane growth apart from some temporary chlorosis of leaves on new cane.

Table 3

Experiment 3. Records taken after treatment on April 2 1968 (Adjusted means)

Treatments	Couch infestation 0–10 Sept. 1968	July 1969	May 1970	Total cane length tied in (ft per plot) April 1969	Relative	April 1970	Relative
Chlorthiamid	2.2***	4.2*	6.8	216*	128	160	112
Dichlobenil	2.6***	4.8	6.5	238**	141	156	109
Bromacil	0.6***	1.0***	2.3***	242**	144	186	131
Terbacil	0.6***	1.4***	3.7***	229*	136	199	140
Untreated	6.2	6.7	7.7	169	100	142	100
S.E. mean ±	0.6	0.7	1.0	16		18	

*, **, *** = significantly different from the untreated control at the 5%, 1%, 0.1% level

Records taken in April 1969 showed that significantly greater total lengths of cane were tied in on all plots treated with herbicides than on the untreated plots (Table 3). Similar records on 1970 fruiting cane showed a continuing benefit from the original treatments with bromacil and terbacil, but differences between treatments just failed to reach significance at the 5% level.

DISCUSSION

The release of the crop from weed competition

The most striking feature of these trials was the large increase in the production of fruiting cane which followed even temporary weed suppression. The fact that treatment with chlorthiamid and dichlobenil produced these increases despite stunting of early cane growth and rapid recolonisation by the weeds, suggests that the timing of the release from competition may be more important than its duration. Spencer-Jones and Wilson (1968) reported similar conclusions on blackcurrants and gooseberries. Compared with the untreated control even the slight check obtained with bromacil and terbacil in Experiment 1 held the couch grass back sufficiently to allow much better cane growth. This in itself might have justified the cost of herbicide treatment, regardless of the final level of weed control obtained.

Weed control and crop tolerance. In all three experiments chlorthiamid and dichlobenil rapidly killed couch foliage. The degree of initial control and the persistence of the effect varied but from late summer onwards fresh growth appeared and thereafter couch grass spread rapidly at each site. The levels of weed control efficiency of these two herbicides are in line with those reported for chlorthiamid by Allen (1966) and for dichlobenil by Spencer-Jones and Wilson (1968). It was not possible to detect any worthwhile difference in efficacy between the two herbicides despite the higher dosage of dichlobenil used, but the latter was slightly more harmful to young cane growth. Treatment was applied in these experiments just before cane emergence and the stunting effect might have been avoided altogether if it had been possible to make the applications earlier (Allen, 1966). The evidence suggests that single applications of either herbicide can be expected to suppress couch grass for only a limited period of time.

The granular herbicide treatments appeared less vulnerable to dry soil conditions than did bromacil and terbacil, which had no visible effect in Experiment 2 and only a suppressing effect in Experiment 1. However, with the moist soil conditions in Experiment 3, these two herbicides gave the most effective control of couch grass at any of the sites. There was no indication that one was more effective than the other and both were tolerated by the crop. Lawson and Waister (1968) have previously reported that raspberries are tolerant to bromacil at 2 lb a.i./ac., and Rath and O'Callaghan (1968) have reported promising tolerance to terbacil in Ireland. Clay and Davison (1968), however, found some reduction in cane numbers and cane length after application of terbacil at the time of cane bud burst and sucker emergence. Earlier application would probably have been beneficial for these herbicides also to avoid dry soil conditions.

The overall effect of the herbicide treatments cannot be judged solely in terms of reduction of the original infestation. In all three experiments the level of weed infestation in the untreated plots increased as time passed. Herbicides which were able to hold back this spread were therefore achieving some measure of useful control.

Not even the most effective single herbicide treatment in these experiments was able completely to eradicate the perennial weed problem. Subsequent management involving routine application of simazine and minimal disturbance of the rows by cultivations permitted even the cleanest rows to become moderately re-infested within two years. In Expt. 2, resistant species filled the gaps left by the control of susceptible species. Colonisation from the alleys was a major source of re-infestation by couch grass at the other two sites, especially from late summer onwards, when fallen new cane made further rotavation impossible. A light hand-hoeing along the rows in late summer on plots treated with chlorthiamid and dichlobenil might have prolonged considerably the duration of effective weed control.

Supplementary herbicide treatment normally has to be delayed until the following winter because of problems of access and crop tolerance. Unless this is to become an annual treatment the initial herbicide treatment must maintain an effective level of weed control beyond the end of the first growing season. The results of these experiments suggest that major considerations in the choice of the most suitable herbicide to achieve this objective will be soil moisture conditions at the time of application, the range of weed species present and the availability of labour for supplementary cultivation. It might also be worthwhile to consider whether overall application of these herbicides would in the long term prove to be more economic than band application if recolonisation from untreated alleys necessitates repeated herbicide application to the rows.

Acknowledgments

Thanks are due to the chemical firms who supplied the samples of herbicides and to the farmers who permitted the use of their crops for these experiments.

References

ALLEN, M.G. (1966). Experiments with 2,6-dichlorothiobenzamide (Chlorthiamid) in raspberries. Proc. 8th Brit. Weed Control Conf. 76-84.

CLAY, D.V. and DAVISON, J.G. (1968). Herbicide evaluation trials on raspberries and rose rootstocks. Proc. 9th Brit. Weed Control Conf. 928-932.

LAWSON, H.M. and WAISTER, P.D. (1968). An evaluation of four herbicides for routine weed control in a minimal cultivation management programme for raspberries. Proc. 8th Brit. Weed Control Conf. 916-921.

RATH, N. and O'CALLAGHAN, T. (1968). Preliminary trials with terbacil for weed control in soft fruits. Proc. 9th Brit. Weed Control Conf. 922-927.

SPENCER-JONES, D.H. and WILSON, D. (1968). Trials to investigate the herbicidal efficacy of dichlobenil in bush fruit with special reference to the control of Agropyron repens. Proc. 9th Brit. Weed Control Conf. 907-915.

EFFECTS ON SUBSEQUENT CEREAL CROPS OF RESIDUAL HERBICIDES USED IN RASPBERRY EXPERIMENTS

J.S. Wiseman and H.M. Lawson
Scottish Horticultural Research Institute, Invergowrie, Dundee

Summary Simazine, atrazine and bromacil at 2 lb a.i./ac and chlorthiamid at 4 lb a.i./ac were applied overall to a raspberry plantation every April for four years. Barley drilled 12 months after the final application was unaffected on plots originally treated with simazine, atrazine or chlorthiamid, but it was three years before normal crop growth was obtained on plots treated with bromacil. The distribution of residues of bromacil was very uneven across the plots, perhaps due to the extensive cultivations required to incorporate the vegetative mass of the plantation into the soil. Band application of these and other residual herbicides to raspberry rows at and well above dosages required for control of perennial weeds did not affect the growth of cereals drilled $1\frac{1}{2}$ and 2 years later. The dilution of any residual herbicide in the soil by cultivation, particularly at right angles to the rows is thought to have been an important factor.

INTRODUCTION

Repeated annual applications of persistent herbicides in the management of soft fruit plantations may lead to a build-up of herbicide residues in the soil. Also, the high rates of application of such herbicides as chlorthiamid, dichlobenil, bromacil and terbacil required to control dense infestations of *Agropyron repens* in established plantations raise the question of the safety interval required between the last date of application and the sowing of follow ing crops. Clay and Ivens (1966) and Allott (1968) took soil samples from undisturbed raspberry plots treated annually with 2 lb/ac simazine and reported that there was very little evidence of a build-up of residues from this dosage rate. Stephens (1962) found that dichlobenil applied at 4,6 and 8 lb/ac to uncropped ground in November 1961 affected the growth of a range of crops sown or planted on the site in May 1962. Clay and McKone (1968) compared the rate of breakdown of chlorthiamid with that of simazine in uncropped soil and found that 12 lb/ac chlorthiamid caused a 50% reduction in the growth of lettuce sown 14 months later. Allott (1968) found that simazine, atrazine and terbacil applied at 2 lb/ac to bare soil were completely toxic to lettuce, cauliflower, red beet and swede turnips for at least 20 weeks.

Little or no evidence is, however, available on actual field experience with crops sown after raspberry plantations have been discontinued. To provide information on this aspect of the problem, the subsequent cultivation and cropping history of three completed raspberry herbicide experiments have been studied.

METHODS AND MATERIALS

Details of the previous history of the experimental sites are given in Table 1. Dichlobenil, chlorthiamid and atrazine were applied as granular formulations. All other herbicides were applied by knapsack sprayer in water volumes of 60-100 gal/ac. When the original herbicide experiment was finished the plantations were incorporated into the soil by rotovation and the sites subsequently drilled with cereal crops.

Table 1

Site and crop details

	Experiment 1	Experiment 2	Experiment 3
Original crop	Raspberries	Raspberries	Raspberries
Planted	April 1964	April 1962	April 1960
Herbicides applied	April 1964 to April 1967	April 1967	April 1967
No.of applications	4	1	1
Plot size	54 ft x 18 ft	54 ft x 6 ft	20 ft x 6 ft
Row width	6 ft	6 ft	6ft
Plant spacing	2 ft	2 ft	2 ft
Area sprayed	overall	2 ft band	2 ft band
Replications	4	6	3
Supplementary cultivation	None	Alleys (4 ft) rotovated	Alleys (4 ft) rotovated
Crop rotovated in	Jan. 1968	August 1968	October 1968
Cereal sown	March 1968	September 1968	March 1969
Soil physical analysis % sand	59.0	54.7	69.2
% silt	19.2	21.8	13.4
% clay	18.2	20.0	13.7
% loss on ignition	7.4	7.0	7.4

Records were made of the type, depth and frequency of cultivations. In Expt. 1 germination counts were made on 20 x 1 ft^2 quadrats/plot. The crop was combine harvested ($10\frac{1}{2}$ ft cut) leaving 3 ft discards at each end of the plot. Grain yield and 1000 grain weights were assessed. At the other sites visual records only were made because of the limited width of the plots. Annual rainfall at Invergowrie was 22 in. in 1967, and 29 in. in both 1968 and 1969. All herbicide rates quoted in this paper refer to lb or oz a.i./ac.

RESULTS

Expt. 1

Site: West Loan, Mylnefield, Invergowrie.

The original herbicide treatments are shown in Table 2. They were applied every April from 1964 to 1967 inclusive to examine their suitability for routine weed control. In January 1968, the raspberry plantation was incorporated into the soil by rotovation to a depth of 6 in. Two rotovations were carried out at right angles to each other. In March 1968, the site was ploughed to a depth of 10 in., harrowed and sown with barley (cv. Ymer).

The emergence and early growth of barley seedlings was apparently normal and uniform over the whole site and germination counts showed no significant differences between treatments. However, when the crop reached a height of 3 in. the barley plants and weeds turned yellow and died over large, irregular patches of the plots previously treated with bromacil. No visible symptoms of herbicide residues were detected on any of the other plots. When the plots were combine harvested in early September the yield of barley on plots treated with bromacil was found to be significantly lower at the 1% level than that on the control plots (Table 2). Grain size was unaffected and it appeared that yield reductions were largely attributable to the patches of bare ground on plots treated with bromacil. None of the other treatments differed significantly from the control in yield or grain size.

Table 2

Harvest records from barley grown after raspberry herbicide experiment 1.

		1968		1969		1970	
Raspberry herbicide treatment	Dose lb/ac	Yield cwt/ac	1,000 grain wt.(g)	Yield cwt/ac	1,000 grain wt.(g)	Yield cwt/ac	1,000 grain wt.(g)
Control	Hoed	38.0	39.6	34.3	45.3	31.2	44.3
Simazine	2	36.7	39.5	36.8	43.5	33.2	44.0
Atrazine	2	35.5	41.3	35.5	43.8	30.0	43.5
Bromacil	2	19.7	36.5	27.6	39.5	29.6	42.3
Chlorthiamid	4	37.3	41.4	35.4	43.8	29.2	43.3
S.E. Mean ±		1.3	1.5	2.4	1.1	1.5	0.5
Coeff. of variation %		8.0	7.8	14.3	4.9	9.5	2.2

The site was ploughed to a depth of 12 in. in March 1969, harrowed and sown with barley (cv. Golden Promise). Barley emergence on all plots was again normal but as the season progressed a slight depression in height of the barley crop was visible on irregular areas of plots which had been treated originally with bromacil. At harvest, 1,000 grain weight on these plots was significantly lower at the 1% level than that on control plots but reduction in yield of grain was not quite significant at the 5% level. Yields on plots treated with bromacil varied considerably due to the irregular distribution of affected patches of crop. None of the other treatments differed significantly from the control in yield or grain size.

The site was ploughed to a depth of 12 in. in March 1970, harrowed and sown with barley (cv. Golden Promise). No visible effect of original treatment with bromacil was noted during the growing season and no significant differences in germination counts, yield or grain of 1,000 grain weights between the control treatment and bromacil were found.

Soil samples (20 cores per plot) to 4 in. depth were taken after the drilling of the first barley crop from all four replicates of plots treated with bromacil. The samples from each plot were bulked, air dried, sieved and mixed. Bioassays were carried out, based on the method described by Holly and Roberts (1963) but using the swede turnip (cv. Danestone) as the test plant, to determine the quantity of bromacil present (Table 3).

Table 3

Bromacil residues as detected by bioassay

Last date of application and dose	Dates of soil sampling	Estimated quantity of bromacil present oz/ac	Months after last application
April 1967	April 1968	5.8	12
2 lb/ac	Nov. 1968	4.9	19
	March 1970	3.9	35

It appeared that the original dose applied, plus any residual carry-over from previous treatments had disappeared at a high rate during the first year, but that breakdown thereafter was slow.

Expt. 2

Site: East Balgillo, Broughty Ferry.

The original herbicide treatments were as follows:

Herbicide	Dosage lb /treated ac
Chlorthiamid	8.25
Dichlobenil	10.00
Bromacil	2.00
Terbacil	2.00
Untreated	-

Application was made to a 2 ft band along the row in early April 1967 to compare the efficiency of the four herbicides for the control of a mixed perennial weed infestation. No further herbicide treatments were made. In August 1968 the crop was rotovated to a depth of 6 in. Two rotovations were carried out at right angles to each other. The site was then ploughed to a depth of 1 ft. Winter wheat (cv. Capelle) was sown in September 1968 and the position of the plots marked out. Although the crop was irregular no evidence of crop injury or retardation relating to the positions of the original plots was found, even allowing for lateral movement due to soil cultivations. No indication was found in the crop of the lines of the original plot row bands even at harvest.

The site was ploughed to a depth of 1 ft in March 1970 and harrowed. Barley (cv. Golden Promise) was sown but again no visible evidence of herbicide residues could be detected in the crop at any growth stage.

Expt. 3

Site: East Loan, Mylnefield, Invergowrie.

The original herbicide treatments were as follows:

Herbicide	Dosage lb /treated ac		
Simazine	2.00		
Fluometuron	2.20	4.40	6.60
Terbacil	2.00	4.00	6.00
Bromacil	2.00	4.00	6.00
Chlorthiamid	8.25	16.50	24.75
Dichlobenil	8.25	16.50	24.75

Band treatments were applied in early April 1967 to assess the tole ance of the raspberry crop to single applications of these herbicides. I 1968 no row treatments were applied but rotovation in the alleys was continued. In October 1968 the crop was incorporated to 6 in. by two rotovations at right angles to each other. In March 1969 the field was ploughed to a depth of 10 in., harrowed and sown with barley (cv. Gol Promise) and the position of the plots marked out. Germination and gr of the crop was uniform all over the site. No evidence of crop injury retardation relating to the position of the original plot row bands was fou even allowing for lateral movement due to soil cultivations, despite the w range of dosage rates which had been initially used.

The site was ploughed in March 1970, harrowed and sown with b (cv. Golden Promise). Again no visible evidence of herbicide residues detected in the crop.

Expt. 4

Site: South Bullion, Invergowrie.

In 1970, a small unreplicated experiment was laid out to gain preli ary evidence on the relative tolerance of a range of crops to bromacil.

Table 4

Crop vigour scores 2/7/70

Crop	Bromacil oz/ac					Crop	Bromacil oz/ac			
	0	1	2	4	8		0	1	2	4
Barley	10	10	10	10	9	Carrot	10	7	5	2
Wheat	10	10	7	7	4	Lettuce	10	10	4	0
Oats	10	10	10	10	9	Swede	10	10	10	2
Red beet	10	9	8	6	3	Cabbage	10	10	7	2
Leek	10	9	8	6	5	Broad bean	10	10	10	9

0 = crop killed 10 = normal growth

The crops were drilled on 27 May and bromacil sprayed overall at a number of rates several days later. Crop vigour was assessed regularly thereafter (Table 4). Oats and broad beans exhibited tolerance similar to that of barley. All other crops tested, including wheat, were less tolerant than barley, and carrots and lettuce were particularly sensitive.

DISCUSSION

The annual rates of application of atrazine and chlorthiamid used in Expt. 1 were found to be at least equivalent to simazine for the control of annual weeds in the plantation and also kept perennial weeds to a minimum (Lawson and Waister 1968). The lack of any adverse effect on barley sown only one year after the last application of any of these three herbicides was therefore most satisfactory. The rate of application of bromacil used in the experiment proved to be unnecessarily high and it was suggested that 1 lb/ac might be adequate for annual treatment. This should be borne in mind when comparing the degree of injury to succeeding barley crops by the four herbicides. The results obtained with the annual rate of 2 lb/ac bromacil are, however, of particular interest since the recommended single dosage for the control of dense infestations of perennial weeds is 2.8 lb/ac.

Allott (1970) has suggested that residual herbicides normally show an annual rate of breakdown in undisturbed soil in excess of 80%. If this is applied to bromacil, the maximum amount present in the soil immediately after the final application of bromacil is unlikely to have exceeded 2.8 lb/ac. Current recommendations (Baywood 1970) suggest that a period of two years between application of bromacil and ploughing-in the plantation should be observed, to avoid residual damage to following crops. The results of Expt. 1 suggest that where overall application has been made this time factor recommendation may require further investigation.

In Expt. 3 up to three times the dosage of bromacil and other herbicides required for weed control were applied as band treatments. The results suggest that the dilution of the treated band with the untreated soil of the alleys by the various cultivations involved in incorporating the crop, ploughing and preparing the seed-bed, may have been a major factor in reducing these potentially high residues below levels toxic to barley. Similarly, wheat drilled 18 months after the more normal dosages applied in Expt.2 was unaffected. It is possible that shorter delay periods before the drilling of cereal crops could be used where herbicide application was limited to bands along the raspberry rows rather than overall provided the soil is thoroughly mixed by cultivation across the rows.

In Expt. 1 the distribution of the herbicide residues in the soil after ploughing was patchy, as shown by the effect on the crops. The cultivations required to incorporate the raspberry plantation into the soil and in particular the great mass of vegetation involved may have contributed to this situation. Plot boundaries were still clearly defined but had moved up to 2 ft in the direction to which the plough furrows had been thrown. Discard areas allowed for this lateral movement when crop records were being taken, but the uneven distribution of residues across the rest of the plots made the assessment of residue levels by normal soil sampling methods of limited value. To obtain an accurate picture of the distribution of the herbicide across the plots other than by sowing a sensitive crop it would have been necessary to analyse each soil core separately and then plot on a grid the position from which the sample was taken, so that areas of high and low concentration could be determined. This situation, together with the bioassay results presented in Table 3 raises the question of the possible persistence of pockets of contaminated soil long after the bulk of the herbicide has disappeared. If this occurs, the recommendation of suitable delay periods between herbicide use and the safe drilling of following crops is made much more difficult.

Although cereals are commonly sown after raspberry plantations in Eastern Scotland, there is the possibility that other crops might be sown either directly after the plantation or after an apparently normal intermediate cereal crop. The use of bromacil in the raspberry crop has brought it into arable rotations for the first time in the United Kingdom and information on the relative sensitivity to it of various drilled crops is very limited. The results of Expt. 4 suggest, however, that cereals are among the more tolerant crops. Normal growth and yield from a cereal crop need not necessarily mean, therefore, that the bromacil has been sufficiently removed to allow safe planting of the more sensitive vegetable crops.

Further investigations are being conducted on various aspects of cultivation and plantation removal to investigate how these affect the speed and evenness of disappearance of residues of bromacil in the field.

References

ALLOTT, D.J. (1968) Annual report of the Horticultural Centre, Loughgall. 26-29.

ALLOTT, D.J. (1970) Personal communication.

BAYWOOD (1970) Personal communication.

CLAY, D.V. and IVENS, G.W. (1966) An interim report on a soil management study in raspberries. Proc. 8th Brit. Weed Control Conf. 85-91.

CLAY, D.V. and McKONE, C.E. (1968). The persistence of chlorthiamid, lenacil and simazine in uncropped soil. Proc. 9th Brit. Weed Control Conf. 933-938.

HOLLY, K. and ROBERTS, H.A. (1963) The persistence of phytotoxic residues of triazine herbicides in the soil. Weed Res. 3 1-10.

LAWSON, H.M. and WAISTER, P.D. (1968) An evaluation of four herbicides for routine weed control in a minimal cultivation management programme for raspberries. Proc. 9th Brit. Weed Control Conf. 916-921.

STEPHENS, R.J. (1962) Pre-sowing and pre-planting treatment with 2, 6-dichlorobenzonitrile: a preliminary report. Proc. 6th Brit. Weed Control Conf. 515-517.

Proc. 10th Br. Weed Control Conf. 1970

THE INFLUENCE OF CERTAIN SOIL-ACTING HERBICIDES ON THE GROWTH AND YIELD OF SOFT FRUIT CROPS

D. J. Allott* and S. D. Uprichard
Horticultural Centre, Loughgall, Co Armagh, Northern Ireland

Summary Experiments are described in which soft fruit crop tolerance to terbacil, bromacil and lenacil are compared with other soil-acting herbicides. Crop tolerances show that terbacil is a promising herbicide for the control of simazine resistant weeds in raspberries and established blackcurrants. Terbacil and bromacil were applied to newly planted raspberries at 1.0 lb/ac without crop injury. At 2.0 lb/ac both herbicides reduced yield. Terbacil was toxic to unrooted blackcurrant cuttings but chlorthiamid, atrazine and simazine had no adverse effects. Strawberries were less tolerant to terbacil than to bromacil. Phenmedipham was shown to provide a promising additional treatment to simazine in cases where a contact herbicide is desirable in strawberries. A1862 was more toxic to strawberries than simazine when applied in the spring.

INTRODUCTION

An annual application of simazine is normally sufficient to maintain freedom from annual weeds in most soft fruit crops but simazine resistant and perennial weeds can present problems. Experiments were, therefore, designed to examine the tolerance of soft fruit crops to herbicides which have the capacity to control such weeds. Due to its ability to control grass weeds including Agropyron repens at relatively low doses, terbacil featured prominently in these investigations.

Simazine resistant perennial weeds are likely to be particularly troublesome shortly after planting when crops can be expected to be at their most susceptible stage. This paper, therefore, describes experiments that were initiated at the Horticultural Centre, Loughgall primarily to examine the tolerance of various soft fruit crops to herbicides applied shortly after planting.

METHOD AND MATERIALS

Raspberry experiments 1 and 2 were planted in April 1967 and March 1968 respectively. Herbicides were applied a month later and the treatment repeated each March. Unrooted blackcurrant cuttings in experiment 3 were planted in April 1967 and the growth of new shoots were measured in 1968. Treatments in experiment 4 on mature blackcurrants were applied in March. Experiment 5 was carried out on 2 year strawberries and the treatments applied in May to assess the tolerance of this crop to herbicides applied at a season when the strawberries are considered to be susceptible to damage. Crop yields are presented throughout in terms of lb/plot. The statistical significance of treatments is expressed as the standard error of a difference between two treatment means. Weed scores were conducted on a scale from 0-5 where 0 = no weeds and 5 = weeds dominant. Commercial herbicide formulations were used with the exception of the new triazine A1862. Herbicides were applied in 50 gals/ac of water from a knapsack sprayer. All herbicide doses refer to lb a.i./ac.

* Civil Service Management Division, Management Services Building (2), Stoney Road, Stormont, Belfast BT4 3SX.

RESULTS

Experiment 1 Raspberries (cv Malling Jewel)

Results from this experiment are presented in table 1 from which it is evident that at 2.0 lb/ac terbacil reduced the yield of raspberries compared to the hand weeded control but not compared to terbacil at 1.0 lb/ac or to simazine at 2.0 lb/ac. Chlorthiamid caused a severe yield reduction at both doses compared to all other treatments which was also reflected in cane height and cane number measurements. Simazine, fluometuron and chlorthiamid gave a particularly good overall weed control as shown by 1970 weed scores which reflect weed scores in earlier years.

Table 1

The effect of soil-acting herbicides on the mean yield, mean cane height and mean cane number in raspberry (cv Malling Jewel)

Herbicide	Dose lb/ac	Mean yield lb/plot	Mean cane height ft	Mean no canes/yd	Mean weed score
Hand weeded control	-	14.16	2.92	10.75	2.40
Terbacil	1.0	11.26	2.95	11.20	0.80
Terbacil	2.0	8.01	2.27	12.50	0.20
Lenacil	1.0	16.53	3.14	15.25	1.40
Lenacil	2.0	17.54	3.18	16.45	0.20
Simazine	2.0	10.83	2.75	12.20	0.00
Fluometuron	2.0	7.23	2.29	11.30	0.00
Chlorthiamid	5.0	3.90	2.06	5.90	0.20
Chlorthiamid	7.5	2.24	1.91	3.65	0.00
S.E. of a difference		± 2.722	± 0.18	± 2.973	
D.F. error 32					

Note: yields recorded in 1969. Cane measurements recorded in December 1968. Weed scores recorded in May 1970

Experiment 2 Raspberries (cv Malling Jewel)

Mean yields and mean weed scores are presented in table 2 from which it is evident that bromacil at 2.0 lb/ac and chlorthiamid both reduced yield. At 1.0 lb/ac bromacil and terbacil had no adverse effects and gave a similar weed control. At 2.0 lb/ac lenacil increased the yield compared to all other treatments. The principal weeds were <u>Polygonum persicaria</u>, <u>Polygonum aviculare</u> and <u>Stellaria media</u>.

Table 2

The effect of soil-acting herbicides on the mean yield and mean weed scores in raspberry (cv Malling Jewel)

Herbicide	Dose lb/ac	Mean yield lb/plot	Mean weed score 21 8 68	Mean weed score 15 9 69
Hand weeded control	-	22.02	3.00	4.25
Simazine	2.0	19.47	0.50	0.25
Atrazine	2.0	17.41	0.50	0.00
Lenacil	1.0	25.31	2.00	2.50
Lenacil	2.0	30.05	1.00	0.50
Bromacil	1.0	20.63	0.00	0.75
Bromacil	2.0	15.48	0.00	0.25
Terbacil	1.0	20.80	0.00	0.75
Fluometuron	2.0	21.69	1.00	1.00
Chlorthiamid	5.0	10.03	0.00	0.25
S.E. of a difference D.F. error 27		± 1.691	-	-

Experiments 3 & 4 Blackcurrants (cv Baldwin)

Preliminary experiments were conducted in blackcurrants and as table 3 shows terbacil at 1.0 lb/ac inhibited the growth of blackcurrants whilst simazine which was used as the control, atrazine, lenacil and chlorthiamid had no adverse effects when applied shortly after planting unrooted cuttings. It is evident from table 3 that terbacil at 0.25 lb/ac can be safely used in mature blackcurrants but that this dose was not sufficient to ensure an adequate weed control where the principal weeds were Ranunculus repens, Senecio vulgaris, Cerastium vulgatum, Stellaria media, Poa annua, Urtica dioica and Luzula campestris. Simazine, atrazine, A1862, lenacil and chlorthiamid also had no adverse effects on the mature plants. Weed control was unsatisfactory with lenacil, moderate with chlorthiamid and good with simazine, atrazine and A1862.

Table 3

Effect of soil-acting herbicides on the mean growth and mean yield of blackcurrants (cv Baldwin)

Herbicide	Dose lb/ac	Mean growth cm/bush (newly planted unrooted cuttings)	Mean yield lb/plot (mature bushes)	Mean weed score (mature bushes)
Hand weeded control	-	-	10.75	2.33
A1862	2.0	-	11.23	0.33
Simazine	1.0	51.10	-	
Simazine	2.0	-	9.17	0.66
Atrazine	1.0	55.00	-	
Atrazine	2.0	-	9.61	0.66
Lenacil	1.0	48.93	-	
Lenacil	2.0	-	9.23	4.33
Terbacil	0.25	-	9.92	2.33
Terbacil	1.0	0.00	-	
Chlorthiamid	5.0	50.30	-	
Chlorthiamid	7.5	-	10.48	1.33
S.E. of a difference		± 12.41	± 1.485	-
D.F. error		8	12	

Experiment 5 Strawberries (cv Templar)

A May application of terbacil and A1862 reduced the yield of strawberries marginally but in general treatment differences were not significant as shown in table 4. Terbacil gave a superior weed control to other herbicides on a site where the principal weeds were: *S. media*, *P. aviculare*, *P. annua* and *S. vulgaris*.

Table 4

The effect of a spring application of soil-acting herbicides on the yield of strawberries (cv Templar)

Herbicide	Dose lb/ac	Mean yield lb/plot	Mean weed score 15 8 69
Hand weeded control	-	18.45	3.25
Simazine	1.0	17.33	0.25
A1862	1.0	12.11	0.75
Phenmedipham	1.0	18.28	1.50
Lenacil	1.6	19.44	0.50
Terbacil	0.25	12.16	0.00
Bromacil	0.25	17.17	1.00
S.E. of a difference		± 3.542	-
D.F. error 18			

DISCUSSION

The safety and effectiveness of simazine for the control of annual weeds in bush and cane fruits is well established. The regular use of simazine, however, may allow simazine resistant weeds to become established. Alternatively weeds such as Agropyron repens may present problems shortly after planting a soft fruit crop where attempts to eradicate them before planting have not been completely successful. The introduction of dichlobenil and chlorthiamid (Sandford 1964) enabled a number of perennial weeds to be controlled in soft fruits but as this paper shows raspberries are susceptible to damage by chlorthiamid applied shortly after planting. The substituted uracils such as terbacil and bromacil appear to be safe over a wider crop spectrum. At a dose of 1.0 lb/ac both terbacil and bromacil were equally satisfactory in newly planted raspberries. Lenacil was shown to be safe in all the crops. There were indications that it increased the yield of raspberries, in some cases, when applied at 2.0 lb/ac. The reason for this cannot readily be explained. The general inability of the uracils to control Senecio vulgaris, which is particularly common in Northern Ireland, might be considered to be a disadvantage but as they are unlikely to replace simazine and would only be used where simazine resistant weeds are know to be present this problem should only arise occasionally, if at all.

A low dose of terbacil (0.25 lb/ac) was shown to be safe in established blackcurrants but it failed to provide an adequate weed control. The same dose in strawberries, however, gave an excellent control. This difference in weed control can be attributed to differences in weed flora and to the different times of application. The blackcurrant treatments were applied in March and the strawberry treatments in May when the recorded rainfall was 1.15 and 4.13 in. respectively. The heavier May rainfall was thus, more likely to lead to an effective weed control. In spite of the spring application to strawberries, simazine failed to reduce yield as could have been expected. It was hoped that the new triazine A1862 would be safer but this damaged the crop.

The available evidence, therefore, indicates that terbacil is a useful herbicide for the control of simazine resistant weeds in raspberries where it can be used more safely than chlorthiamid. It is also likely to be of value in established blackcurrants. Strawberries are less tolerant to terbacil but further investigation involving autumn applications to this crop are desirable before final conclusions are drawn. Crop tolerances to bromacil were similar to terbacil except that bromacil appeared to be less likely to reduce yield in strawberries but again further investigations are necessary under Northern Ireland conditions.

Like simazine, terbacil and bromacil are persistent herbicides. For this reason if they are to be used regularly over a number of years it is important to accumulate information about their soil persistence. Where simazine has been used over a number of years at Loughgall signs of toxicity to the crops due to a build up of the herbicide to phytotoxic levels have not occurred. If any build up has occurred the limits of crop tolerance have not been reached, even after ten years of annual treatments. It has been shown that under Northern Ireland conditions (Allott 1969) such a build up is unlikely to occur where simazine is applied annually at the doses that were used in these experiments. Similar evidence is not available for terbacil and bromacil. If these herbicides are to be used with confidence further information concerning their soil persistence will be necessary. This problem is currently being investigated at Loughgall.

Acknowledgements

The assistance of Mr G. Stephens of the Biometrics Division of the Ministry of Agriculture with respect to computer programming is gratefully acknowledged. The authors also express thanks to the Du Pont Company (UK) for samples of terbacil and bromacil and to Messrs Geigy (UK) Ltd for samples of A1862 that were used in this work.

References

ALLOTT, D.J. (1969) The persistence of simazine applied annually in the prolonged absence of soil cultivation. Weed Res., 9, 4,279-287.

SANDFORD, H. (1964) The use of 2, 6 - dichlorothiobenzamide in top and soft fruit. Proc. 6th Br. Weed Control Conf. 2, 619-628

Proc. 10th Br. Weed Control Conf. 1970

THE TOLERANCE OF BLACKCURRANTS TO CHLORTHIAMID AND DICHLOBENIL; EFFECTS ON GROWTH AND YIELD AND RESIDUES IN THE SOIL

D.V. Clay and C. E. McKone
ARC Weed Research Organization, Begbroke Hill, Sandy Lane, Yarnton, Oxford

Summary The tolerance of blackcurrants to annual treatments with chlorthiamid at doses up to 48 lb/ac and dichlobenil at doses up to 24 lb/ac was tested over a 3 year period. There was no reduction in crop growth or fruit yield resulting from any of the treatments. The higher rates of chlorthiamid (24 and 48 lb/ac) caused noticeable slight marginal chlorosis of expanded leaves at the edge of the leaf canopy in summer each year.

Residues of chlorthiamid and dichlobenil measured (as total benzonitrile) in soil samples taken from the treated plots in March 1969 and 1970 before the annual herbicide application showed that 90% or more of the annual dose of herbicide had dissipated. Chlorthiamid appeared slightly more persistent than dichlobenil; residues were largely confined to the top 4 in. of soil.

INTRODUCTION

The herbicides chlorthiamid and dichlobenil have become widely used in recent years in bush and cane fruit for the control of annual weeds and a wide range of perennial weeds. When used on established crops early in the year there have been no published reports of yield reductions from normal commercial rates of application (up to 10 lb/ac a.i.) and in some instances bush growth has been increased following the removal of severe weed competition (Spencer-Jones and Wilson, 1968). Slight toxicity in the form of marginal chlorosis of leaves in the summer has, however, been found on some fruit crops (Sandford, 1964; Davison, 1970b) but this has not been directly associated with any reduction in fruit yield.

Some information on the persistence of chlorthiamid and dichlobenil in soil is available. Beynon et al. (1966) and Beynon and Wright (1968) found that in field conditions the half life of these herbicides varied from 1 to 12 weeks with an average of 4 weeks depending on soil type, dose and weather conditions. In mineral soils the herbicidally active residues were less than 25% of the applied dose 2 months after application. The persistence and penetration of the herbicides was greater in peat soils, significant residues occurring at 12 in. depth, 32 weeks after treatment. Measurable amounts of the relatively inactive breakdown product, 2,6-dichlorobenzamide were found in all soils after 32 weeks and were present to at least 12 in. depth. Clay and McKone (1968) working with a range of doses of chlorthiamid on an uncropped sandy loam soil found a very rapid initial loss of herbicide (80% loss within a month) but there was enough herbicide remaining 14 months after application of 12 lb/ac to damage a following lettuce crop.

The experiment described here was set up to test the tolerance of blackcurrants to repeated annual applications of a range of doses of chlorthiamid and dichlobenil. Information was needed on the effect of repeated applications on the crop and the response to the high doses which might be used as spot treatments for the control of small infestations of perennial weeds not controlled by normal doses. There was also a need for more information on residue levels of these herbicides in the soil following repeated annual applications of high doses, to assess any possible harm to the growing crop or to a subsequent one.

METHOD AND MATERIALS

The experiment was carried out at Begbroke Hill on a well drained sandy loam soil overlying a calcareous gravel to a depth of 20 to 30 inches. A soil analysis is given below:

Coarse sand (%)	Fine sand (%)	Silt (%)	Clay (%)	Organic (%) matter	pH
50.4	24.0	10.4	15.2	3.1	6.7

The land was ploughed the previous autumn and was then cultivated and consolidated before planting in March 1966. 1 year old blackcurrant bushes, cultivar Baldwin, were planted in rows of five bushes with 6 ft between the rows and 3 ft between bushes along the rows. The experiment was laid out on a randomised block design, the three parallel blocks being separated by 10 ft alleys. The ten treated rows were each separated by a guard row; there were two control plots in each block.

The bushes were cut back to just above ground level after planting and the area received an overall application of simazine at 2 lb/ac a.i. in early April.

An application of compound fertilizer was made in early spring each year with additional potash fertilizer in 1969. A full programme of fungicide and insecticide applications was maintained throughout each year.

Treatments

The herbicide treatments applied to the plots each year commencing spring 1967 are detailed below. In the second year the doses of some of the chlorthiamid and dichlobenil treatments were increased.

Date of treatment	Dose applied (lb/ac a.i.)
21.4.67	Chlorthiamid 3,6,9,12,15; dichlobenil 6,12; simazine 2.
18.3.68 21.4.69 3.4.70	Chlorthiamid 3,6,12,24,48; dichlobenil 6,24; simazine 2.

Chlorthiamid and dichlobenil were both applied as a 7½% a.i. granular formulation from a "pepper pot" hand applicator. Simazine (50% w.p. formulation) was sprayed on to the plots using an Oxford Precision Sprayer or a knapsack sprayer. The whole area each side of the plot row up to the centre of the adjacent guard rows was treated and also an area extending one yeard from each end of the rows.

Weed control on untreated plots was maintained by handweeding and by spot applications of paraquat in the dormant season as necessary.

Assessments

Observations were made on the crop and injury symptoms recorded. Total yield of fruit was recorded either for the whole five bushes in the plot (1968) or for the central three bushes only (1969, 1970).

An estimate of the amount of new growth made by the bushes each year based on the method outlined by Freeman and Thompson (1960) was obtained by measuring during the early spring the length of a fixed proportion of all shoots over 15 cm long produced during the previous year. Similar measurements were made either on the amount of wood pruned off or on the new wood remaining on the bushes after pruning to check on any effects of treatments on the severity of pruning and on the amount of fruiting wood present.

Measurement of residues of chlorthiamid and dichlobenil in the soil

Soil samples were taken from two replicates of some of the treated plots in March 1969 and 1970 prior to retreatment with herbicide to determine the amount of herbicidally active chemical remaining. Soil samples were taken with a 1 in. diameter sampling tube from 12 positions selected at random in the alleys, the positions being recorded on a plan to avoid re-sampling in subsequent years. A 0-4 in. sample was taken on all plots, deeper samples being taken on the higher dose plots. The soil samples were passed through a 1/8 in. mesh sieve as soon as taken, mixed thoroughly and stored in a deep freeze at -10°C until analysed. The subsequent treatment of the samples and method of analysis followed that described by Clay and McKone (1968). The residues reported are given as total nitrile which, in the case of samples from plots treated with chlorthiamid, includes chlorthiamid and its herbicidally active breakdown product dichlobenil.

RESULTS

Observations of phytotoxic effects of treatments

No treatments caused any visible symptoms of injury in 1967. In 1968 slight marginal and interveinal chlorosis was observed in July on some shoots in plots treated with chlorthiamid at 48 lb/ac. The symptoms occurred on expanded leaves at the top of the leaf canopy. In 1969 similar symptoms developed in August on plots treated with 24 and 48 lb/ac of chlorthiamid. 20 to 50% of exposed, expanded leaves at the edge of the canopy were affected but symptoms did not occur on all shoots of an affected bush nor on all bushes in the affected plots. There was little difference in severity between the two doses of chlorthiamid. In July 1970 marginal and interveinal chlorosis again developed on the same chlorthiamid treatments. Severity was greater on the 48 lb/ac treatment but the incidence of the symptoms was obscured by severe marginal scorching of leaves due to moisture stress in all treatments.

Effect of treatments on fruit yield

The yield data for 1968 to 1970 are presented in Table 1. None of the herbicide treatments had any significant effect (P=0.05) on the yield of fruit in any year and there was no indication of a cumulative effect over the 3 year period.

Table 1

The effects of treatments on total yield of fruit (tons/ac) for 1968-70

Treatment		1968	1969	1970	Mean (1968-70)
Chlorthiamid	3 lb/ac	4.05	5.07	6.37	5.16
"	6 lb/ac	4.05	5.38	7.01	5.48
"	12 lb/ac	3.61	5.06	7.05	5.24
"	24 lb/ac	3.67	5.45	6.61	5.24
"	48 lb/ac	4.11	4.94	6.30	5.12
Dichlobenil	6 lb/ac	3.34	5.21	6.46	5.00
"	24 lb/ac	3.33	5.11	6.83	5.09
Simazine	2 lb/ac	2.77	4.92	6.53	4.74
Untreated control		3.62	5.50	6.78	5.30
S.E. of means		0.391	0.338	0.412	0.243

Table 2

The effects of treatments on the number of new shoots per bush

Treatment		March 1968	March 1969	March 1970	Mean (1968-70)
Chlorthiamid	3 lb/ac	41	88	73	67
"	6 lb/ac	41	81	78	67
"	12 lb/ac	44	80	80	68
"	24 lb/ac	39	78	73	63
"	48 lb/ac	40	77	75	64
Dichlobenil	6 lb/ac	42	83	84	70
"	12 lb/ac	46	81	77	68
Simazine	2 lb/ac	37	79	85	67
Untreated control		39	83	81	68
S.E. of means		3.5	5.2	5.5	3.4

Table 3

The effect of treatments on the length of new shoots per bush (decimetres)

Treatment		March 1968	March 1969	March 1970	Mean (1968-70)
Chlorthiamid	3 lb/ac	214	374	222	270
"	6 lb/ac	210	335	249	265
"	12 lb/ac	236	373	250	286
"	24 lb/ac	216	333	235	262
"	48 lb/ac	201	308	249	253
Dichlobenil	6 lb/ac	220	383	263	289
"	12 lb/ac	238	349	244	277
Simazine	2 lb/ac	202	336	266	268
Untreated control		213	379	254	282
S.E. of means		22.1	27.3	16.6	14.5

Effect of treatment on crop growth

The total number of new shoots over 15 cm long and total length of these shoots per bush measured before growth commenced in spring 1968, 1969 and 1970 is presented in Tables 2 and 3. There were no significant effects ($P = 0.05$) of any of the treatments on the growth of the bushes. The measurements made after pruning did not show any effects of the treatments on the severity of pruning or on the amount of fruiting wood present on the bushes.

Residues of chlorthiamid and dichlobenil in the soil

The results of the residue determinations are given in Table 4. They indicate only a low carry over of herbicide from year to year with no indication thus far of any build up. Chlorthiamid persisted in rather greater quantities than dichlobenil; only in the 48 lb/ac treatment were appreciable quantities recovered below 4 in.

Table 4

Chlorthiamid and dichlobenil residues in the soil (lb/ac total benzonitrile)

Treatment	Depth (in.)	Sample date 24.3.69	Sample date 18,19.3.70
Chlorthiamid 6 lb/ac	0–4	0.19	0.26
	4–6	0.01	0.01
	Total	0.20	0.27
Chlorthiamid 24 lb/ac	0–4	0.72	1.32
	4–6	0.04	0.02
	Total	0.76	1.34
Chlorthiamid 48 lb/ac	0–4	1.81	1.68
	4–6	0.23	0.13
	6–8	NS*	0.05
	Total	2.04	1.86
Dichlobenil 6 lb/ac	0–4	0.19	0.15
	4–6	0.01	0.01
	Total	0.20	0.16
Dichlobenil 24 lb/ac	0–4	0.56	0.43
	4–6	0.03	0.01
	Total	0.59	0.44
S.E. of means	0–4	0.045	0.091
	4–6	0.020	0.008

*NS - no sample taken

DISCUSSION

The effect of treatments on the crop

The results indicate no harmful effect from repeated annual applications of high doses of chlorthiamid and dichlobenil on bush growth and fruit yield. This provides further evidence of the high degree tolerance of blackcurrants to the doses of these herbicides needed to control most perennial weeds and the possibility of using even higher doses as overall or spot applications for the control of particular weeds which are resistant to the maximum dose of 10 lb/ac currently recommended, providing clearance is obtained (Davison 1970a, 1970b). The distinct marginal chlorosis which has been observed following the use of chlorthiamid and dichlobenil (Sandford 1964, Davison 1970b) has not so far been shown to be associated with a reduction in growth or yield.

Residues in the soil

The data obtained on residues of herbicide in the soil are reassuring in that even for the highest doses not more than 10% of the annual applied dose was carried over to the next year. Earlier work has shown that in mineral soils at least 75% of the applied dose is dissipated within two months of treatment (Beynon and Wright, 1968; Clay and McKone, 1968). From the data presented chlorthiamid appears to be slightly more persistent than dichlobenil which corroborates the results reported by Beynon and Wright (1968) on a comparable sandy loam soil although on a peat soil they found dichlobenil was more persistent. Organic matter content may in fact be an important factor influencing soil residue levels resulting from the use of these herbicides since Beynon and Wright found appreciably higher residues of benzonitrile particularly from dichlobenil in a peat soil compared with the mineral soils.

Acknowledgements

The help of Messrs. Shellstar Ltd, Mi-dox Ltd, and Fisons (Agrochemical Division) Ltd in supplying the chemicals used in this experiemtn is gratefully acknowledged. Thanks are due to the members of the Horticulture and Chemistry Sections at the Weed Research Orgainzation for assistance with this experiment.

References

BEYNON, K.I., DAVIES, L., ELGAR, K., and WRIGHT, A.N. (1966) Analysis of crops and soils for residues of 2,6-dichlorobenzonitrile (dichlobenil) and 2,6-dichlorothiobenzamide (chlorthiamid). J.Sci.Fd Agric. 17, 151-161.

BEYNON, K.I. and WRIGHT, A.N. (1968) Persistence, penetration and breakdown of chlorthiamid and dichlobenil herbicides in field soil of different types. J.Sci. Fd Agric., 19, 718-722.

CLAY, D.V. and McKONE, C.E. (1968) The persistence of chlorthiamid, lenacil and simazine in uncropped soil. Proc. 9th Br. Weed Control Conf., 933-938.

DAVISON, J.G. (1970a) Evaluation of herbicides and cutting treatments for the control of Heracleum sphondylium. Proc. 10th Br. Weed Control Conf.

DAVISON, J.G. (1970b) Experiments with chlorthiamid, dichlobenil and MCPB for the control of Convolvulus arvensis and Calystegia sepium in gooseberries. Proc. 10th Br. Weed Control Conf.

FREEMAN, G.H. and THOMPSON, J.A. (1960) The assessment of wood growth on blackcurrant bushes. Rep. E. Malling Res.Stn., 1959, 67-69.

SANDFORD, H. (1964) The use of 2,6-dichlorothiobenzamide (W.L. 5792), in top and soft fruit. Proc. 7th Br. Weed Control Conf., 208-216.

SPENCER-JONES, D.H. and WILSON, D. (1968) Trials to investigate the herbicidal efficacy of dichlobenil in bush fruit with special reference to the control of Agropyron repens. Proc. 9th Br. Weed Control Conf., 907-915.

Proc. 10th Br. Weed Control Conf. 1970

EXPERIMENTS WITH DICHLOBENIL, CHLORTHIAMID AND MCPB FOR THE CONTROL OF CONVOLVULUS ARVENSIS AND CALYSTEGIA SEPIUM IN GOOSEBERRIES

J.G. Davison
ARC Weed Research Organization, Begbroke Hill, Sandy Lane, Yarnton, Oxford

Summary Dichlobenil and chlorthiamid were applied at 10 and 20 lb/ac in March/April and May in two successive years for the control of *Convolvulus arvensis* and *Calystegia sepium* in gooseberry. Chlorthiamid was generally found to be more effective than dichlobenil and dose was more important than the time of application. Marginal chlorosis of crop leaves occurred at all three sites in both years. Dichlobenil at 20 lb/ac applied as the fruits were swelling caused a significant increase in fruit drop at one site. Yields were not affected.

Dichlobenil and chlorthiamid gave better control of *Convolvulus* in the year of treatment than did MCPB at 2.5 lb/ac applied the previous August or September. MCPB applied in late August was more effective in controlling *Calystegia* than 10 lb/ac of dichlobenil or chlorthiamid applied in the following spring. Control of both weeds with dichlobenil and chlorthiamid was generally better when MCPB was applied in the previous season.

INTRODUCTION

The introduction of dichlobenil and chlorthiamid has enabled many of the perennial weeds of blackcurrant and gooseberry to be controlled, but more detailed information is needed on the response of certain weeds, including *Convolvulus arvensis* L. (bindweed). Sandford (1964), working with chlorthiamid found that *C. arvensis* was one of the weeds that was suppressed only under optium conditions. Spencer-Jones and Wilson (1968) found that spring applications of dichlobenil gave good control until June, regrowth then occurred. Fryer and Evans (1968) recommend MCPB for the control of *C. arvensis* in blackcurrant and gooseberry when shoot growth of the crop has ceased.

The present work was conducted with the object of determining the relative effectiveness of dichlobenil, chlorthiamid and MCPB in controlling *C. arvensis*, with particular reference to dose and time of application of the first two.

METHOD AND MATERIALS

Three split-plot randomised block experiments were carried out in mature crops of gooseberry cv. Careless. Dichlobenil and chlorthiamid were applied as 7.5% w/w granules either from a hand shaker (all early applications in 1969 and the late application to Expt. 1 in 1969) or from a motorized knapsack applicator. In 1970 the early knapsack applications were applied over the bushes, all other applications were directed under the bushes. The MCPB was applied as the sodium salt in 100 or 200 gal/ac.

Treatments, replication, application dates and other site details are given in table 1.

Table 1

Site details including treatments and application dates

	Experiment No. 1		Experiment No. 2		Experiment No. 3	
Location	Worcester		Evesham		Chipping Campden	
Soil type	Coarse sandy loam (gravelly)		Silty clay loam		Silty loam	
Size of sub-plots (ft)	20 x 8		18 x 9		16 x 8	
No.recorded bushes/sub-plot	3		5		3	
Replication - main plots	4		3		4	
- sub plots	12		9		8	
Main plot treatments	1969	1970	1969	1970	1969	1970
MCPB 2.5 E	31.8	12.8	31.8	12.8	1.9	12.8
MCPB 2.5 L	24.9	24.9	24.9	24.9	-	-
Control	-	-	-	-	-	-
Sub-plot treatments						
D 10 E	1.4	19.3	-	-	2.4	17.3
D 20 E	1.4	19.3	2.4	17.3	2.4	17.3
D 10 L	15.5	19.5	-	-	21.5	19.5
D 20 L	15.5	19.5	20.5	19.5	21.5	19.5
C 10 E	-	-	3.4	17.3	2.4	17.3
C 20 E	1.4	19.3	3.4	17.3	-	-
C 10 L	-	-	20.5	19.5	21.5	19.5
C 20 L	-	-	20.5	19.5	-	-
S 2 (Control)	1.4	19.3	2.5	17.3	2.4	19.3

- = no treatment

Key to treatments

D = dichlobenil
C = chlorthiamid
S = simazine

2,10 etc = dose (lb/ac)
E = early
L = late

The sub-plot controls received simazine for the control of annual weeds and these are referred to as 'simazine treated controls'. In Expt. 3 there were two series of control plots because uneven distribution of C. arvensis was suspected. This proved to be so, therefore weed control results are not presented for this experiment.

In Expts. 1 and 2 there was a uniform stand of C. arvensis and Calystegia sepium. The percentage of the ground and bush covered with each of these weeds was assessed at approximately monthly intervals. At the same time marginal and general chlorosis of crop leaves were assessed. Crop yield and number of berries/it were determined for Expts. 2 and 3 in 1970.

One block of Expt. 1 and part of the adjoining commercial crop was assessed for American gooseberry mildew (Sphaerotheca mors-uvae) on 12th June 1970. Five

Table 2

Convolvulus arvensis - % ground cover in 1969 and 1970

Year	1969			1970								
MCPB treatment	mean			control			early			late		
assessed	17.7	15.8	31.8	13.7	12.8	24.9	13.7	12.8	24.9	23.7	12.8	24.9
Expt. 1												
D 10 E	8	15	23	9	10	10	4	9	1	5	8	9
D 20 E	2	7	11	4	5	6	2	2	1	2	4	6
D 10 L	6	17	23	8	9	5	2	3	1	4	6	6
D 20 L	2	7	13	2	1	2	1	2	1	1	1	2
C 20 E	1	1	2	0	0	1	0	<1	0	1	1	1
S 2	50	40	33	45	20	6	13	27	1	27	32	9
Expt. 2												
C 10 E	17	48	36	20	28	5	11	18	1	22	17	5
C 20 E	2	11	16	10	23	5	3	4	1	7	13	6
C 10 L	17	38	34	1	2	2	2	1	1	2	2	3
C 20 L	2	8	9	0	<1	1	<1	0	<1	<1	1	1
D 20 E	4	33	32	5	7	3	3	5	2	10	9	10
D 20 L	2	16	24	0	1	2	0	1	1	0	<1	2
S 2	47	49	23	35	11	3	36	23	1	42	6	3

Table 3

Convolvulus arvensis - % bush cover in 1969 and 1970

Year	1969	1970											
MCPB treatment	mean	control				early				late			
assessed	24.9	11.6	13.7	12.8	24.9	11.6	13.7	12.8	24.9	11.6	13.7	12.8	24.9
Expt. 1													
D 10 E	1	0	1	2	6	0	1	1	0	0	1	2	2
D 20 E	<1	0	1	2	<1	0	0	<1	0	0	0	0	0
D 10 L	5	0	0	1	1	0	<1	<1	0	0	0	<1	1
D 20 L	1	0	0	0	1	0	0	0	0	0	0	0	<1
C 20 E	<1	0	0	0	1	0	0	<1	<1	0	0	0	1
S 2	9	0	6	7	12	0	4	7	0	0	2	3	3
Expt. 2													
C 10 E	12	0	2	5	1	0	3	5	1	0	3	7	2
C 20 E	7	0	2	2	2	0	1	1	<1	0	1	1	1
C 10 L	16	0	<1	<1	<1	0	1	0	<1	<1	3	<1	1
C 20 L	8	0	<1	0	0	0	0	0	0	0	<1	<1	<1
D 20 E	8	0	1	1	1	0	0	<1	0	0	1	2	1
D 20 L	6	0	0	0	1	0	0	0	0	0	0	0	1
S 2	6	4	19	15	2	0	5	8	0	<1	24	26	2

Table 4

Calystegia sepium - % ground cover in 1969 and 1970

Year	1969			1970								
MCPB treatment	mean			control			early			late		
assessed	17.7	15.8	31.8	13.7	12.8	24.9	13.7	12.8	24.9	13.7	12.8	24.9
Expt. 1												
D 10 E	4	11	23	3	9	7	0	<1	0	1	3	3
D 20 E	1	4	14	4	1	2	0	<1	<1	0	1	1
D 10 L	3	7	15	2	8	6	0	<1	0	1	2	1
D 20 L	1	3	13	1	1	1	0	0	0	0	<1	1
C 20 E	1	1	3	0	1	1	0	0	0	0	<1	<1
S 2	8	20	35	16	45	14	1	3	0	4	18	8
Expt. 2												
C 10 E	4	22	23	11	13	3	<1	1	0	3	7	3
C 20 E	1	5	11	2	7	3	1	2	0	0	1	<1
C 10 L	7	20	27	3	2	1	<1	0	0	1	0	1
C 20 L	1	4	8	<1	<1	<1	0	0	0	0	<1	<1
D 20 E	2	14	19	6	9	3	<1	1	0	<1	1	2
D 20 L	1	5	9	<1	1	1	0	0	<1	0	<1	<1
S 2	27	36	29	47	19	3	4	2	0	37	17	2

Table 5

Calystegia sepium - % bush cover in 1969 and 1970

Year	1969	1970											
MCPB treatment	Mean	control				early				late			
assessed	24.9	11.6	13.8	12.8	24.9	11.6	13.7	12.8	24.9	11.6	13.7	12.8	24.9
Expt. 1													
D 10 E	25	0	2	9	14	0	0	0	0	0	<1	1	1
D 20 E	8	0	0	1	1	0	0	0	0	0	0	<1	<1
D 10 L	24	2	3	7	12	0	0	0	0	0	1	1	1
D 20 L	7	<1	<1	1	2	0	0	0	0	0	<1	1	3
C 20 E	4	0	<1	1	2	0	0	0	1	0	0	<1	<1
S 2	65	8	39	79	78	0	<1	1	0	0	1	4	12
Expt. 2													
C 10 E	35	<1	5	27	27	0	<1	<1	0	0	1	6	8
C 20 E	6	0	1	5	9	0	1	1	0	0	0	0	<1
C 10 L	59	10	4	8	2	0	1	0	0	<1	1	0	1
C 20 L	15	5	1	0	0	1	0	0	0	1	0	0	0
D 20 E	39	0	3	22	30	0	0	<1	0	0	<1	1	4
D 20 L	19	1	<1	1	1	<1	0	0	0	0	0	0	0
S 2	70	13	46	62	42	<1	1	5	0	2	10	25	37

fruiting shoots were selected from the middle bush of each plot, avoiding shoots in the centre. The total number of berries and the number slightly (<25% surface area) and severely affected (>25%) by mildew on the apical 10 in. of each shoot were recorded on each bush. Five new shoots, that were longer than 10 in., were also inspected for presence or absence of mycelium on their apical leaves. In the adjoining crop two rows were selected 20 yd to the west and east of the experiment and six and four bushes were assessed in the same way. In Expt. 3 the number of berries that had fallen from the bushes was assessed on 6th June 1970 by counting the number in two 9 in. quadrats placed in the same position under each bush.

RESULTS

Weeds

Ground cover results for Convolvulus and Calystegia in 1969 are the means of the three main plot treatments since these had not been applied at the time of assessment. Similarly, the bush cover results are the means of the two main plot treatments that had not received MCPB.

a) Convolvulus arvensis In Expts. 1 and 2 maximum ground cover occurred towards the end of July in 1969 and in mid-June in 1970. With both dichlobenil and chlorthiamid dose was found to be more important than time of application except in Expt. 2 in 1970 when the late application was best. Chlorthiamid was more effective than dichlobenil at the same dose except with the early application in Expt. 2 in 1970. In both experiments there was a uniform 10% cover when the late treatments were applied in 1969. When they were re-treated in 1970 there was up to 50% reduction in comparison with the simazine treated controls.

MCPB applied in 1969 to plots that had not received dichlobenil or chlorthiamid delayed development and reduced maximum ground cover of Convolvulus in 1970. The early application was more effective than the late, but it was still not as effective as dichlobenil or chlorthiamid. When MCPB was used in conjunction with dichlobenil and chlorthiamid there was generally an improvement in control.

Bush cover data are presented in table 3. The low value for the simazine treated controls in Expt. 2 in 1969 was probably due to competition or masking by Calystegia. Dichlobenil and chlorthiamid treatments resulted in a control of not less than 60% up to mid-August 1970. The results for MCPB on the simazine treated controls were variable, but like the ground cover results none was better than any of the dichlobenil and chlorthiamid treatments without MCPB.

b) Calystegia sepium Where no MCPB was applied reduction in ground cover of Calystegia due to dichlobenil and chlorthiamid (table 4) was similar to that of Convolvulus (table 2). Reduction in emergence prior to application of the late treatment in 1970 was also similar. Control in 1970 from the MCPB application in late August 1969 was at least equal to that of dichlobenil and chlorthiamid applied at 10 lb/ac in 1970. The late application of MCPB was more effective in Expt. 1 than in Expt. 2. When MCPB was applied in conjunction with dichlobenil and chlorthiamid better results were always achieved particularly when the latter were applied late.

Cover of bushes by Calystegia (table 5) followed closely the trend of ground cover.

Table 6

Gooseberry - Marginal chlorosis in 1970 (% of leaves affected)

Treatment	Experiment 1		Experiment 2		Experiment 3	
	13.7	12.8	13.7	12.8	13.7	12.8
D 10 E	0	0	-	-	0	1
D 20 E	3	5	14	37	1	9
D 10 L	0	2	-	-	0	1
D 20 L	1	4	6	22	1	6
C 10 E	-	-	7	20	1	11
C 20 E	28	33	32	66	-	-
C 10 L	-	-	0	7	1	6
C 20 L	-	-	8	22	-	-
S 2	0	0	0	0	1	1

Crop

a) Chlorosis (table 6) Marginal leaf chlorosis was observed from mid-July onwards in all three experiments in both 1969 and 1970. It occurred mainly on the older leaves of new shoots and the apical leaves of old shoots that had not made any new growth in the current season. As its occurrence was not influenced by MCPB applied the previous year, the values for 1970 (table 6) have been bulked. More marginal chlorosis occurred with chlorthiamid than with dichlobenil and it was more severe with early than late applications. In Expt. 2 chlorosis was more severe in 1970 than 1969; in Expt. 3 the converse was true. General chlorosis occurred only in Expt. 2. It showed a similar trend to the marginal chlorosis but was more severe in 1969 than in 1970.

b) Fruit drop (table 7) One week after the late application of dichlobenil and chlorthiamid in 1970 it was apparent that many developing fruits had fallen from the bushes in Expt. 3. In an assessment on 3rd June there were no differences due to the MCPB treatment in 1969, but the high dose of dichlobenil caused a significant increase in drop (P=0.5) while the low dose approached significance. Fruit drop [illegible] negligible in Expts. 1 and 2.

c) Fruit yield and size (table 7) The 1969 application of MCPB did not affect yield therefore the yields in table 7 for Expts. 2 and 3 are based on 9 and 6 sub-plots respectively. None of the dichlobenil or chlorthiamid treatments was significantly different from the simazine treatments. There were significant differences in the berry wt. (expressed as no. berries/lb in table 7). In Expt. 2 the berries were larger where dichlobenil at 20 lb/ac or chlorthiamid at 10 lb/ac were applied late and in Expt. 2 they were smaller where chlorthiamid at 10 lb/ac was applied late.

d) American gooseberry mildew On 12th June 1970 80% of the berries in block II of Expt. 1 were affected with mildew, on 10% it was severe (i.e. more than 25% of the berry covered with mycelium); 95% of the new shoots were affected. In the adjacent non-experimental area less than 50% of the berries were affected and only 1% severely affected and less than 50% of the new shoots were affected.

Table 7

Gooseberry - fruit drop, yield and number of berries/lb in 1970

Treatment	Fruit drop* Expt. 3 3/6.	Yield (tons/ac) Expt.2 16/6.	Yield (tons/ac) Expt.3 23/6.	No. berries/lb Expt.2 16/6.	No. berries/lb Expt.3 23/6.
D 10 E	38	-	8.0	-	121
D 20 E	60	1.5	6.4	124	126
D 10 L	67	-	7.6	-	116
D 20 L	102	1.5	8.6	110	114
C 10 E	52	+	8.1	123	122
C 20 E	-	1.6	-	144	-
C 10 L	53	+	7.2	113	151
C 20 L	-	1.4	-	131	-
S 2 (a)	38	1.8	9.3	133	125
S 2 (b)	37	-	7.8	-	129
S.E. of means	12.3	0.18	0.77	4.2	7.7

* Number of berries in 3.5 ft^2/plot + Yields not taken

DISCUSSION

Dichlobenil and chlorthiamid both gave satisfactory control of Convolvulus and Calystegia on the ground up to at least early August. Chlorthiamid gave generally better control than dichlobenil though some of the differences were small. Increasing the dose from 10 to 20 lb/ac was generally more effective in improving control than delaying application from mid-March/early April to mid-May. Both weeds impede harvesting, which takes place in June, if they cover even part of the bushes and control measures may be justified for this reason alone. In 1970 all treatments, except the late application of chlorthiamid in Expt. 2 were effective in preventing this. Control of Convolvulus was better than that reported by Spencer-Jones and Wilson (1968) for dichlobenil and more reliable than reported by Sandford (1964) for chlorthiamid. Differences due to soil type have not been as great as the above authors suggest. The good control achieved with mid-May applications indicates the possibility of post emergence applications where these weeds occur in patches that do not justify overall pre-emergence treatment. The 1970 results are of particular interest in that good control was achieved under hot dry conditions in 1970 when the granules remained visible on the soil surface until mid-June.

The work has not continued long enough to indicate whether eventual elimination of Convolvulus will be achieved with repeated annual applications of dichlobenil or chlorthiamid but it seems unlikely that build up will occur. The reduced emergence of both weeds in May 1970, 12 months after the first application, might be due to herbicide residues in the soil (Clay and McKone, 1970) in which case chlorthiamid would be expected to be more effective than dichlobenil because of its greater persistence. Where MCPB was applied the advantage of early application was apparent and this would seem to be a worthwhile follow up treatment to a spring application of dichlobenil or chlorthiamid for the control of Convolvulus.

The relative value of dichlobenil, chlorthiamid and MCPB for the control of Convolvulus and Calystegia will be influenced by factors other than their direct effect on these weeds e.g. their effect on other weeds, crop tolerance, financial and managerial considerations. The results presented do not indicate any immediate benefits in the form of increased yield. Harvesting was, however, easier where Calystegia was prevented from spreading over the bushes.

The occurrence of marginal chlorosis, probably due to the breakdown product 2,6-dichlorobenzamide (Verloop and Daams, 1970) does not appear to influence yield. Similar symptoms have been reported in gooseberries with chlorthiamid (Sandford, 1964) but they did not occur when dichlobenil was applied at 30 lb/ac (Spencer-Jones and Wilson, 1968). The fruit drop that occurred in Expt. 3 requires further investigation. Climatic conditions after application were probably similar at all sites but the fruit size when the treatments were applied (3/8 in. diameter) was less than in Expts. 1 and 2 while the yield was greater than in Expt. 2 and probably in Expt. 1 also.

The increased level of American gooseberry mildew, despite a full fungicide programme, occurred in a year in which the disease was prevalent. It is thought to be associated with the more healthy appearance of the crop over the experimental area in the previous autumn, this was attributed to the excellent control of annual weeds throughout the season. Increased mildew has been associated with increases in growth of blackcurrants (Upstone and Davies, 1967).

Acknowledgements

The co-operation of the growers on whose crops these experiments were conducted and the help of Fisons (Agrochemical Division) Ltd, Midox Ltd and Shellstar Ltd who supplied the herbicides and Shellstar Ltd who also supplied the granule applicator are gratefully acknowledged. Thanks are also due to Miss J.P. Crabtree and P.J.G. Fairbank for assistance in the experimental work.

References

CLAY, D.V. and McKONE, C.E. (1970) The tolerance of blackcurrants to chlorthiamid and dichlobenil; effects on growth and yield and residues in the soil. Proc. 10th Br. Weed Control Conf.

FRYER, J.D. and EVANS, S.A. (1968)(Eds.) Weed control handbook, Vol.2, Blackwell Scientific Publications, Oxford, 5th ed.

SANDFORD, H. (1964) The use of 2,6-dichlorothiobenzamide (W.L.5792) in top and soft fruit. Proc. 7th Br.Weed Control Conf. 208-16.

SPENCER-JONES, D.H. and WILSON, D. (1968) Trials to investigate the herbicidal efficacy of dichlobenil in bush fruit with special reference to the control of Agropyron repens. Proc. 9th Br. Weed Control Conf. 907-15.

UPSTONE, M.E. and DAVIES, J.C. (1967) The effect of simazine in the incidence of American gooseberry mildew on blackcurrants. Pl. Path., 16, 86-9.

VERLOOP, A. and DAAMS, J. (1970) [Relationships between the side effects of dichlobenil on woody plants and the transformation of the herbicide in plants and soil] Z. PflKrankh. PflPath. PflSchutz, Sonderh. 5, 141-6.

Proc. 10th Br.Weed Control Conf.1970

EXPERIMENTS WITH TERBACIL FOR THE CONTROL OF PERENNIAL GRASSES IN STRAWBERRIES

N. Rath and D. W. Robinson
Soft Fruits Research Station, Clonroche, Co. Wexford

Summary Terbacil at $\frac{1}{2}$ to 1 lb/ac reduced the yield of strawberries each year when applied annually to a weed-free plantation during a three year period. Doses of 1 and 2 lb/ac were effective against perennial grasses and, compared with unsprayed plants, caused no yield reduction or loss of crop vigour when applied during the dormant period to a plantation severely infested with Agropyron repens and Agrostis stolonifera. Severe injury occurred when terbacil at 1 and 2 lb/ac was applied to actively growing strawberry plants.

Although the tolerance of strawberries to terbacil is limited, its use in plantations infested with perennial grasses is justified in view of the absence of alternative means of control.

INTRODUCTION

Preliminary trials with terbacil in strawberries showed that this crop was less tolerant of the herbicide than raspberries or blueberries (Rath and O'Callaghan 1968). Nevertheless because terbacil was so effective against certain perennial weeds that were tending to build up in simazine- and lenacil-treated plantations e.g. Agropyron repens and Lathyrus pratensis, it was considered that further work with terbacil was warranted. One of the experiments started in 1968 (Rath and O'Callaghan 1968), was continued in 1969 and 1970 to test the effect of repeated annual applications of terbacil and several new experiments were started.

MATERIALS AND METHODS

Experiment 1

An experiment was laid down on a block of Cambridge Vigour strawberries which had been planted on 10 May 1966. The strawberries had been used for trials with chloroxuron and diphenamid in 1966 and 1967 but none of these previous treatments had had any harmful effect on plant size or crop yield. The treatments listed in Table 1 were applied on 24 April 1968. Lenacil at 1 lb/ac was included as a control treatment. Each plot consisted of two rows with 25 plants in each row. The rows were spaced 34 in. apart and the plants were 18 in. apart in the row. Each treatment was replicated six times in a randomised block design. The treatments were repeated on the same plots on 3 March 1969 and 25 March 1970. Paraquat was applied to all plots for the control of runners at 0.5 lb/ac on 7 September 1968 and on 24 September 1969. The plots receiving lenacil were cultivated as required to control weeds in the spring and autumn of each year. The plots treated with terbacil received no cultivations but each year it was necessary to remove a few tolerant weeds by hand.

Results

In 1968 terbacil at $\frac{3}{4}$ and 1 lb/ac caused severe damage to the strawberry foliage. The damage appeared in early May as scorching of the outer edges of the leaves. The symptoms became progressively worse until late May. During June and July the plants made a good recovery and by early August symptoms of herbicide damage had almost disappeared. Similar, though less severe symptoms occurred in 1969. However, during August 1969 the foliage of all terbacil-treated plants were considerably greener than those treated with lenacil. The pattern of herbicide damage in 1970 was very erratic. During May several plants in every terbacil-treated plot in three of the six blocks became severely scorched and stunted, while adjacent plants in the same plot remained completely free of herbicide damage. The herbicide damage became progressively more severe during May and June. By early June several of the most severely affected plants began to recover. In early July a total of 3, 21 and 12% of the strawberries had died and 2, 12 and 7% were severely damaged on the plots treated with doses of ½, ¾ and 1 lb/ac respectively. No symptoms of herbicide damage occurred on the plots in the other three blocks.

In early August all plots treated with terbacil began to grow very vigorously. By late August these plants had produced more young leaves since harvest time and were much larger and greener than the plants which had received lenacil. There was no difference in vigour between the different terbacil treatments.

On 30 June 1970 plant heights and widths were slightly, though not significantly, reduced by terbacil at ¾ and 1 lb/ac (Table 1).

Table 1

Effect of terbacil on height and width of strawberry plants (cv. Cambridge Vigour)

Herbicide (lb/ac)		Plant height (in.)	Plant width (in.)
Lenacil	1	9.1	16.0
Terbacil	½	9.1	16.8
Terbacil	¾	8.4	15.4
Terbacil	1	8.5	15.5
'F' test		N.S.	N.S.
S.E. (df = 15)		±1.03	± 1.48

In 1968 terbacil at 1 lb/ac reduced yield of marketable fruit compared with lenacil at 1 lb/ac and terbacil at ½ lb/ac (p = 0.01) and with terbacil at ¾ lb/ac (p = 0.05) (Table 2). Yield of marketable fruit was again reduced by the higher doses of terbacil in 1969 and 1970. However, in these years the reduction was not significant. Compared with annual applications of lenacil over a 3 year period, terbacil at ½, ¾ and 1 lb/ac reduced yield by 5, 14 and 22% respectively.

As the plantation was in its fourth cropping year in 1970, fruit size was small. There was, however, no significant difference between treatments in size of berries (Table 3).

Compared with lenacil, terbacil at all doses gave excellent control of annual weeds. The terbacil-treated plots remained completely free of annual weeds throughout the duration of the experiment. However, at the end of three years the plots receiving terbacil at ½ lb/ac were slightly infested with broad-leaved perennial weeds. The most important of these were *Potentilla anserina*, *P. reptans* and *Mentha arvensis*. All terbacil-treated plots remained completely free of grass weeds. Lenacil failed to give adequate weed control and at the end of the three years these plots were severely infested with *Holcus lanatus*, *Potentilla anserina* and *Mentha arvensis*. The most important annual weeds were *Senecio vulgaris*, *Sonchus oleraceus*, *Euphorbia helioscopia* and *Viola arvensis*.

Table 2

Effect of annual application of terbacil on yield of strawberry (cv. Cambridge Vigour)

Herbicide (lb/ac)		Yield (cwt/ac)			
		1968	1969	1970	Total
Lenacil	1	180.3	133.9	108.5	422.7
Terbacil	½	168.0	115.8	107.2	391.0
Terbacil	¾	159.5	116.7	86.3	362.5
Terbacil	1	129.4	111.2	87.7	328.3
'F' test		**	N.S.	N.S.	*
S.E. (df = 15)		8.85	8.03	5.89	16.20

Table 3

Effect of terbacil on mean berry size of strawberries (July 1970)

Herbicide (lb/ac)		Mean no. berries per lb
Lenacil	1	95
Terbacil	½	95
Terbacil	¾	94
Terbacil	1	92
'F' test		N.S.
S.E. (df = 15)		8.55

Experiment 2

A second experiment using terbacil on strawberries was carried out on a grower's plantation near the Soft Fruit Research Centre at Clonroche. This site was planted with cultivar Cambridge Vigour in April 1968. The plants were spaced 2 ft apart in rows 3 ft apart. Subsequently this plantation became badly infested with perennial grass weeds, the most important being *Agrostis stolonifera* and *Agropyron repens*. The area was almost totally covered with these weeds by November 1969. The most prevalent broad leaved weed present was *Cirsium arvense*. At the time of spraying the plantation consisted of a uniform stand of moderately vigorous strawberry plants. The treatments listed in Table 4 were applied on 4 November 1969 and on 20 February 1970. Plot size was 8 yd x 2 rows. A randomised block design with five replications was used. An estimate of the grass weeds present on each plot was obtained on 2 June 1970 by placing a foot square quadrat at random three times on each plot and by weighing the green grass foliage enclosed by the quadrat. The plots were rated for weeds present on 9 September.

Results

Herbicide damage to the grass weeds first became apparent on 1 April 1970, five months after the autumn treatment. The tips of the grass leaves were scorched, the damage being most severe on Treatments K and L where the higher doses (1 and 2 lb/ac) were used in November and again in February. Symptoms of herbicide damage was also apparent on Treatments C, D, G, H and J. The damage to the grass became progressively more severe on the spring-treated plants until on 29 May the grass weeds on Treatment L were almost eliminated and good control was obtained with

Treatments H and K. In early June the grass weeds on plots receiving Treatment D began to show symptoms of severe herbicide damage. These symptoms became more severe during June.

Table 4

Treatments applied to perennial grass weeds and strawberries (Experiments 2 and 3)

Treatment no.	Terbacil (lb/ac)	
	4 November 1969	20 February 1970
A	0.0	0.0
B	0.5	0.0
C	1.0	0.0
D	2.0	0.0
E	0.0	0.0
F	0.0	0.5
G	0.0	1.0
H	0.0	2.0
I	0.0	0.0
J	0.5	0.5
K	1.0	1.0
L	2.0	2.0

In late June the grass on all plots which received terbacil in November only began to recover and by early September there was little difference between the grass weeds on these plots and on the unsprayed control plots. Perennial grasses also recovered on plots receiving the lower doses of terbacil in February. However, the grass weeds had not made any recovery on the plots receiving Treatments H, K and L (Table 5). In early September all unsprayed plots and those that had received terbacil in November only were infested with *Poa annua*. *Poa annua* was absent on all plots treated with terbacil in February. No treatment had any effect on *Cirsium arvense*, the principal broad-leaved perennial weed present.

Table 5

Effect of terbacil on perennial grass weeds

Treatment no.	Weight of fresh green grass (g) 2/6/'70	Weed rating* 11/9/'70
A	121.1	9.6
B	108.3	9.6
C	97.0	9.6
D	63.3	7.8
E	103.9	10.0
F	61.3	7.8
G	34.3	6.2
H	17.0	1.8
I	104.0	10.0
J	32.6	5.0
K	9.7	3.2
L	8.9	1.0
'F' test	***	
S.E. (df=44)	12.20	
LSD (p = 0.05)	34.80	

* 10 = ground completely covered by grass weeds 1 = ground completely free of grass weeds

Symptoms of herbicide damage appeared in early June on some strawberry plants receiving Treatment L. This consisted of interveinal and marginal scorching of the younger leaves. On a few plants the symptoms became more severe until early July. After this date no further increase in herbicide damage occurred. Similar, though less severe, damage occurred on plots receiving Treatment D. The remaining treatments caused no visible injury.

The treatments had no statistically significant effect on plant heights or widths or on crop weight (Table 6) although yield was lower on plots treated with terbacil at 2 lb/ac in November and again in February compared with untreated plots. In September, plants in Treatments H, K and L were more vigorous and greener than all others.

Table 6

Effect of terbacil on yield and vigour of strawberries (cv. Cambridge Vigour)

Treatment	Crop yield (cwt/ac)	27 July 1970	
		Mean plant height (in.)	Mean plant width (in.)
A	32.7	10.0	16.1
B	33.4	9.3	17.3
C	40.4	10.4	18.0
D	34.2	9.9	20.2
E	36.6	10.7	18.1
F	45.3	10.3	19.1
G	52.4	10.9	19.8
H	38.7	9.5	19.0
I	35.4	11.1	18.4
J	41.8	10.0	18.1
K	37.3	11.2	19.6
L	28.6	10.6	21.1
'F' test	N.S.	N.S.	N.S.
S.E. (df=44)	2.85	1.57	3.39

Experiment 3

To test the effect of terbacil on actively growing strawberry plants another trial was laid down in the same plantation as that used for Experiment 2. The treatments listed in Table 7 were applied on 26 May 1970. Plot size was 2 rows x 30 yd. Each treatment was replicated four times in a randomised block design. At the time of spraying the weather was extremely warm (air temperature 17°C) and bright and the soil was dry. The plantation was severely infested with Agrostis stolonifera and Agropyron repens which were growing vigorously when sprayed.

Table 7

Effect of terbacil on yield of strawberries (cv. Cambridge Vigour)

Terbacil (lb/ac) 26/5/'70	Crop yield (cwt/ac)
0	39.5
½	27.4
1	21.1
2	11.1
'F' test	***
S.E. (df=9)	2.32
LSD (p=0.05)	7.42

Results

All doses of terbacil caused severe marginal scorching of the strawberry foliage shortly after application. This damage was most severe where the higher doses were used. The damage became progressively worse during June and early July. At this time the plants receiving the highest dose were severely stunted. However, in no case did the herbicide treatment cause any plant death. Similar, though less severe, stunting occurred on the plots receiving terbacil at ½ and 1 lb/ac. During late July and August the plants gradually recovered. By early September treated plants were almost as vigorous as unsprayed control plants.

The application of terbacil also caused rapid scorching of Cirsium arvense, the most prevalent broad-leaved weed. However, this weed also recovered during late July and August. Applications of terbacil did not cause rapid scorching of the foliage of the grass weeds present. During early June the grass weeds began to die back from the tips of the leaf blades. This damage continued during July and August. By early September the grass weeds on the plots receiving terbacil at 2 lb/ac were almost completely controlled. During early September perennial grass weeds began to recover on the plots receiving terbacil at ½ lb/ac. At that time Poa annua developed on plots receiving terbacil at ½ lb/ac. All doses of terbacil caused large reductions in crop yield ($p = 0.01$). Compared with unsprayed plots terbacil at ½, 1 and 2 lb/ac caused crop reductions of 30, 47 and 72% respectively (Table 7).

DISCUSSION

These results show clearly that the tolerance of strawberries to terbacil is limited even when relatively low doses (½ - 1 lb/ac) are used. Yield reduction was particularly severe when terbacil was applied in April or May when the strawberries were growing rapidly and the foliage was soft. Treatments made when the plants were dormant (February) or were growing slowly (November) caused much less injury.

Terbacil applied at 1 lb/ac in a weed-free plantation in March or April decreased crop yield significantly. However, this dose caused no reduction in yield when applied to plots heavily infested with Agropyron repens and Agrostis stolonifera in November or February.

Terbacil applied at 1 lb/ac in November did not give good control of these perennial grasses, but application in February continued to give reasonable suppression of grass weeds throughout the active growing season. Terbacil applied at 2 lb/ac to grass-infested strawberries in February also caused no reduction in yield compared with unsprayed plots and maintained the ground in a virtually grass-free condition until the autumn.

Cirsium arvense occasionally occurs in association with Agropyron repens and Agrostis stolonifera. The results obtained in Experiments 2 and 3 emphasise the tolerance shown by this thistle to terbacil. Where C. arvense is prevalent, treatment with terbacil is unlikely to be worthwhile unless action is also taken against this species, possibly with 2, 4-D.

The stimulating effect of terbacil on the vigour of strawberries in Experiment 1 is noteworthy. This may be due to the effect of the herbicide on nitrogen metabolism and uptake as has been reported by Ries et al (1967) following the application of simazine.

The results of these experiments show that the decision to use terbacil in strawberries cannot be made lightly by growers. Some reduction in yield directly attributable to phytotoxicity is likely to result. Moreover, there may be a risk to subsequent seeded crops due to the prolonged residual effect of terbacil in the soil. However, it is impossible to control established Agropyron repens in strawberries either by cultural means or by herbicides already available. This weed not only has a severe deleterious effect on the existing crop but it will also affect subsequent crops unless thorough cultural or chemical means of control are adopted between crops. These results suggest, therefore, that on soil types similar to those at Clonroche, an application of terbacil at 1 to 2 lb/ac during the period when the strawberry is not in active growth could be beneficial in plantations severely affected with perennial grasses. Split-applications of lower doses also appear useful and will be investigated further. More information is also required on the persistence of terbacil on different soil types and under various climatic conditions.

Acknowledgements

The authors wish to thank Mr. J. Doyle for technical assistance and Mr. D. Conniffe for the statistical analyses.

References

RATH, N. and O'CALLAGHAN, T. (1968) Preliminary trials with terbacil for weed control in soft fruits. Proc. 9th Brit. Weed Control Conf. 2, 922 - 927.

RIES, S. K., CHMIEL, H., DILLEY, D. R. and FILNER, P. (1967) The increase in nitrate reductase activity and protein content of plants treated with simazine. Proc. nat. Acad. Sci. 58, 526 - 532.

THE USE OF PHENMEDIPHAM IN STRAWBERRIES

D. W. Robinson* and N. Rath
Soft Fruits Research Centre, Clonroche, Co. Wexford

Summary Field trials were carried out with phenmedipham for the control of weeds in strawberries during 1968, 1969 and 1970. Newly planted and established crops showed good tolerance even when doses higher than those needed to control annual weeds were used. Many weeds were susceptible to phenmedipham including some, e.g. Veronica agrestis which are resistant to a simazine/lenacil programme.

The results suggest that phenmedipham is a useful foliar-acting herbicide to supplement currently used soil-applied herbicides in strawberries.

INTRODUCTION

Good progress has been made in developing suitable chemical methods of weed control in strawberries during the last ten years. The most successful herbicides introduced for this crop in the 1960's, viz. simazine and lenacil, are a big improvement in terms of better weed control or selectivity over the herbicides they superceded e.g. chlorpropham, 2,4-DES and chloroxuron.

Lenacil and simazine are soil-acting herbicides effective against a wide range of weeds. Used in rotation on ground free from perennial weeds they can often provide weed-free conditions for most of the year (Rath and O'Callaghan 1970). However, lenacil and simazine do not always give consistent results. Both herbicides provide inadequate control of certain species e.g. Veronica spp. They are also ineffective if applied when the soil is dry. If a grower is unable to irrigate and postpones spraying until rain falls, weed seedlings are often too advanced to be controlled effectively by a soil-acting herbicide.

Simazine and lenacil are also less satisfactory on soils with a high organic content. Good results can often be obtained by using high doses, but the optimum dose on such soils can vary within wide limits and frequently needs to be determined specifically for a particular area.

There is an increasing need for suitable herbicides to suppress simazine- and lenacil-resistant weeds in strawberries and to provide good control of weeds in the young-plant stage which are no longer susceptible to a soil-acting herbicide. Several trials have been conducted at the Soft Fruits Research Centre, Clonroche, Co. Wexford to find foliar-acting herbicides suitable for overall application in strawberries. In 1968 promising results were obtained with phenmedipham and further trials were conducted with this herbicide in 1969 and 1970.

MATERIALS, METHODS AND RESULTS

Experiment 1

This experiment was carried out on strawberries, cultivar Cambridge Vigour to test the effect of phenmedipham on crop and weeds. The strawberries were planted on 7 March 1968 at the Soft Fruits Research Station, Clonroche, Co. Wexford, and phenmedipham was applied at 0, 1, 1.5 and 2 lb/ac on 17 May 1968. Each plot consisted of 25 plants spaced 1.5 ft apart. A randomised

* Address: Kinsealy Research Centre, Dublin. 5.

block design with five replications was used.

The principal annual weeds present at time of spraying were *Viola arvensis* (three true leaves), *Galeopsis tetrahit* (three pair true leaves), *Euphorbia helioscopia* (six true leaves), *Polygonum convolvulus* (three true leaves), *Spergula arvensis* (two whorls of leaves), *Fumaria officinalis* (six leaves), *Stellaria media* (six leaves), *Anagallis arvensis* and *Chrysanthemum segetum*.

All doses of phenmedipham caused slight yellowing of the strawberry foliage. However, the plants quickly recovered and by mid-June there were no obvious differences between treated and untreated plants. Crop weights were not recorded but the herbicide had no apparent effect on yield or berry quality. All three doses gave good control of the annual weeds present (Table 1).

Table 1

Effect of phenmedipham on seedling weeds

Weed species	No. of weed seedlings/ft²			
	Phenmedipham (lb/ac) 17 May 1968			
	0	1	1.5	2
Polygonum convolvulus	11.2	0.6	0.6	0.4
Viola arvensis	3.5	0.1	0.2	0.0
Galeopsis tetrahit	1.8	0.1	0.0	0.0
Spergula arvensis	0.8	0.0	0.0	0.0
Stellaria media	0.5	0.0	0.0	0.0
Fumaria officinalis	0.5	0.0	0.0	0.0
Anagallis arvensis	0.4	0.0	0.0	0.1
Euphorbia helioscopia	0.3	0.1	0.0	0.0
Chrysanthemum segetum	0.5	0.1	0.0	0.0

Experiment 2

To test the effect of phenmedipham on newly planted strawberries, the herbicide was applied at 0, 0.6, 1.2 and 2.4 lb/ac on 4 June 1968 on the cultivar Cambridge Vigour, planted on 29 February 1968. Plant spacing was 18 in. apart in rows 34 in. apart and plot size was 8 yd x 1 row (16 plants). A randomised block design with three replications was used.

Annual weeds present at the time of spraying included *Galeopsis tetrahit*, *Stellaria media*, *Spergula arvensis*, *Poa annua*, *Senecio vulgaris*, *Sinapis arvensis*, *Myosotis arvensis*, *Polygonum convolvulus*, *P. aviculare*, *P. persicaria*, *Viola arvensis*, *Euphorbia helioscopia* and *Aphanes arvensis*. On this occasion some of the weeds present had attained a height of 4 in.

Phenmedipham again caused slight yellowing from which the plants quickly recovered. However, only the highest dose gave adequate control of the weed species present. Crop yield was small as plants were in their first season but no treatment had any adverse effect (Table 2).

Experiment 3

An experiment was laid down in 1969 to examine the effects of phenmedipham on mature strawberry plants. Cambridge Vigour runners were planted 18 in. apart in rows 34 in. apart on 29 February. During 1968 and early 1969 a simazine and paraquat herbicide programme maintained the plantation in a weed free condition. On 21 May 1969 the plants were sprayed with phenmedipham at 0, 0.6, 1.2 and 2.4 lb/ac. Plot size was 8 yd x 1 row (16 plants) and a randomised block design with three replications was used. At the time of spraying the plantation was weed free except for occasional plants of Tussalago farfara.

Phenmedipham at 0.6 or 1.2 lb/ac had no injurious effect on plant foliage or vigour but the 2.4 lb dose caused slight crinkling and chlorosis of the strawberry leaves.

Crop yield was lower on the plots receiving phenmedipham at 0.6 lb/ac but the higher doses, 1.2 and 2.4 lb/ac, had no effect on crop yield (Table 3).

Table 2

Effect of phenmedipham on yield of young strawberry plants

Phenmedipham (lb/ac)	Crop yield (cwt/ac)
0	0.57
0.6	0.64
1.2	0.74
2.4	0.60
'F' test	N.S.
S.E. (df = 6)	0.02

Table 3

Effect of phenmedipham on yield of established strawberries

Phenmedipham (lb/ac)	Crop yield (cwt/ac)
0	161.5
0.6	144.8
1.2	158.9
2.4	157.8
'F' test	N.S.
S.E. (df = 6)	6.87

Experiment 4

An experiment with phenmedipham was laid down on a plot of Cambridge Vigour on a grower's holding near Clonroche on 2 March 1970. The runners were planted 2 ft apart in rows 3 ft apart in April 1968. Phenmedipham was applied at 0, 0.6, 1.2 and 2.4 lb/ac on 2 March, 1970. The principal annual weeds present at the time of spraying were Veronica agrestis and Senecio vulgaris. Other important weeds included were Poa annua, Stellaria media and Lamium purpureum. The most important perennial weeds present were Lolium perenne, Tussalago farfara and Cirsium arvense. The weed species present were rated on 15 May 1970. Plant height and width were measured on 25 July 1970 but fruit yield was not recorded.

Phenmedipham at 2.4 lb/ac gave good control of all annual broad-leaved weeds but failed to control Poa annua. Phenmedipham at 0.6 and 1.2 lb/ac was not effective against well established Senecio vulgaris. All doses gave excellent control of Veronica agrestis with four to five true leaves. The lower doses also gave some control of the small number of other annual weeds present. All doses of phenmedipham failed to control the perennial weeds present. None of the treatments had any effect on plant height or width (Table 4).

Table 4

Effect of phenmedipham on the height and width of strawberry plants

Phenmedipham (lb/ac)	Plant height (in.)	Plant width (in.)
0	12.4	24.8
0.6	12.4	26.4
1.2	13.4	26.1
2.4	13.5	26.8
'F' test	N.S.	N.S.
S.E. (df = 12)	± 1.05	± 3.76

Experiment 5

To test the tolerance of strawberries to phenmedipham, excessively high doses were applied in a plantation of cultivar Cambridge Vigour on 5 June 1970. The runners had been planted on 16 October 1968. Plant spacing was 18 in. apart in rows 34 in. apart. The plantation was maintained weed free in 1969 using paraquat and simazine. Phenmedipham was applied at 0, 1, 2 and 4 lb/ac on 5 June 1970. The weather at the time of application was very warm (air max. 20°C) and bright and the plantation was weed free. Plot size was 12.5 yd x 2 rows, i.e. 50 plants. A randomised block design with four replications was used.

Within two days the highest dose of phenmedipham had caused moderate scorching of the more exposed strawberry leaves. The scorching occurred principally around the edges of the leaves with irregular patches extending between the veins. Slight scorching also occurred on the plots receiving phenmedipham at 2 lb/ac. The treatments did not cause any damage to the fruit trusses which were present at the time of spraying. No further scorching occurred after four days. At this time the plants on all plots receiving phenmedipham showed slight chlorosis. The plants receiving the lowest dose quickly regained green colour but those sprayed with the highest dose remained slightly yellow until late July, two weeks after fruit harvest.

In spite of the general chlorosis and the necrosis caused by the highest dose none of the treatments had any harmful effect on crop yield, fruit size, berry quality or plant vigour (Table 5).

Table 5

Effect of phenmedipham on yield, berry weight, plant height and plant width

Phenmedipham (lb/ac)	Crop yield (cwt/ac)	No. of berries per lb	Plant height (in.) 23 July 1970	Plant width (in.) 23 July 1970
0	155.2	35.6	12.4	24.8
1	146.7	34.5	12.4	26.4
2	148.0	32.4	13.4	26.1
4	156.9	32.0	13.5	26.8
'F' test	N.S.	N.S.	N.S.	N.S.
S.E. (df = 9)	± 5.79	± 9.11	± 1.06	± 3.76

DISCUSSION

The need for a range of herbicides to control all common weeds is particularly important in perennial crops. In these crops there is a much greater danger than in annuals of a rapid build-up of high populations of resistant weeds following the use of a limited range of herbicides. The need for herbicides as alternatives to simazine, lenacil and chloroxuron in strawberries is pressing as there are many reports of weed species being inadequately controlled by these herbicides (e.g. Hughes 1970). Veronica spp. are among the most troublesome in this respect. The results suggest that phenmedipham will be a useful additional herbicide in strawberries to increase the range of weed species that can be controlled by chemical means.

As a contact herbicide, the effect of phenmedipham is short lived. It also fails to control some important weed species e.g. Poa annua. Phenmedipham, therefore, will not replace the standard soil-applied herbicides, simazine and lenacil, but could be a useful supplement under dry weather conditions or where weed species susceptible to phenmedipham are tending to become prevalent. There is also evidence from observational trials that winter applications of phenmedipham could control effectively a number of weed species such as Senecio vulgaris, Stellaria media and Veronica spp. that frequently cause difficulties in mild areas by growing throughout the winter months.

A significant feature of these experiments was the tolerance shown by both newly planted and established strawberries to high doses of the herbicide. Even where a dose four times higher than normal was applied under warm, bright conditions, the plants recovered quickly and soon outgrew the check. The dose required in practice will vary according to the weed species present and the stage of weed growth, but the results suggest that higher doses than those normally recommended in sugar beet (1 lb/ac) will be justified on occasions.

As phenmedipham is a foliar-acting herbicide its action will not be influenced by soil type. It will be particularly useful in strawberries grown on peatland where the effect of soil-acting herbicides is less predictable than on mineral soils.

These trials at Clonroche have been conducted on Cambridge Vigour, the most widely grown strawberry cultivar in Ireland. Results similar to those reported in this paper have also been obtained on the cultivars Gorella, Red Gauntlet and Cambridge Favourite in unreplicated trials in S.W. England (Fielder 1968). In view of reports of differences between cultivars in susceptibility to herbicides (van Staalduine 1961) further work with phenmedipham is needed on a wider range of cultivars and also to determine residue levels on fruit.

Acknowledgements

The authors wish to thank Mr. John Doyle for technical assistance and Mr. D. Conniffe for the statistical analyses.

References

FIELDER, G. J. (1968) Personal communication.

HUGHES, H. M. (1970) Use of lenacil and simazine on newly planted strawberries. Expl. Hort., 21, 33 - 35.

RATH, N. and O'CALLAGHAN, T. (1970) Comparison of herbicide programmes in strawberries. Proc. 10th Brit. Weed Control Conf. (In press).

VAN STAALDUINE, D. (1961) The use of simazine in strawberries. Proc. 5th Brit. Weed Control Conf. 1960, 1, 341 - 350.

Proc. 10th Br. Weed Control Conf. 1970

COMPARISON OF HERBICIDE PROGRAMMES IN STRAWBERRIES

N. Rath and T. O'Callaghan
Soft Fruits Research Centre, Clonroche, Co. Wexford

Summary Very good results were obtained in strawberries with a lenacil/simazine programme used over four growing seasons. This programme, based on spring application of lenacil (1.6 lb/ac) plus summer and winter applications of simazine (1.0 lb/ac/ treatment), gave almost complete control of annual weeds without any significant reduction in yield. This programme was less phytotoxic than one based on simazine applied in spring, summer and winter and gave more effective weed control than programmes based on lenacil alone or on post-harvest applications of lenacil or simazine.

INTRODUCTION

Many reports have been published on the effect of individual herbicides in strawberries (Robinson 1969). There is an increasing trend, however, for several herbicides to be used in rotation. This helps to prevent a build up of tolerant weeds and may reduce the risk of damage by any one herbicide. The two most widely used soil-acting herbicides in strawberries in Ireland are simazine and lenacil. An experiment was laid down at the Soft Fruit Research Centre, Clonroche in 1967 with the object of comparing a rotation of lenacil and simazine with programmes based entirely on the use of either herbicide. The chemical treatments were applied at three periods viz. spring (March to May), summer (August), and winter (December to January).

As the risk of damage to strawberries from soil-applied herbicides is greater in the spring than at other times of the year (Ivens 1963), programmes were also included where simazine and lenacil were applied in the summer and winter only. The programmes used are summarized in Table 1.

Table 1

Herbicide programmes used on strawberries (1967 - 1970)

Treatment	Month of application		
	March-May	August	December-January
A	lenacil	simazine	simazine
B	lenacil	lenacil	lenacil
C	simazine	simazine	simazine
D	Cultivation*	lenacil	lenacil
E	Cultivation*	simazine	simazine
F	Cultivation	as necessary throughout	the year

* In 1967 only

METHOD AND MATERIALS

The strawberries, cultivar Cambridge Vigour, were planted 18 in. apart in rows 34 in. apart on 3 May, 1967. The plot size was two rows by 12.5 yd. A randomised block design with five replications was used. The soil, part of the Clonroche series, was a loam or clay loam derived from ordovician shale and drift material and contained in the 0 - 6 in. layer approximately 22% coarse sand, 12% fine sand, 37% silt, 25% clay and 4% organic matter.

At the time of planting the principal weeds present were *Poa annua*, *Anagallis arvensis* and *Aphanes arvensis*. The site was free of perennial weeds except for occasional plants of *Agropyron repens* and *Ranunculus repens*.

The programmes listed in Table 1 were carried out in 1967 and were repeated on the same plots in 1968, 1969 and 1970. Doses used on all occasions were lenacil 1.6 lb/ac and simazine 1.0 lb/ac. The herbicides were applied in 30 gal of water per acre and application was timed as far as possible to coincide with moist soil conditions. Before application of herbicides any weeds present were noted and then removed either by hand or by a carefully directed application of paraquat.

Where simazine was applied shortly after planting (Treatment C), the roots of the runners had been dipped in steam-activated charcoal before planting. During the first season the dates of application of herbicide were 8 May 1967, 28 August 1967 and 10 January 1968. Treatments D and E were cultivated on 8 May 1967. Treatment F was cultivated on 8 May and 10 August 1967. In 1968 herbicide treatments were applied on 3 May, 28 August and 17 December. On 3 May 1968 lenacil was inadvertently applied to treatment C and was omitted from Treatment A. Simazine was not applied to Treatment C on that occasion. Treatment F was cultivated on 24 January, 4 May, 8 June and 28 August in 1968.

In 1969 the herbicides were applied on 1 May, 29 August and 30 December. The F plots were cultivated on 26 March, 30 May, 13 August and 4 October.

In 1970 the spring application of herbicide was given on 19 May and F plots were cultivated on 19 March and 22 May. Where simazine and lenacil were applied in the summer and winter only (Treatments D and E) cultivation in the spring was given only in 1967.

Paraquat was applied at $\frac{1}{2}$ lb/ac to the alleyways of all plots for the control of runners on 24 August 1967, 6 September 1968 and 15 September 1969.

RESULTS

Slight leaf injury occurred on plots receiving Treatment C in spring 1968 and more severe injury, interveinal chlorosis and necrosis, was evident in spring 1969. No damage that could definitely be attributed to lenacil treatment occurred on any plot throughout the course of the experiment.

Significant differences between treatments in yield of marketable fruit occurred in 1968 and 1969 but not in 1970 (Table 2). In 1968 crop yield of Treatment C (simazine in spring, summer and winter) was significantly reduced ($p = 0.05$) compared with treatments based on lenacil only (B) or on cultivations only (F). Treatment based on lenacil only (B) was slightly better ($p = 0.05$) than spring lenacil plus summer and winter simazine (A).

Table 2

Effect of herbicide programme on crop yield (cwt/ac)

Treatment	1968	1969	1970	Total
A	168.8	125.5	119.3	413.6
B	195.3	122.5	127.1	444.9
C	153.2	88.9	113.3	355.4
D	187.4	120.0	115.5	422.9
E	175.4	120.7	125.0	421.1
F	188.7	123.8	145.3	457.8
'F' test	*	**	N.S.	
S.E. (df = 20)	±7.80	±5.92	±11.18	

In 1969 the yield of Treatment C (simazine only) was again significantly reduced (p=0.01) compared with all other treatments. The treatments had no significant effect on plant heights in 1969 or in 1970 (Table 3). However, plant heights in 1969 and 1970 and plant width in 1970 were reduced on plots receiving Treatment C (simazine only) compared with all other treatments.

Table 3

Effect of herbicide programme on height and width of strawberry plants

Treatment	16 June 1969		30 July 1970	
	plant height (in.)	plant width (in.)	plant height (in.)	plant width (in.)
A	10.3	15.1	9.5	19.8
B	10.3	15.1	9.4	20.8
C	9.5	13.6	7.9	17.4
D	10.3	14.8	9.1	19.5
E	10.4	12.3	9.1	19.1
F	10.8	15.4	9.3	18.5
'F' test	N.S.	N.S.	N.S.	N.S.
S.E. (df = 20)	0.87	1.07	1.19	2.83

In 1967 the herbicide treatments gave good weed control. In December 1967 approximately 15% of the ground was covered by annual weeds where herbicide treatments had been used whereas 64% was covered where cultivations only were used. *Poa annua* and *Senecio vulgaris* were the most prevalent weeds.

In 1968 herbicide treatments again gave good weed control with Treatments C and A maintaining the ground completely weed free. The cultivated plots were badly infested with *Poa annua* and *Senecio vulgaris* by August 1968.

During 1969 Treatments A, B, C and E gave excellent weed control but Treatments D and F were much less effective. In May 1969 the most important weeds present in Treatment D were *Poa annua*, *Viola arvensis* and *Senecio vulgaris*. Only *Poa annua* and *Viola arvensis* occurred on the cultivated plots. The plots receiving herbicide treatments became slightly infested with perennial weeds, principally *Holcus lanatus* and *Lathyrus pratensis*.

During spring 1970 all herbicide treatments gave excellent control of annual weeds. In early June plots receiving Treatments A, B, C and E were completely free of annual weeds. Plots receiving Treatment D were slightly infested with Senecio vulgaris and Sonchus oleraceus. Weed control on the cultivated plots was again inadequate. In June all cultivated plots were badly infested with Poa annua, Senecio vulgaris and Sonchus oleraceus. During June and July perennial weeds increased slightly on all plots receiving herbicides. However, by August perennial weeds did not constitute a serious problem on any treatment, while Treatment C remained almost completely free of perennial weeds. Plots receiving Treatments A, B, C and E remained almost completely free of annual weeds in summer 1970 but weeds grew strongly on plots receiving Treatments D and F. By August approximately 70% of the ground in each case was covered with annual weeds. The most important weeds on the cultivated plots were Senecio vulgaris, Poa annua and Sonchus oleraceus. Senecio vulgaris and Sonchus oleraceus were also present on plots receiving Treatment D. However, Treatment D gave complete control of Poa annua.

By 1970 marked differences in weed flora occurred between treatments. Plots receiving Treatment C were completely free of annual weeds and almost completely free of perennials while plots receiving Treatments A, B and E were completely free of annual weeds and slightly infested with perennials. Treatment F was badly infested with annuals and completely free of perennials.

During the life of the experiment, the passage of spraying machinery caused no apparent damage to the soil surface of non-cultivated plots. Water infiltration was not impaired by any treatment and there was no evidence of run-off or erosion from any plot.

DISCUSSION

The results of this experiment show the excellent results that can be obtained in strawberries with a lenacil/simazine programme over a four year period. This programme based on spring application of lenacil plus summer and winter applications of simazine gave almost complete freedom of annual weeds without any significant reduction in yield. This programme was less effective in suppressing seedling perennial weeds than one based on simazine alone. There was also evidence that crop yield was slightly, although not significantly, reduced in the third cropping year compared with the cultivated, unsprayed treatment. Nevertheless, this programme was, on balance, the most satisfactory of the six treatments.

Good results were also obtained with the treatment consisting of simazine applied in the summer and winter. The degree of weed control, however, was less effective than that obtained by the programme that included spring application of lenacil in addition to simazine in the summer and winter.

The results also confirm that simazine is a more effective herbicide against common arable weeds in Ireland, but lenacil is safer on strawberries. In all three cropping seasons, leaf injury was most obvious and crop yield was lowest on plots sprayed three times each year with simazine. This reduction in yield was most marked in 1969. From a comparison of Treatments C and E, the reduction in yield appears to be due largely to the spring application of simazine. This result confirms the greater susceptibility of strawberries to simazine applied in the spring (Ivens 1963), even where a relatively low dose (1 lb/ac) in relation to the high clay content of the soil (25%) is used.

Simazine was inadvertently omitted from this treatment in spring 1968 but it seems likely that the damage that occurred to these plots in that season was due to the application of simazine on 10 January, which was followed by relatively mild weather for 10 weeks. This resulted in conditions favouring early crop growth and simazine damage.

The results with lenacil in this experiment confirm the good tolerance of strawberries recorded in many other experiments (Cleary 1966). The tolerance of newly planted strawberries to lenacil is particularly advantageous because of some limitation in previous methods of weed control in new plantings: cultivation is expensive, especially when the plants are small; chloroxuron frequently gives inadequate weed control, and simazine is risky unless an activated charcoal root dip is used, an unpleasant task for operatives because of the mess and extra work involved.

In spite of these advantages, lenacil is not likely to be used, as in Treatment B, as the sole herbicide in strawberries. Lenacil is expensive; not only is the standard dose higher than that of simazine, but in Ireland lenacil costs at present over four times as much as simazine per lb of active ingredient. Further, repeated applications of any one herbicide will result in a build up of resistant species. *Viola arvensis* and *Senecio vulgaris* are already tending to become more prevalent in this experiment on the plots treated with lenacil only.

There was some evidence in this experiment of a greater tendency for perennial weeds to become established on herbicide-treated plots than on plots cultivated regularly. A rapid build-up of perennial weeds has occurred in many fruit plantations where cultivation has been replaced by herbicides. Nevertheless, the problem of perennial weeds in this experiment was never acute showing that, provided the ground is initially substantially free from perennials, regular treatment with a soil-applied herbicide, coupled with spot treatment or removal of small plants can give an effective degree of control.

While the use of a lenacil/simazine programme appears to be preferable to the use of either herbicide alone, additional herbicides will still need to be developed to control weeds that are resistant to both simazine and lenacil, e.g. *Veronica* spp.

Acknowledgements

The authors wish to thank Mr. D. Conniffe for the statistical analyses and Mr. J. Doyle for technical assistance.

References

CLEARY, T. F. (1966) Trials with herbicides in young strawberry plants. Proc. 8th Brit. Weed Control Conf., 1, 62 - 68.

IVENS, G. W. (1963) The effect of herbicides on the strawberry plant, considered in relation to mode of growth and crop management. 16th Int. Hort. Cong. 1962, 5, 138 - 145.

ROBINSON, D. W. (1969) Herbicides in strawberry production. Proc. Symposium on 'Strawberry growing in the 1970's' Baywood Chemicals Ltd., London 1969, 37 - 52.

Proc.10th Br.Weed Control Conf.1970

EXPERIMENTS WITH TERBUTHYLAZINE FOR WEED CONTROL IN STRAWBERRIES

D. J. Parker and K. G. Stott
Research Station, Long Ashton, Bristol

Summary A new triazine residual herbicide terbuthylazine was compared with simazine and lenacil for weed control in both established and newly planted strawberries. Rates of 0.5 and 1 lb a.i./acre applied in Autumn and Spring gave adequate weed control, but caused an unacceptable level of crop damage. Lenacil at 2 lb a.i./acre and simazine at 0.5 lb a.i./acre gave a reasonable control of weeds without crop damage. Lenacil gave very significantly the highest crop yield.

INTRODUCTION

Existing herbicides for weed control in strawberry trials have not proved entirely satisfactory at Long Ashton. Rates which give adequate weed control have often proved too phytotoxic for breeding trials where the risk of killing even occasional strawberries cannot be tolerated. Rates that have proved safe have not given completely adequate weed control, particularly in progeny trials run for two or three years. Hence two trials to compare a new triazine herbicide, terbuthylazine (2-chloro-4-ethylamine-6-tert.butylamine-s-triazine) with lenacil and simazine were laid down in newly planted runners and also in two year old plants with runners. Though the solubility of terbuthylazine (8.5 ppm) is slightly higher than simazine (5 ppm) and lenacil (6 ppm), it is reputed to be less freely leached through the soil and hence improved protection was anticipated (Hocombe 1969).

Experiment 1 New runners

METHODS AND MATERIALS

Cambridge Favourite runners were planted in clean ground on 15 October 1969 one foot apart in rows 1ft 9in. apart The soil was a slightly sandy loam, similar in character to those at Long Ashton ascribed by Cope (1970) to the Greinton series. The experimental area was divided into four randomised blocks, each containing an untreated control and four treated plots. Each recorded plot contained 55 runners. The herbicides were applied to moist soil using a manual knapsack fitted with a four nozzle boom adjusted to spray over each row.

Treatments

1.	Terbuthylazine	0.5 lb a.i./100 gal./ac.	on 24 October 1969 and 23 April 1970
2.	Terbuthylazine	1.0 lb a.i./100 gal./ac.	" " " " " " "
3.	Simazine	0.5 lb a.i./100 gal./ac	" " " " " " "
4.	Lenacil	2.0 lb a.i./100 gal./ac.	" " " " " " "

The number of germinating weed seedlings was recorded on 21 November 1969 and their development followed throughout the winter and following year. Observations on strawberry health were made at intervals and the number of live plants remaining was recorded in June 1970. Ripe fruits were picked every other day from 11 June to 6 July 1970 and their number and weight recorded.

RESULTS

Weed control

Weed seedlings present in November consisted mainly of Stellaria media (chickweed), Capsella bursa-pastoris (Shepherd's purse), Matricaria spp. (Mayweeds) and Poa annua (annual meadow grass).

Table 1

Mean No. of weed seedlings per treated plot of 12 yd^2 (21.11.69)

Terbuthylazine 0.5 lb.	Terbuthylazine 1 lb.	Simazine 0.5 lb	Lenacil 2.0 lb	Control
35	42	54	84	651***

*** Significantly different from all treatments at the 0.1% level

Table 1 shows that all treatments gave a very significant control of weed seedlings. Both rates of terbuthylazine were significantly more effective than lenacil ($P < 0.01$), but not simazine. Simazine was marginally ($P < 0.05$) more effective than lenacil. By April weeds covered less than 5% of the area of treated plots, but over 80% of the control plots. By early June, control plots were dominated by a dense stand of Matricaria recutita wild chamomile and Matricaria matricariodes rayless mayweed, with some Stellaria media, Capsella bursa-pastoris, Poa spp. Gallium aparine (cleavers) and Lamium purpureum, purple dead nettle. The same flora covered about 20% of the total area of both simazine and lenacil plots, but plots receiving 1 lb of terbuthylazine were almost weed free. Though the 0.5 lb rate of terbuthylazine was effective until late spring, weed control then declined rapidly and by June these plots were noticeably more infested than those of other treatments.

Crop response

No differences in the health of runners were apparent for two months but by January those treated with the higher rate of terbuthylazine had lost a greater proportion of their original leaves and a few new leaves showed marginal chlorosis. Less damage was observed in plots receiving the lower rate. No evidence of phytotoxicity was observed in the simazine and lenacil treatments. However after the spring application of the 1 lb rate of terbuthylazine the strawberries began to die, and by June they were all dead. Table 2 shows that significantly more had died in plots receiving the 0.5 lb rate than in untreated plots, or those receiving simazine or lenacil. Significantly more ($P < 0.01$) survived with lenacil than with simazine.

Crop yields were significantly the same in plots treated with 0.5 lb of terbuthylazine as in the weed ridden controls, where as the number of fruits produced by each plant, the size of the fruits (assessed as weight) and the total yield of each plot was very significantly more in the simazine and lenacil treatments. Lenacil gave a very significantly greater total yield ($P < 0.001$) than all the other treatments.

Table 2

Mean number of living plants and crop yield

Treatment	No.plants per plot	No.fruit per plant	Berry size weight/fruit(gm)	Total weight fruit/plot(gm)
Terbuthylazine 1 lb/ac	0.0***	0.0***	0.0***	0.0*
Terbuthylazine 0.5 lb/ac	20*	3.3	7.9	506
Control	29	4.9	7.5	1042
Simazine 0.5 lb/ac	35	6.8*	10.1***	2372**
Lenacil 2.0 lb/ac	49***	8.3**	11.0***	4445***

*** Results significantly different from the control at the 0.1% level, ** at the 1% level, and * at the 5% level.

Experiment 2 Established plants.

METHOD AND MATERIALS

In order to compare the phytotoxicity of terbuthylazine and simazine in established strawberries, rates of 0.5, 1, and 2 lb a.i/100 gal/ac of both materials were applied on 14th August 1969 to two year old selected seedling plants with runners. Each treatment covered a 16 yard run of row and contained about 50 mother plants and was replicated in three randomized blocks. The ground had been well cultivated so that runners mainly occupied the space between mother plants in the rows. Runners ranged between those rooted with three expanded leaves to unrooted runners with two emerging leaves. The soil was a free draining reddish brown loam, ascribed by Cope (1970) to the Tickenham series. The number of germinating seedlings was recorded in November and observations of weed and strawberry behaviour were made at intervals until the bed was ploughed out in the spring.

RESULTS

Table 3 shows that simazine gave a significantly better control of weed seedlings, mainly *Senecio vulgaris* groundsel, than terbuthylazine applied at the same rates. Higher rates of simazine, but not of terbuthylazine proved significantly better than lower rates.

No damage to strawberries was apparent with simazine. The higher rates of terbuthylazine caused chlorosis of young leaves on runners, but these symptoms disappeared by the end of September and no differences were found the following April in the number of surviving mother plants and runners.

Table 3

Mean No. of weed seedlings per treated plot of 16 yd^2 (21.11.69)

Rate lb/ac	Simazine		Terbuthylazine
0.5	9	***	71
	**		
1	3	***	53
2	0	***	40

*** means significantly different at the 0.1% and ** at the 1% level

DISCUSSION

Despite the physico-chemical properties of terbuthylazine, sufficient was leached into the rooting zone to kill maiden strawberries. Damage following the autumn application was negligible compared with that following the spring application, which supports the views of Ivens and Clay (1968) that herbicide damage to strawberry is greater when root growth is active. Autumn and spring applications of 0.5 lbs/ac of terbuthylazine did not achieve very satisfactory weed control, particularly of *Matricaria* spp., nor did they increase crop yield compared with the weed infested controls. Higher rates would give better weed control, but would kill more strawberries. Hence the material does not appear suitable for weed control in maiden strawberries.

Though the degree of weed control achieved by simazine was slightly better than that of lenacil, this was achieved at the expense of increased toxicity to the strawberries. Simazine plots produced only half the crop produced by lenacil plots, not because of a marked reduction in the number or size of fruit produced by each plant, but mainly because fewer plants survived to harvest. Lenacil was the best treatment and the results agree with the general views of Edwards (1968), Allott (1968) and Hughes (1968) that lenacil achieves a satisfactory degree of weed control in strawberries grown for annual cropping. However by harvest time sufficient weeds were present to ensure that weed control in subsequent crops, and especially in breeding trials would be difficult to maintain without mechanical and hand cultivations.

The second trial shows that like simazine (Ivens 1962, Robinson 1962) terbuthylazine is less toxic to established plants than to newly planted runners, but does not suggest that the material has more merit for weed control in established plants than simazine.

Acknowledgements

Thanks are due to Mr.J.S.Coles for assistance with these experiments, to the Statistics Section for statistical analyses and to Geigy (U.K.) Ltd who supplied the terbuthylazine.

References

ALLOTT, D.J. (1968) The tolerance of newly planted strawberries to certain soil acting herbicides. Proc.9th Brit.Weed Control Conf. 2, 881 - 886.

CLAY, D.V. and IVENS, G.W. Pot experiments on the susceptibility of strawberries to simazine. Proc.9th Brit.Weed Control Conf.2, 891 - 899.

COPE, D.W. (1970) Soil Survey of Long Ashton Research Station. Ann.Rep.Long Ashton Res.Sta. for 1969, 170 - 184.

EDWARDS, C.J. (1968) Trials on the selectivity of lenacil in strawberries. Proc.9th Brit.Weed Control Conf. 2 878 - 880.

HOCOMBE, S.D. (1969). Private communication.

HUGHES, M.H. (1968) Comparisons of herbicide on yields of 1 year old strawberry plants. Proc.9th Brit.Weed Control Conf. 2, 887 - 890.

IVENS, G.W. (1962) Recent results from strawberry herbicide trials. Proc.6th Brit. Weed Control Conf. 2, 579 - 588.

ROBINSON, D.W. (1962) A comparison of chemical and cultural methods of weed control in strawberries. Proc.6th Brit.Weed Control Conf.2, 589 - 597.